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EXAMINING PATTERNS OF EXECUTIVE FUNCTIONING ACROSS DIMENSIONS OF PSYCHOPATHOLOGY

A Dissertation

Submitted to the Graduate faculty of
Louisiana State University
Agricultural and Mechanical College
in partial fulfillment of the
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in

The Department of Psychology

by
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ABSTRACT

Executive functioning is a multifaceted collection of higher-order cognitive processes used to perform goal-oriented tasks. Although this construct is heavily researched, a major issue regarding the current literature stems from the influence of task impurity, which interferes with how executive functioning performance is interpreted. Additionally, while executive functioning has been previously explored in clinical populations, less work has evaluated this topic measuring dimensional psychopathology. The present study sought to examine the role of executive functioning, as it relates to dimensional psychopathology. Data was analyzed from a total of 731 individuals between the age of 18-59 years who took part in the Nathan Kline Institute (NKI)-Rockland project. A three-factor model of executive functioning (i.e., inhibition, shifting, and fluency) proposed by Karr et al. (2018) using scores primarily from the Delis-Kaplan Executive Function System (D-KEFS) and an original three-factor model of dimensional psychopathology (i.e., internalizing, externalizing, and thought disorder symptoms) using the Adult Self-Report (ASR) and Peter's et al. Delusions Inventory (PDI) were constructed with confirmatory factor analyses and then compared using structural equation modeling. Results supported both three-factor models as having adequate fit for this sample and indicated that internalizing and externalizing psychopathology had positive and negative relationships with different factors of executive functioning, while thought disorders traits were not related to executive functioning. Implications for future work are discussed.

INTRODUCTION

Utility of Executive Functioning in Clinical Assessment

Executive functioning can be defined as a set of related, yet distinct, higher-order cognitive abilities designed to support goal-directed behaviors (Smolker, Depue, Reineberg, Orr, & Banich, 2015). The clinical utility of this construct cannot be understated. It has been suggested that personalizing approaches to treatment in consideration with a client's executive functioning may be useful (Snyder et al., 2015), as pre-treatment executive functioning can influence treatment outcomes (Mohlman & Gorman, 2005). This may suggest understanding a client's current use or misuse of compensatory strategies prior to beginning therapy may also be important, in order to more efficiently implement commonly used strategies, such as progress monitoring and goal setting (Castagna, Roye, & Calamia, 2018). Executive dysfunction is common across different types of psychopathology and, once identified and treated, can improve overall functioning.

For example, empirically supported treatments, including cognitive behavioral therapy (CBT), often focus on providing clients with compensatory strategies to improve daily functioning by identifying and reducing maladaptive behaviors (Ramsay, 2017), many of which are related to executive dysfunction. Studies would suggest that compensatory strategies to combat executive dysfunction are also beneficial for a multitude of disorders, including schizophrenia (Kluwe-Schiavon et al., 2013), bipolar disorder (Deckersbach et al., 2010), and attention deficit/hyperactivity disorder (ADHD) (Hahn-Markowitz et al., 2011; Ramsay, 2017). While fewer studies have focused on treatment outcomes of compensatory behaviors in mood disorders, one could argue that cognitive restructuring and behavioral activation techniques, methods commonly used in evidence-based practices for treating depression and anxiety, are

often consistent with compensatory strategies (Dimidjian et al., 2011; Mohlman & Gorman, 2005; Snyder et al., 2015), including treatment monitoring, thought challenging, and developing systems to complete tasks (e.g., setting alarms, establishing hierarchal models towards an end goal).

In addition to therapy, executive dysfunction can also influence the efficacy of pharmaceutically based treatments, as well. For example, there is evidence to suggest that pre-treatment executive functioning may influence responses to medications amongst clinical populations, including those with depression (McLennan & Mathias, 2010), schizophrenia (Kim et al., 2008), obsessive compulsive disorder (OCD) (D'Alcante et al., 2012), and bipolar disorder (e.g., Gruber et al., 2008). Given the variability of disorders and the medications commonly used to treat these disorders, executive functioning deficits within this domain may suggest poor medication management and/or compliance (Snyder et al., 2015). Future research into this relationship may also improve pharmaceutical treatments by identifying more specific neurobiological targets that are potentially manifesting as these behavioral deficits (Snyder et al., 2015).

Measuring Executive Functioning

Theories suggest that the complex nature of executive functioning can be conceptualized within the Unity and Diversity model (Miyake et al., 2000), which subdivides executive functioning into a correlated three-factor model consisting of inhibition, monitoring, and cognitive flexibility. Specifically, inhibition is the ability to perform a desired response while suppressing an automatic response. Monitoring requires that one incorporate new information into their working memory processes. Lastly, cognitive flexibility is the ability to switch between cognitive processes and avoid proactive interference (Miyake & Friedman, 2012). This model of

executive functioning has been widely studied across various samples of both younger and older adults using a number of different measures from cognitive and clinical psychology (Fisk & Sharp, 2004; Fournier-Vicente, Larigauderie, & Gaonac'h, 2008; Hedden & Yoon, 2006; Hull, Martin, Beier, Lane, & Hamilton, 2008; Ito et al., 2015; Latzman & Markon, 2010; Vaughn & Giovanello, 2010).

Executive functioning is commonly studied from a performance-based perspective using objective measures to examine the cognitive subdomains of executive functioning and how their interrelationships makeup an overall executive functioning ability. However, it is also studied from a general, daily functioning perspective, measuring perceptions of abilities commonly used throughout the day. This aspect of executive functioning is commonly assessed using self-report measures (e.g., BDEFS: Barkley 2011 and BRIEF-A: Roth & Gioia, 2005) or through clinical interviewing and includes aspects of self-organization and planning, self-motivation and initiation, time management and task monitoring, self-restraint, and self-regulation. From a clinical perspective, it is important to measure both the perceptions of daily functioning (e.g., self-report measures) and cognitive (e.g., performance-based measures) aspects of executive functioning. Both performance-based and self-report measures have shown to be predictive of functioning (Nikolas & Nigg, 2013) and, although they are only modestly correlated (Dehili et al., 2017; Toplak, West, & Stanovich, 2013), both contribute incremental variance in predicting functional outcomes (Kamradt, Ullsperger, & Nikolas, 2014). Specifically, performance-based tests provide information about a person's cognitive capabilities, while self-reports inform how these cognitive abilities may translate to real world situations (Snyder et al., 2015).

When quantifying or conceptualizing executive functioning from any perspective, it is important to consider what measures are being chosen across studies. Inconsistent methods of

measuring executive functioning is a problem in the current literature that limits both research and how executive functioning is utilized clinically (Alvarez & Emory, 2006; Nowrangi et al., 2014). For example, many studies will often use a single measure to assess executive functioning which may measure one or multiple domains of executive functioning and also contain variance related to other non-executive functioning constructs (i.e., test impurity) (Snyder et al., 2015). This issue can make it difficult to determine the origin of specific executive functioning deficits. Additionally, by using a single test to measure this construct, you can potentially bias future research by incorrectly labeling an executive functioning deficit when the test failure could represent a deficit related to some other aspect of the measure.

Neuropsychological measures of executive functioning were originally designed for individuals with dementia or frontal lobe damage (Snyder et al., 2015). However, recent theories would suggest that multiple systems are required within the brain to perform executive functioning tasks. Older or more traditional measures of executive functioning may not be sensitive to all aspects of executive functioning. Therefore, it is important to not only remain consistent in the measures used to assess individual domains but to also use multiple measures to assess these domains, in order to factor out any non-executive functioning variability captured by a single measure.

Measuring executive functioning using cognitive measures can also have important clinical implications when conceptualizing levels of functioning (Friedman et al., 2007, 2011; Miyake & Friedman, 2012; Young et al., 2009). Currently, clinical assessments are trending towards the Unity and Diversity model, in order to identify predictive factors and symptoms consistent with clinical diagnoses (Miyake & Friedman, 2012). One battery commonly used in clinical practice (Karr et al., 2018) is the Delis–Kaplan Executive Function System (D-KEFS;

Delis, Kaplan, & Kramer, 2001), a measure that consists of nine subtests and has demonstrated factor structures consistent with the cognitive domains of the Unity and Diversity model for selected subtests (e.g., Kerr et al., 2018; Latzman & Markon, 2010).

Executive Functioning Profiles Across Different Domains of Psychopathology

Before discussing the literature on executive functioning within psychopathology, it is important to note that, as mentioned above, measurement inconsistencies are common across studies and may be used within meta-analyses when quantifying specific domains of executive functioning (see Table 1 for task descriptions by domain). Specifically, inhibition is commonly measured using the Stroop task, Go/no-go task, Antisaccade task, and others. While each of these tasks measure aspects of inhibition, their designs include non-executive functioning abilities (i.e., motor movements, speech, reading ability) needed to successfully complete a task and can potentially confound results. Additionally, while most clinical samples are compared to those without diagnoses, some studies make comparisons to other clinical samples, potentially causing inconsistencies within the results as well. A summary of this section can be viewed in Table 2.

Table 1. Executive functioning domains and measures

Processes	Measures	Description
Inhibition	Antisaccade	Visual, distractor cue is briefly presented, while target cue is presented immediately after in an opposite direction
	Color Word Interference Test (CWIT) or Stroop Task	Orally respond to word reading, color naming, and an incongruent trial (e.g., "red" written in blue ink).
	Continuous Performance Test (CPT) or Go/No-Go	Required to respond to targeted stimuli and withhold from non-targets.
	Hayling	Complete obvious sentences where the final word is omitted. Complete an accurate and inaccurate trial.

(table cont'd.)

Processes	Measures	Description
	Stop Signal Task (SST)	Quickly categorize and respond to stimuli unless presented with a stop signal.
Shifting	Design Fluency	Participants are asked to alternate between connecting empty and filled dots.
	Dots Triangles Test	Determine if there are more dots or triangles present on half of a presented grid. Blocks one and two include dots or triangles, respectively, while block three randomly presents dots or triangles.
	Intradimensional/Extradimensional Shift (ID/ED)	Select a stimulus based on a single dimension and are asked to switch between previously non-rewarded stimuli and then to different stimulus. Participants learn rules from administrator feedback.
	Object Alternation Test (OAT)/Delayed Alternation Test (DAT)	Find hidden object that is alternates between two locations. Immediate and/or delay periods are included.
	Sorting Test	Using six cards, participants place them into two groups of three, describing similarities in both groups. There are two stages of freely constructing and two stages of recognizing up to 16 unique concepts within the two sets of cards.
	Trail Making Test - B (TMT-B) and D-KEFS Trail Making Test	Alternate between sequentially connecting letters and numbers.
	Wisconsin Card Sorting Test (WCST)	Participants are presented with 4 different base cards and required to learn rules via administrator feedback (e.g., "correct" or "incorrect"). Rules change after a finite number of consecutively correct trials.

(table cont’d.)

Processes	Measures	Description
Updating	Controlled Oral Word Association Test (COWAT) and Other Verbal fluency Measures (E.g., D-KEFS Verbal Fluency)	Participants are provided one minute to generate as many words beginning with either a letter or from a category.
	N-Back	Indicate if a presented stimulus matches a previously presented stimulus that falls within the required sequential location (e.g., 2-back = N, T, S, N).
	Tower of London	Participants move a pattern of discs from an original to end configuration, within the parameters of which discs can be placed on top of other discs.

Table 2. Qualitative Summary of Research Reviewed in the 'Executive Functioning Profiles Across Different Domains of Psychopathology' Section

Psychopathology	Inhibition	Shifting	Updating
Internalizing			
MDD	Large-Moderate	Small	Small
Anxiety	Mixed	Mixed	Mixed
PTSD	Small	Moderate	None
OCD	Small	Small	Large
Externalizing			
Substance Abuse	Large	Small	Small
ADHD	Large	Large	Unclear
Thought Disorder			
Schizophrenia	Large	Large	Large

Internalizing

Depression. The Internalizing spectrum is composed of syndromes from fear, distress, eating pathology, and sexual problems subfactors (Kotov et al., 2017). The fear and distress clusters consist of depressive and anxiety disorders (e.g., major depressive disorder (MDD), generalized anxiety disorder (GAD), PTSD, OCD, etc.), while the other two are made up of

features commonly associated with eating and sexual disorders. Snyder (2013) conducted a meta-analysis examining executive functioning profiles amongst individuals with MDD. Results demonstrated significantly worse performances for those with MDD on tasks measuring inhibition, shifting, and updating. Specifically, tasks of inhibition (i.e., Color-Word Stroop, Hayling) demonstrated the strongest relationships of the three domains, as effect sizes ranged from moderate to large, with the exception of the Stroop Interference trial, which was smaller. Overall, individuals with MDD demonstrated slower performances, worse accuracy, and higher interference costs. Although effect sizes on tasks measuring shifting (i.e., WCST, TMT, Intradimensional/Extradimensional Shift) and updating (i.e., n-Back) were small, participants with MDD demonstrated significantly worse performances on these tasks than those without MDD.

Anxiety. Unlike depression, executive functioning profiles amongst individuals with anxiety have received much less attention, with much of the literature demonstrating inconsistent findings. Specifically, some evidence of shifting deficits has been noted amongst individuals with panic, generalized, and social anxiety disorder (Cohen et al., 1996; Airaksinen et al., 2005; Mantella et al., 2007), while other studies found no differences in this area (Airaksinen et al., 2005; Boldrini et al., 2005) or inhibition (Van der Linden et al., 2005; Price & Mohlman, 2007), using both the Hayling and Stroop Task. Studies examining non-clinical samples have also noted that general worry impairs inhibition responses (Snyder et al., 2010; Eysenck and Derakshan, 2011). Additionally, one study (Visu-Petra et al., 2013) found that worry in general was associated with greater deficits in inhibition and shifting, but that greater social worries were related to improved updating performance. However, this last finding was unique to their sample

and was only found on measures without a time-sensitive component, suggesting replication of this finding may be needed to justify the claim.

Post-Traumatic Stress Disorder (PTSD). Meta-analyses measuring executive functioning profiles amongst individuals with PTSD demonstrate worse executive functioning in general, as compared to those without (Scott et al., 2015). Specifically, one meta-analysis suggested that individuals with PTSD perform worse on measures of shifting, demonstrating a medium effect size (Polak et al., 2012), but did not find significant differences related to inhibition, while one review (Aupperle et al., 2012) reported that inhibition deficits are commonly noted amongst individuals with PTSD. Overall, these results suggest that the relationship between PTSD and cognitive domains of executive functioning may require further study.

Obsessive Compulsive Disorder (OCD). Previous research suggests that individuals with OCD demonstrate impaired performances across all three domains of executive functioning. One meta-analysis (Snyder, Kaiser, Warren, & Heller, 2015a) demonstrated significant, large effect sizes for deficits on tasks of updating, while impaired performances on tasks of inhibition (i.e., Stroop Task, Stop Signal Task) and shifting demonstrated small (i.e., Intradimensional/Extradimensional Shift (ID/ED), Object Alternation Test (OAT)/Delayed Alternation Test (DAT), Wisconsin Card Sorting Task (WCST)) to large (i.e., Trail Making Test-B (TMT-B)), effect sizes. However, it is important to note that there were no differences between Go/No-Go task and cued task switching performances.

Disinhibited Externalizing

Substance Abuse. One meta-analysis (Smith et al., 2014) examined inhibition profiles amongst individuals with varying substance abuse disorders, including cocaine, MDMA, methamphetamine, tobacco, alcohol dependence and heavy drinking, cannabis, gambling, and

internet addiction. Overall, results indicated the largest inhibition deficits (i.e., Go/No-Go, SST) amongst individuals using psychostimulants. Significant, small to moderate effect sizes for inhibition deficits were also observed amongst individuals with alcohol dependence. While, there was no evidence to suggest inhibition deficits for individuals using opiates or cannabis, other studies have indicated worse performance on tasks of inhibition amongst individuals using cannabis (Moreno et al., 2012). Similarly, for those with addiction-like behavioral disorders, including gambling and internet addiction, moderate to large effect sizes were demonstrated on tasks of inhibition, suggesting higher rates of impulsivity amongst this sample. Effect sizes here are much larger than a previous study who demonstrated a small effect size (Lipszyc & Schachar, 2010). Spronk and colleagues (2013) conducted a meta-analysis examining executive functioning amongst cocaine abusers and found small effect sizes suggesting worse shifting performances comparing users and non-users across different tasks (i.e., Dots Triangles Test, ID/ED, WCST). Additionally, although findings on shifting performances were limited, results trended towards reduced performances amongst users.

Attention Deficit Hyperactivity Disorder (ADHD). Although ADHD is commonly associated with general executive dysfunction, one theory suggests that behavioral inhibition deficits are most impairing for individuals with ADHD, leading to secondary cognitive difficulties (Barkley, 1997), which may support a characteristic of ADHD, cognitive performance variability (Mostert et al., 2015). One meta-analysis (Bálint, et al., 2009) indicated that individuals with ADHD demonstrated significant deficits on shifting and inhibition task performances, when compared to non-ADHD controls. Specifically, a large effect size was found on tasks of switching (e.g., TMT B), while moderate to small effect sizes were found on tasks of inhibition (i.e., interference control, word, and color). Additionally, on the CPT, individuals with

ADHD demonstrated more commission and omission errors, with moderate effect sizes for both, further suggesting difficulties with response inhibition. These results are consistent with other meta-analyses (Boonstra et al., 2004; Nigg et al., 2017) that also suggested adults with ADHD demonstrate deficits on tasks of inhibition and shifting. Moreover, these results are consistent amongst children and adolescents with ADHD (Snyder et al., 2015). However, contrary to these results, in a meta-analysis by Mostert and colleagues (2015), adults with ADHD did not perform differently on tasks measuring inhibition, shifting, or updating (i.e., verbal fluency task), when compared to non-ADHD peers. While global executive dysfunction may be common amongst individuals with ADHD (Nigg et al., 2017), further research into the specific deficits amongst ADHD presentations may be necessary to determine more consistent executive functioning profiles.

Thought Disorders

Schizophrenia. Compared to other clinical samples mentioned within this review, individuals with schizophrenia demonstrate the highest degree of executive dysfunction. A meta-analysis conducted by Snyder and colleagues (2015) indicates large effect sizes across all three domains of executive functioning, with average effect sizes of 0.95, 0.92, and 0.83 on tasks of inhibition, shifting, and updating, respectively. These results are consistent with previous meta-analyses that noted large effect sizes across executive functioning domains as well (Dickinson et al., 2007; Stefanopoulou et al., 2009). However, it is important to note that this population commonly demonstrates general cognitive impairment and in one meta-analytic review (Laws, 1999), individuals with schizophrenia did not perform significantly worse than their non-schizophrenia peers on one executive functioning task, the WCST, after controlling for IQ within the analyses. Therefore, given the low cognitive functioning rates commonly found within this

population, it may be important to consider general intelligence in the context of executive dysfunction.

Neuroimaging Profiles of Executive Functioning and Psychopathology

Neural Correlates of Executive Functioning

Historically, executive dysfunction was believed to derive from damage to the "frontal lobe" (Stuss & Alexander, 2000). Studies have demonstrated that the prefrontal cortex (PFC) coordinates the use of specific subregions to carry out individual executive functioning processes (Friedman & Miyake, 2016; Kim, Cilles, Johnson, & Gold, 2011; Nee, Wager, & Jonides 2007; Rottschy et al., 2012; Wager & Smith, 2004). For example, response inhibition has been linked to the anterior PFC and right dorsolateral (dlPFC), along with the anterior insula, premotor cortex, caudate/putamen, anterior cingulate, and parietal cortex (Ardilla et al., 2017; Friedman & Miyake, 2016; Wager et al., 2005). Additionally, studies have demonstrated relationships between individual domains of executive functioning and the parietal region, such as shifting and the somatomotor and angular gyrus. Therefore, it has been suggested that the PFC may serve to synchronize activation of cortical and subcortical regions that are necessary for accomplishing specific executive functioning tasks.

More recently, the abundance of neuroimaging studies focused on executive functioning have implicated many regions and networks responsible for completing executive functioning processes. Amongst this wealth of information lies a trend which identifies the frontoparietal network as being responsible for these higher-order processes (Friedman & Miyake, 2016). Duncan and Owen (2000) theorize that the frontoparietal network activates in order to maintain goal-directed attention and therefore, makes it difficult to separate regions and networks when identifying individual task activation. Reineberg and colleagues (2015), similarly found that

resting state fMRI analyses revealed a positive relationship between this network and improved, common executive functioning. Together, this may suggest that the frontoparietal network is responsible for more general executive functioning performance, while specific regions within this network may be more task-specific.

Internalizing Disorders

Previous studies have used fMRI and other neuroimaging techniques to identify cortical associations with executive functioning amongst individuals with psychological disorders. For example, in a review conducted by Rogers and colleagues (2004) reviewed significant cortical hypo/hyperactivation amongst individuals with depression. Results indicated that individuals with depression demonstrated hypoactivation within the dlPFC and anterior cingulate cortex (ACC). Previous studies demonstrated that individuals with depression also performed worse on verbal fluency tasks and WCST and demonstrated reduced activation within dlPFC. Additionally, reduced ACC activation was also noted in those with depression on tasks measuring inhibition (Stroop task) and updating (Tower of London). Previous, non-task-based neuroimaging studies examining individuals with depression have also demonstrated reduced activation within similar regions (Wang et al., 2015).

Similar findings suggesting hypoactivation within the PFC have been identified amongst individuals with GAD. Price and colleagues (2011) conducted a study with older adults who were diagnosed with GAD, measuring attention control. The authors used an emotional Stroop (eStroop) task, revealing that individuals with GAD had more difficulty controlling attention when presented with negative words. Specifically, for non-GAD participants, negative words caused greater activation within the dorsomedial (dmPFC) and left ventrolateral (vlPFC), two regions with established relationships to executive functioning (Smolker et al., 2015). Although

the ACC was not indicated as a region with significant differences within this study, the eStroop design contains long blocks, previous studies suggest that ACC becomes less activated with practice (Milham et al., 2003).

Although many task-based neuroimaging studies focus on emotional processing within individuals with social anxiety disorder (SAD), few examine the relationships between executive functioning and neural activation. However, previous neuroimaging studies have demonstrated neural activity unique to individuals with SAD that may contribute to executive dysfunction amongst this population. For example, Liao and colleagues (2010) examined SAD using resting state functional connectivity. Results indicated abnormalities on tracts traveling both to and from the amygdala and noted a significant relationship between the orbitofrontal gyrus and amygdala. Other functional neuroimaging studies have suggested that individuals with SAD demonstrate abnormalities within the amygdala, posterior insula, dorsal ACC, vlPFC, and temporal gyrus (Guyer et al., 2008; Phan et al., 2005; Simmons et al., 2008). Together, despite the scarcity of research focusing directly on task-based results amongst individuals with SAD, non-clinical executive functioning results suggest that the cortical anomalies highlighted within the dorsal ACC and vlPFC may contribute to some executive dysfunction (Duncan, 2010; Friedman & Miyake, 2016) within this sample.

Few studies have examined the relationship between PTSD and fMRI performances on executive functioning tasks. One study, conducted by Garrion and colleagues (2008), conducted a study measuring response inhibition amongst youth who have experienced trauma at a young age. Results from this study indicated that individuals with PTSD, or PTSD symptoms, performed similarly to non-PTSD peers. Interestingly though, despite similar performances on behavioral measures, neural activation varied between the two groups during tasks. Specifically,

during inhibition trials, the non-PTSD group showed significantly increased activation in the medial frontal gyrus (MFG), an area that is often linked to response inhibition (Aron et al., 2003; Garavan et al., 1999; Menon et al., 2001). This suggests that individuals with PTSD, or PTSD symptoms, are not using frontal structures in a way that similar to those without PTSD.

Differences in cortical activation have also been found amongst those with varying types and degrees of trauma and anxiety. The majority of studies examining anxiety and executive functioning tasks have been conducted on patients with OCD, with few examining patients with PTSD or GAD (McTeague et al., 2016). On inhibition tasks, individuals with OCD demonstrated increased response times compared to non-OCD peers and reduced activation within the left precentral gyrus, bilateral caudate nucleus, right putamen, right ACC, right MCC, right occipital cortex, left angular cortex, and bilateral superior/middle temporal cortex (Kang et al., 2013) and greater activation within the superior parietal cortex. Interestingly, on switching tasks, patients with OCD demonstrated a slower performances and greater non-switching errors, when compared to non-OCD peers. Additionally, individuals with OCD demonstrated increased activation within the left putamen, bilateral ACC, and left postcentral gyrus (Remijnse et al., 2013). In another study, Gu and colleagues (2008), found that individuals with OCD demonstrated greater switch errors, but no significant differences in non-switch errors and, that individuals with OCD failed to show any significant differences in activation when comparing switching to non-switching, while non-OCD peers demonstrated increased activation within the PFC, a finding that is consistent in healthy control executive functioning studies (Braver et al., 2003; Cools et al., 2004).

Externalizing Disorders

It is not surprising that different substances can have unique impacts on the structural and functional integrity of the brain. Interestingly, one study examined the effects of cannabis use on working memory and selective attention (Harding et al., 2012). Results of the study suggested that individuals performed equally well during tasks than the non-cannabis using peers. Both groups demonstrated activation within the ACC and dlPFC and performances were comparable. However, this is not the case for individuals with methamphetamine abuse (MA). On a stroop task, the MA group demonstrated impaired activation within the right PFC and worse response times, compared to non-abusing peers (Salo et al., 2009). In a study measuring alcoholics (Desmond et al., 2003), on verbal working memory tasks, the alcoholic group demonstrated deactivation within the left frontal lobe, as well as deficits within frontocerebellar circuitry, an area that has been linked to verbal rehearsal processes (Desmond, 2001). Overall, these results suggest that although differences occur amongst individuals who abuse varying substances, executive functioning deficits are still recognized within these samples, and appear to demonstrate a correlation to important cortical regions necessary for completing executive functioning tasks.

Although ADHD diagnoses persist across an individual's lifespan, neuroimaging studies have demonstrated variability in cortical activation when comparing children to adults. Specifically, Peterson and colleagues (2009) examined the effects of psychostimulants amongst children with ADHD, and how these medications influenced performance on a Stroop task. Results indicated that, during Stroop task-performance, individuals with ADHD taking psychostimulants demonstrated reduced activation within the ventral ACC and posterior cingulate cortex, suggesting activation levels that were comparable to non-ADHD peers, and

trended towards increased activation within the lateral PFC. Along with these results, individuals with ADHD trended towards improved Stroop performance when on, compared to off stimulants. Findings suggested that improved functional interactions between the lateral PFC and ACC may reduce ADHD symptoms. Cortese and colleagues (2012) conducted a meta-analysis examining children and adults with ADHD. Findings suggested similar cortical de/activation on tasks measuring executive functioning. Specifically, the frontoparietal network was underactive in both children and adults during tasks and hypoactivation within this network is consistent with theories of executive dysfunction (Duncan, 2000; Friedman & Miyake, 2017). Schneider et al (2010) also found deficits within this network when adults with ADHD performed inhibition tasks, as well as increased activation within the insular cortex, another region that has demonstrated anomalous activation (Bush et al., 1999).

Thought Disorders

Like many disorders, heterogeneity in symptoms is very common within thought disorders and schizophrenia. However, research into thought disorders and psychotic features have demonstrated some consistencies when examining neural activation. Minzenberg and colleagues (2009) conducted a meta-analysis on neuroimaging studies examining individuals with schizophrenia and their performances on executive functioning tasks. On tasks of executive functioning, results indicated that, when compared to non-schizophrenia controls, individuals with schizophrenia demonstrated reduced activation bilaterally within the dlPFC, right vlPFC, right dorsal ACC, pre-supplementary motor area (pre-SMA), left ventral premotor cortex, posterior areas in the temporal and parietal cortex, and subcortical areas, such as the mediodorsal thalamus and putamen. Conversely, results trended towards greater activation within a midline cortical region located in the temporal and parietal cortices, insula, and amygdala. Given the

hypoactivation of the regions above and their previously documented relationships with executive functioning performance, hyperactivation was interpreted as compensatory strategies for cortical deficits.

Current Mental Health Classification System

The vast majority of prior work on psychopathology and executive functioning has been conducted using diagnostic groups. The DSM-5 was developed as an improved guide for classifying and diagnosing mental health symptoms and disorders (American Psychiatric Association, 2013). The development of the DSM and other diagnostic tools (i.e., International Classification of Diseases 10th Edition; WHO, 1992) have evolved over the years to improve our understanding of mental health symptoms and psychiatric classifications. These developments provide more accurate prevalence rates, enhance diagnostic procedures, and offer a universal language within the mental health and medical communities (Kendell & Jablensky, 2003).

However, current classification systems are not without limitations. Many have criticized the current diagnostic system for high degrees of comorbidity between disorders, a lack of consideration for clinical presentation (i.e., symptoms, onset, stage of illness), heterogeneity of mechanisms within a disorder, categorical and diagnostic thresholds, and reification of disorders, or the idea of labeling a disorder based on an arbitrary criteria of symptoms (Carragher et al., 2015; Cuthbert & Insel, 2013; Hyman, 2010; Insel et al., 2010; Kotov et al., 2017). Additionally, the current system fails to utilize biological advancements that do not fit a system that was developed prior to acknowledging the value of biomarkers (Cuthber & Insel, 2013). These, along with other limitations to the current system, are identified as some of the reasons for inconsistent findings from studies examining clinical populations.

Improving Classification Systems

In order to address many of these concerns, researchers have sought to approach psychopathology using systems that quantify psychiatric classifications (Kotov, 2016). Specifically, using a two-level model, constructs are operationalized dimensionally by constructing empirically-based clusters of symptoms (*syndromes*), thus replacing categorical diagnoses, and grouping syndromes on their covariation (*spectra*), to highlight relevant symptoms and reduce categorized diagnostic comorbidity. This approach essentially addresses the limitations cited above by reducing diagnostic heterogeneity through grouping related and removing unrelated symptoms (Kotov et al., 2017). It also provides a method for retaining all diagnostically relevant information, a common problem in thresholding diagnostic categories (Markon et al., 2011).

One of, if not the most important consideration for improving diagnostic systems of mental health disorders, stems from the impact these changes have on patient care. Stated another way, what is the clinical utility and implications of utilizing a dimensional classification approach and how does this influence treatment? First, improving mental health nosology by removing classifications places a greater emphasis on the symptoms of a disorder, versus focusing on the disorder itself. This approach offers more specific intervention targets, thus improving hierarchical frameworks and skill prioritization within treatment. (Kotov et al., 2017). This may alleviate some variability within psychiatric pharmaceutical research, as well as improving medication efficiency by attempting to treat individual symptoms instead of targeting clusters of symptoms (Cuthbert & Insel, 2013). Next, abstract concepts used to make up a diagnosis are now more susceptible to scientifically-based objective research, including genetics and biomarker testing, potentially reducing the comorbidity of underlying mechanisms that make

up multiple disorders (Cuthbert & Insel, 2013). Lastly, by characterizing everyone from a dimensional perspective, individuals with low pathology are less likely to be overlooked (Kotov et al., 2017). This may improve the current understanding of symptoms from a research perspective, and clinically, improve diagnostic accuracy and offer more appropriate and efficient forms of support (e.g., psychoeducation, therapy) for those with less severe symptoms.

In 2009, the NIMH instituted its Strategic Plan known as the Research Domain Criteria (RDoC) project, with the intent to reclassify mental disorders, from a research perspective, on a dimensional plane, based on observable behaviors and neurobiological measures (Insel et al., 2010). This project altered views on mental health by reconsidering the traditional perspective of mental disorders as clusters of symptoms based on clinical descriptions to translational symptoms and disorders (Cuthbert & Insel, 2013). The RDoC project has 5 major domains of functioning (Cuthbert and Insel 2013), including: negative valence domain, positive valence systems, cognitive systems, systems for social processes, and arousal/modulatory systems. Dimensions within each domain were agreed upon by 30-40 experts within their respective field, who provided a collaborative definition and methods for assessing the dimensions. Importantly, each dimension, or construct, was developed with the expectation that they will be continuously revised and subject to further validation. Within the cognitive systems domain, the construct of cognitive control has a similar definition to the use of executive functioning in the wider literature; in RDoC cognitive control is defined as "a system that modulates the operation of other cognitive and emotional systems, in the service of goal-directed behavior, when prepotent modes of responding are not adequate to meet the demands of the current context." The subdomain listed include those related to monitoring performance, updating goals, and inhibiting responses.

The RDoC project has also identified major issues related to using DSM and ICD criteria in research. First, it views symptoms translationally, using pathophysiological research (i.e., genetics, neuroscience, and behavior) to define symptoms and disorders. Next, it uses a dimensional approach to psychopathology and requires the development of reliable and valid measures to define symptoms. Third focuses on the methodology used for researching a specific symptom within a given sample. This places a greater emphasis on developing more thoughtful research designs. Next, a balanced, integrative approach is implemented when considering behavioral, neural, and constituent elements of a variable and, research must focus on empirically supported constructs. Lastly, in support of the ever-changing nature of RDoC constructs, this method encourages research into new, empirically supported constructs not currently included within the RDoC matrix, as a way to evolve current models.

Prior to initiation of the RDoC movement, but consistent in an effort to mitigate limitations to current mental health taxonomies, psychopathology researchers have sought to develop empirically supported organizational classifications of psychopathology, known as quantitative nosology (Achenbach & Rescorla, 2001; Kotov et al., 2017; Krueger & Markon, 2006; Lahey et al., 2008; Vollebergeh et al., 2001). This approach diverges from the traditional categorical approach to psychopathology, grouping syndromes on a spectrum and assesses the covariation of empirically based symptoms (Kotov et al., 2017). The development of quantitative nosology serves to improve upon the RDoC framework, by further developing the clinical dimensions of psychological phenotypes. Additionally, it attempts to target the limitations of clinical constructs by creating clearer definitions of phenotypes from basic research. Together, these two movements have the potential to improve current mental health diagnoses, with

quantitative nosology offering perspectives to inform phenotypic dimensions for the biological and behavioral constructs focused on within the RDoC model (Kotov et al., 2017).

Taken together, these two methodologies share an underlying approach to better understanding mental health by determining core psychopathological dimensions at the base of every disorder (Carragher et al., 2015). Therefore, latent dimensions within specific disorders are more likely to exhibit similar clinical presentations, cooccurrence rates, share variance within quantitative models, have similar etiology, and demonstrate similar treatment responses (Blanco et al., 2013; Carragher et al., 2015). Previous studies have consistently identified two fundamental dimensions common throughout psychopathology, internalizing and externalizing. Specifically, the internalizing dimension primarily consists of depressive, anxious (i.e., obsessive-compulsive disorder), posttraumatic stress, eating, and sexual disorders, while the traditional externalizing dimensions typically includes neurodevelopmental disorders, such as oppositional defiant disorder (ODD), conduct disorder (CD), intermittent explosive disorder (IED), and attention-deficit-hyperactivity disorder (ADHD), and adult antisocial behavior (Kotov et al., 2017). Although most of the externalizing dimension consists primarily of child and adolescent disorders, similar patterns have been replicated in adult samples (Achenbach & Rescorla, 2003; Carragher et al., 2014; Forbush & Watson, 2013; Krueger & Markon, 2006; Røysamb et al., 2011). More recently, Wright and Simms (2015) conducted a joint structure of mental disorders and DSM-5 pathological personality traits amongst a large sample of outpatient adults. Results indicated a five-factor structure, including: internalizing (anxiety and depressive disorders, along with borderline, avoidant, dependent, and paranoid PDs), disinhibition (substance use disorders, antisocial PD), antagonism (narcissistic and histrionic PDs), detachment (defined by schizoid, avoidant, and dependent PD at the high end and by histrionic

PD at the low end), and thought disorder (psychotic symptoms and schizotypal PD). However, other studies, using self-rating scales found six dimensions, which included: negative affectivity (internalizing), psychoticism (thought disorder), disconstraint (externalizing), aggressiveness (antagonism), introversion (detachment), and somatization (somatoform; McNulty & Overstreet, 2014; Sellbom, 2016).

The Hierarchical Taxonomy of Psychopathology (HiTOP) model (Kotov et al., 2017), is a hierarchical classification system designed to integrate empirically supported research of translational psychopathology into research and clinical practice. It is designed to construct a nosology using an empirically supported foundation of homogeneous components, maladaptive traits, and dimensional syndromes. This model utilized a six spectra model, with each spectrum chosen to best describe the most prominent features of a patient and to study common pathological processes. They include smaller groups and groups of symptoms to better define each heading. These spectra are: internalizing (or negative affectivity), thought disorder (or psychoticism), disinhibited externalizing, antagonistic externalizing, detachment, and somatoform. Consistent with previous studies, the spectra within this model demonstrated positive correlations (Achenbach & Rescorla, 2003; Kotov, Chang, et al., 2011; Krueger & Markon, 2006; Markon, 2010; Røysamb et al., 2011) that are consistent with a general psychopathology factor (Caspi et al., 2014; Lahey et al., 2011, 2012).

Summary of Prior Literature

The clinical utility of quantifying executive functioning provides insight into the daily functioning, cognitive abilities, and improved patient care of individuals with most (if not all) disorders. However, there is a great deal of variability in how executive functioning is defined and the "executive functioning" measure of one study may not overlap that strongly with the

measure in another (e.g., the use of self-report vs. performance measures). Although at least one model, the Unity and Diversity model, is widely used in cognitive psychology, a lot of clinical measures are not studied from within this framework. Executive functioning has so many definitions that by providing a universal term for this construct, it potentially leads to inconsistent interpretations and misunderstandings about someone's functioning. Therefore, studies would benefit from being more explicit in how they define this construct and why and how specific measures were chosen. The complex and multifaceted definition of executive functioning often leads to inconsistencies when attempting to measure or quantify this construct, as well. Studies often label findings as "executive functioning" when only a single domain of executive functioning is measured. Additionally, multiple measures are encouraged for assess individual domains of executive functioning. While interpreting performance can be complicated by task impurity, this issue may be worse if a single measure is used to interpret a global level of executive functioning.

Neuroimaging studies have also been affected by inconsistent measurement and interpretations of executive functioning. Tasks often require multiple cognitive abilities beyond executive functioning and neuroimaging is likely to highlight cortical activation that may or may not be related to the cognitive domain being discussed. For example, commonly used measures of executive functioning, such as the Stroop task or verbal fluency measures, are often used to assess cognitive shifting and monitoring, respectively. However, both of these tasks also rely heavily on other specific abilities (e.g., response speed, semantic knowledge). Not accounting for confounding variables that assess secondary cognitive abilities can lead to misunderstandings about performance-based tasks and their relationships to cortical regions. From an RDoC perspective, determining the neural mechanisms contributing to transdiagnostic symptoms is

essential for improving mental health. Therefore, misinterpretations about task-based abilities can potentially limit research into the foundational causes of symptomology.

Despite these issues, the current literature exploring executive functioning within clinical samples has demonstrated some consistencies. Specifically, individuals with disorders in the internalizing category demonstrate mild to moderate deficits on tasks of inhibition and shifting, as well as mild deficits on updating tasks. Neuroimaging studies have linked similar cognitive deficits within these populations to cortical hypoactivation within the ACC, MFG, and dlPFC. Although there is some variation in both performance and cortical de/activation across disorders, especially amongst individuals with OCD, these results are largely consistent across those with internalizing disorders.

In line with the view of executive functioning as a transdiagnostic feature of psychopathology, neuroimaging studies have shown that deficits within higher order cognition may parallel structural and functional cortical abnormalities (Goodkind et al., 2015; Goschke, 2014; McTeague et al., 2016). Goodkind et al., 2015 in a meta-analysis of studies of individual disorders found that across disorders the most common area of grey volume loss was in regions part of the cognitive control network. In a review by McTeague and colleagues (2016) of both structural and functional neuroimaging studies of individual disorders, support was found for transdiagnostic dysfunction in regions associated with executive functioning and the authors suggested that these deficits may partially explain daily functioning problems.

More recent theories suggest that these regions are largely apart of the general network of cognition (GNC; LeDoux & Brown 2017), a cortical network necessary for emotional consciousness and emotional regulation. This suggests that individuals with internalizing disorders may have difficulty managing their emotions, which may lead to some executive

dysfunction. For example, Seeley (2007) demonstrated that individuals with anxious mood performed worse on executive functioning tasks. Additionally, anxious mood was uniquely related to the salience network, a neural network of connections between the dACC and orbital frontoinsular cortices with subcortical and limbic structures, while executive functioning performance was uniquely related to the executive control network, a neural network of connections between regions of the PFC and left frontoinsula. This finding was interpreted as suggesting that the salience network may be utilizing and interfering with the cognitive resources necessary in executive functioning performance.

Executive functioning profiles for individuals with externalizing disorders differ from those with internalizing disorders. Even though executive dysfunction is associated with severity of mood symptoms (Sommerfelt et al., 2015), deficits within domains appear to vary amongst internalizing disorders (Nigg et al., 2017). However, those with externalizing disorders more commonly demonstrate inhibition deficits (Snyder, et al,. 2015; Young et al., 2009) and are impacted by speed-based tasks than those with internalizing disorders (Nigg et al., 2017). This is consistent with the neuroimaging findings within this group, which, in general, demonstrated hypoactivation within the frontoparietal network. Specifically, during inhibition tasks, reduced activation was found within the dlPFC and ACC, while increased activation was observed in the insular. As might be expected, these cortical anomalies have demonstrated relationships with poorer attention, worse inhibition, and are consistent behaviorally with higher degrees of impulsivity, a trait commonly exhibited by individuals with ADHD and substance abuse disorders.

Additionally, reduced attention and poorer inhibition can potentially lead to increased global executive dysfunction, a trait commonly used to describe individuals with externalizing

behaviors. In a more recent model of executive functioning, Miyake and Friedman (2012) suggest a new domain, Common EF, which is "one's ability to actively maintain task goals and goal-related information and use this information to bias lower-level processing". This new factor is highly correlated with inhibition, to the extent that inhibition-specific factors are sometimes removed from more recent models of executive functioning. Moreover, inhibition is often captured as behavioral disinhibition, a factor commonly observed within externalizing behavior problems. This variable too demonstrated a strong relationship to Common EF, suggesting that an increase in general executive functioning is related to fewer behavioral problems. Therefore, these results suggest that poorer inhibition may result in a more global, executive dysfunction that is commonly observed in those with externalizing disorders.

Individuals in the thought disorders group demonstrated severe impairment across all three executive functioning domains. Consistent with this finding, neuroimaging studies in general demonstrate greater cortex-wide hypoactivation amongst individuals with schizophrenia, than individuals in either internalizing or externalizing groups. Reduced activation was noted within the PFC, dorsal ACC, pre-SMA, premotor cortex, posterior regions of the temporal and parietal cortices, and subcortical areas, including the thalamus and putamen. These findings appear consistent, in that individuals with schizophrenia commonly demonstrate reduced cognitive functioning. Therefore, it is not surprising that this group also demonstrated a greater severity of impairment on these higher order cognitive tasks.

Overall, the current classification system of mental health disorders has numerous limitations that are frequently cited within the literature. One of the greatest hinderances within the current system is the use of a categorical approach to classifying disorders, as it fails to determine the core psychopathological dimensions at the foundation of individual disorders.

Additionally, this system also creates inconsistencies within the literature because individuals with similar diagnoses do not always possess the same symptoms. These limitations, along with others, can make it difficult to the determine the relationships between symptoms and particular deficits. For example, a finding of worse executive functioning in one diagnostic group could reflect comorbidity with other symptoms rather than be unique to that group (e.g., deficits in those with anxiety disorders related to elevated depressive symptoms in that group). Few studies consider comorbidity (e.g., Snyder et al., 2015a), while some studies exclude participants based on some types of comorbidity.

Currently, certain approaches are in place to reconceptualize the current understanding of mental health disorders (i.e., RDoC, hierarchical models of psychopathology), emphasizing the role of transdiagnostic factors within psychopathology. This design not only has the potential to improve understanding of symptoms and traits that make up disorders, as it provides greater consistency for researching symptoms, but it can also improve clinical utility by emphasizing target symptoms for treatment. Therefore, a transition towards a more dimensional approach may be beneficial for the future of mental health.

Current Study

Quantifying executive dysfunction can provide useful information for identifying current and potential functioning capabilities and predicting treatment outcome. Although previous studies have examined the relationship between executive functioning and specific diagnoses, there are potential limitations to the current literature. Specifically, individuals with the same diagnosis can demonstrate within-subject symptom variability, potentially causing differences in symptom frequency or symptom presentations within the same diagnostic category. Few studies have examined dimensions of psychopathology as they relate to the individual domains of

executive functioning, especially within the adult population. However, child and adolescent studies taking this approach have demonstrated that executive functioning is associated with psychopathology at the dimensional level. Therefore, this suggests that executive dysfunction may be broadly related to dimensional aspects of psychopathology and is not just as a byproduct of certain disorders.

Another issue within the current literature stems from measuring executive functioning, in that studies often use single performance measures to quantify executive dysfunction. However, the widely accepted Unity and Diversity model (Miyake et al., 2000), which subdivides this higher order cognitive process into three cognitive domains (i.e., inhibition, shifting, updating), would suggest that individual domains of executive functioning need to be assessed independently, in order to determine where deficits exist. Additionally, in using multiple measures, test impurity can be considered as an individual executive functioning task will have variance related to both executive functioning and other cognitive abilities.

Therefore, the present study attempted to remedy the limitations of previous research by first, evaluating the relationships between the individual domains of executive functioning and psychopathology using a dimensional approach. Additionally, this study used multiple measures to assess each construct and implemented a previously developed scoring method, which aims to reduce non-executive functioning variance (e.g., processing speed, verbal abilities).

Given the above, the specific research questions that will be examined are:

(1) How does symptom severity within a particular domain of psychopathology relate to the individual domains of executive functioning?

(2) Do certain domains of psychopathology have greater executive dysfunction when compared to other domains of psychopathology?

Hypotheses

Hypotheses for each of the research questions is presented below:

(1) Severity of internalizing, externalizing, and thought disorder symptoms will be negatively related to executive functioning performance across domains.

(2) Thought disorder symptoms will demonstrate stronger, negative relationships with fluency and shifting, as compared to externalizing and internalizing symptoms

(3) Severity of thought disorder symptoms and externalizing disorder symptoms will demonstrate stronger, negative relationships with inhibition than the association of inhibition with internalizing disorder symptoms.

METHODS

Participants

The Nathan Kline Institute (NKI)-Rockland project (Nooner et al., 2012) was designed to create a data repository to test existing and generate new hypotheses about psychiatric illness. Recruitment targeted Rockland County, New York, an area of the country with ethnic and economic diversity that models that of the United States, in order to increase generalizability of findings. The NKI project is ongoing and continues to both recruit new participants and collect follow-up data from those enrolled. Subjects included in analyses are part of this project, which represents a non-clinical, open-access sample, where psychiatric exclusion criteria were limited to severe mental illness (McDonald et al., 2016). Behavioral and psychiatric data were excluded from analyses if subjects were not between the ages of 18-59 years or if data were omitted from the original collection. This was done as the age range for the measure of psychopathology used in the proposed study is 18-59. Overall, the sample included 737 individuals, predominantly female (n = 466) with a mean age of 38.39 years (13.22) and a range of 41. The sample is mostly Caucasian (n = 498) English speakers (n = 666). Of the total sample, 722 subjects completed the ASR and D-KEFS.

Measures

Adult Self-Report (ASR; Achenbach and Rescorla, 2003)

The ASR is a self-report questionnaire designed to assess adaptive functioning, behavior, emotional and social problems, personal strengths, and substance use amongst individuals 18-59 years. This instrument contains eight, empirically-based syndrome scales that extend to multiple aspects of psychopathology. Previous factor analyses identified a two-factor model of broad-spectrum groups containing six of the eight subscales, including: Internalizing

(Anxious/Depressed, Somatic Complaints, and Withdrawn) and Externalizing (Aggressive, Intrusive, and Rule-Breaking Behaviors). These traits are comparable to the child instrument, with the exception of one unique syndrome (i.e., Intrusive Behaviors, which is made up of characteristics, such as, *Brags, Loud, Shows off, Talks too much, Teases a lot,* and *Tries to get a lot of attention*). The ASR demonstrates good test-rest reliability for the empirically-based scales (r = 0.78 to 0.91) and internal consistency (α = 0.72 to 0.88) (Achenbach & Rescorla, 2003). Notably, two other subscales designed to assess thought disorder symptoms and cognitive complaints (Thought Problems and Attention Problems) can also be calculated within this measure, though they are not included within the Internalizing or Externalizing factors (Achenbach et al., 2017). The thought problems subscale measures symptoms commonly present amongst individuals with thought disorders, including hallucinations, OCD-symptoms, strange thoughts and behaviors, self-harm and suicide attempts (Abdellaouis et al., 2012) and was included to create a third factor of dimensional psychopathology related to thought disorders.

The Peter's et al. Delusions Inventory (PDI; Peters et al., 1999)

The PDI is a 21-item self-report measure designed to assess delusional ideation within a non-clinical sample. The total score is a sum of items endorsed (0 or 1) by the participant, including: 'Do you ever feel as if you are under the control of some force or power other than yourself?' or 'Do you ever feel as if things in magazines or on TV were written especially for you?'. This measure demonstrates good internal inconsistency (α = 0.88) and test re-test reliability (r = 0.82), as well as adequate convergent validity with the Delusions Symptom-State Inventory (r = 0.61; Foulds & Bedford, 1975) (Peters et al., 2004). This measure was included as a variable of psychopathology to create a third, Thought Disorders factor.

The Delis-Kaplan Executive Function System (D-KEFS)

The Delis-Kaplan Executive Function System (D-KEFS) is a nine-test neuropsychological measure specifically designed to assess executive functioning (Delis, Kaplan, & Kramer, 2001). This assessment has been nationally normed for individuals 8-89 years and has been widely researched since being published (Baron, 2004; Homack, Lee, & Riccio, 2005; Latzman & Markon, 2010; Rabin et al., 2005; Shunk, Davis, & Dean, 2006; Swanson, 2005). Although reliability of individual subtests from the D-KEFS are less than .80 (Delis, Kramer, Kaplan, and Holdnack, 2004), this is comparable to other neuropsychological tests (Drew et al., 2008). Following the factor structure proposed by Karr and colleagues (2018), standard scores of selected subtests were grouped and averaged based upon their respective cognitive domains. In keeping with this model, anticipated cognitive domains from the D-KEFS include: inhibition, shifting, and fluency.

The D-KEFS, a battery of executive functioning commonly used in clinical practice (Karr et al., 2018) has demonstrated factor structures consistent with the cognitive domains of the Unity and Diversity model for selected subtests (e.g., Karr et al., 2018; Latzman & Markon, 2010). Specifically, Markon and Latzman (2010) conducted an exploratory factor analysis on the total achievement scores of the D-KEFS, across three age groups (8-19 years, 20-49 years, and 50-89 years), creating test specific factors that were consistent with the three-factor model of executive functioning. Results of this study indicate that the three factors resembling Inhibition, Updating, and Shifting were made up primarily of scores from individual subtests (e.g., Sorting on factor one, Verbal fluency on factor two, and Color Word Interference Test and Trail Making Test on factor three). Additionally, timed tasks (i.e., Sorting, Verbal Fluency, and Color Word Interference Test and Trail Making Test) loaded independently onto each of the three factors,

suggesting that method variance may have influenced results, as non-executive functioning cognitive skills are noticeably required to complete these tasks (Karr et al., 2018).

Karr and colleagues (2018) attempted to identify the factor structure of the D-KEFS, while removing method variance attributable to speed and language ability, in order to obtain a "pure" measure of executive functioning performance. Results of the study demonstrated a three-factor model from the D-KEFS, which coincided with two of the three executive functioning domains from the Miyake model, including inhibition and shifting. However, the authors argue that, within the D-KEFS subtests, updating, the act of assessing and retrieving information from long-term memory, may be better defined as fluency, given that these measures require individuals to utilize their working memory and lexicon to strategically access and recall information from their long-term memory. Overall, using this model, the authors were able to determine the latent structure of the D-KEFS and identify constructs that explain performances on complex tasks.

Karr and colleagues (2018) address the test impurity issue by factoring out two cognitive abilities common within D-KEFS subtests: processing speed and verbal abilities. Specifically, processing speed is removed from tasks in the inhibition and shifting domains. Within the inhibition domain, the two Color-Word Interference scores were made orthogonal to the summed performance on the Word Reading and Color Naming trials. The variance within these scores were represented in the residualized scores. Similarly, the Trail Making Number-Letter Switching score was made orthogonal to the summed score on the Number and Letter Sequencing trials and represented as a residualized score. Next, the Design Fluency Switching score from the shifting factor was made orthogonal to the Design Fluency score. Lastly, verbal capabilities were factored out of the Verbal Fluency scores within the Fluency domain. The

Verbal Fluency scores were made orthogonal to the WASI Vocabulary subtest and accounted for the variance within the Letter Fluency and Category Fluency conditions, which were represented as residualized scores.

The Inhibition subscale was comprised of performance-based scores from the Tower and Color-word Interference test. Similar to the Tower of Hanoi, the Tower Test requires subjects to manipulate disks across three pegs to match a specific design. Although many scores are derived from this subtest, the Total achievement score, which is comprised of the sum of points and moves-to-complete each trial, is a primary score that was used to quantify part of the inhibition domain. Next, inhibition trials (trials 3 and 4) from the Color-Word Interference Test, in which processing speed was factored out, were also included. This task requires participants to read the color of the ink in which a word is printed, which was incongruent to the word itself and, similarly, read either the color of the word or the word itself, if the word was displayed inside a box.

The shifting domain was made up of scores from three subtests: the Trail Making Test, Design Fluency Test, and Sorting Test. Scores from the Trail Making test and Design Fluency Test were adjusted by controlling for processing speed. The Trail Making Test Number-Letter Switching trial, which required participants to connect dots of letters and numbers sequentially, while alternating between number and letter. Next, a Switching-Total Correct score from the Design Fluency Test were included, which requires participants to draw abstract designs, while alternating between black and empty dots. Lastly, Confirmed Correct Sorts from the Sorting Test were included. This test requires participants to organize and qualify a collection of six cards into two groups with similar properties, based on verbal and aesthetic properties.

The fluency domain consisted of scores from the Verbal Fluency Test. Verbal ability was factored out of Letter and Category Fluency performance scores. Participants were asked to complete one-minute trials, where they generate words from phonemic or semantic indicators. The sum of total correct words from Letter Fluency and Category Fluency subtests were both included to make up this domain. Scores from unique designs from two trials of The Design Fluency Test were served as the third fluency score.

Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 1999)

The WASI-II consists of four subtests with high factor loadings on general intelligence. The vocabulary subtest measures word knowledge, crystalized intelligence, and language development, where item scoring is based on a 0-2-point basis. The vocabulary subtest demonstrates strong reliability in adults (0.90-0.92) and good concurrent validity with the WAIS-IV (0.71 to 0.92). This measure was included to control for the influence of language functioning on the Verbal Fluency measures.

Analyses

All standardized data are age-corrected at $M = 10$, $SD = 3$ or $M = 50$, $SD = 10$, where higher values indicate better performance on task-based measures. However, when assessing dimensions of psychopathology, higher values indicate more severe psychological dysfunction.

Confirmatory Factor Analysis (CFA)

A CFA was estimated to recreate a previously established factor structure of the D-KEFS. Given prior work showing internalizing and externalizing factors of psychopathology based on a subset of ASR subscales, and other studies showing an additional thought disorder factor when using other measures of psychopathology, a CFA model was estimated to test whether a three

factor model of psychopathology (i.e., internalizing, externalizing, and thought disorder) based on the ASR and PDI would have good model fit.

Analyses were run using MPlus Version 7 (Muthén, L. K., & Muthén, 2012) to test the fit of the proposed factor models of the D-KEFS and ASR. If poor fit was obtained, modifications were made based on practical and theoretical considerations in order to proceed with models relating executive functioning to psychopathology.

Although the ASR derives a two-factor model (i.e., internalizing and externalizing), dimensional psychopathology research suggests that severe psychopathology, including thought disorder symptoms, represents a unique third factor of psychopathology that accompanies internalizing and externalizing symptoms (Kotov et al., 2010; Markon, 2010; Wolf et al. 1988). This third factor of psychopathology was constructed using the PDI and thought problems subscale from the ASR. The PDI was chosen for this factor, as it measures symptoms unique to thought disorders. For example, it contains items consistent with both psychotic (e.g., 'hears sounds, voices', 'sees things', 'strange behavior, 'strange ideas') and OCD symptoms (e.g., 'can't get mind off thoughts', 'repeats acts'; Abdellaoui et al., 2012).

Additionally, the attention problems variable was not used during analyses. The original, two-factor model of the ASR (Achenbach et al., 2017) did not include the attention problems within either factor. Therefore, given this subscale did not fit as a sole marker of either internalizing or externalizing, and it is not used in the literature as a marker of thought disorders, it was not included within the CFA models. Overall, a three-factor model of dimensional psychopathology was created to include Internalizing, Externalizing, and Thought Disorder factors.

Structural Equation Modeling (SEM)

SEM was conducted to examine how psychopathology dimensions relate to individual executive functioning domains (see Figure 1). Analyses were performed using MPlus Version 7 (Muthén, L. K., & Muthén, 2012), which uses maximum likelihood estimation techniques to determine the specified latent variable loadings from the covariance matrix.

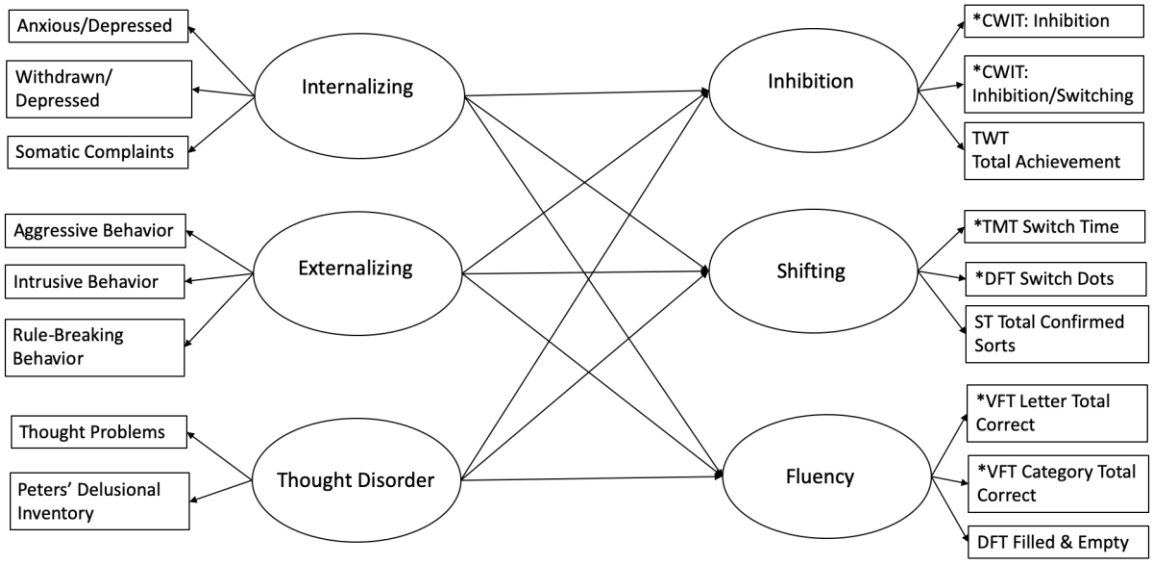

Figure 1. Three-factor models of executive functioning and psychopathology. ST = Sorting Test; CWIT = Color-Word Interference Test; DFT = Design Fluency Test; TMT = Trail Making Test; TWT = Tower Test; VFT = Verbal Fluency Test. *Indicates a value that was residualized of variance attributable to a control variable. Correlations among psychopathology and among executive functioning factors were also estimated but not shown in the figure above.

Model goodness of fit was determined using χ^2 based fit statistics: Bentler's Comparative Fit Index (CFI), the root-mean-square error of approximation (RMSEA), and 90% RMSEA confidence interval. To test hypothesis 1, three factors of executive functioning were regressed on three factors of psychopathology to indicate how the model of psychopathology predicts the three executive functioning domains. To test hypotheses 2 and 3, relationships between executive functioning domains and psychopathology factors were compared by applying equality constraints to test for differences in the strength of specific paths between domains of executive

functioning and psychopathology. For example, if the paths between both internalizing and externalizing factors are set equal as predictors of shifting, and results indicated that this constraint did not worsen model fit, then this suggests that the relationship between internalizing and externalizing with shifting are not significantly different. Lastly, individual psychopathology factors were examined in separate models as they relate to all three executive functioning domains as an exploratory analysis given prior analyses all involve all factors examined simultaneously.

RESULTS

Descriptive statistics can be found in Table 3 and psychopathology and cognitive performance can be found in Table 4. Results indicated that skewness and kurtosis were within normal limits, suggesting a normal distribution. No multivariate outliers were identified using Mahalanobis' distance.

Table 3. Demographics

Demographics	N (%) or mean ± SD (range)
Females	463 (64.5%)
Age (years)	38.39 ± 13.22 (18-59)
Education	15.15 ± 2.19 (9-23)
Race	
White	498 (70.0%)
Black	142 (19.8%)
Asian	41 (5.7%)
Other	36 (5.1%)
Ethnicity	
Hispanic	98 (13.6%)

Table 3 and Table 4 were previously published as Roye, S., Castagna, P. J., Calamia, M., De Vito, A. N., Lee, T. H., & Greening, S. G. (2020). Relationships between multiple dimensions of executive functioning and resting-state networks in adults. *Neuropsychologia*, 107418. Reprinted by permission of Elsevier.

Table 4. Descriptive Statistics for Psychopathology and Cognitive Performance Measures

Psychopathology	*Mean T-scores*	*SD*
Internalizing		
Anxious/Depressed	54.06	6.55
Withdrawn/Depressed	53.75	5.91
Somatic Complaints	54.09	5.52
Thought Disorder		
Thought Problems	52.31	4.54
PDI*	3.29	2.96
Externalizing		
Aggressive Behavior	53.09	4.83
Rule-Breaking Behavior	54.13	5.81
Intrusive	52.61	4.18
Executive Functioning	*Mean scaled scores*	*SD*
Inhibition		
CWIT: Inhibition	10.55	2.78
CWIT: Inhibition/Switching	10.51	2.75
TWT: Total Achievement	9.96	2.48
Shifting		
TMT: Switch Time	10.34	2.84
DFT: Switch Dots	10.82	2.71
ST Total Confirmed Sorts**	21.49	5.24
Fluency		
VFT Letter Total Correct	10.95	3.47
VFT Category Total Correct	11.42	3.45
DFT Filled & Empty	10.66	2.65

Note. ST = Sorting Test; CWIT = Color-Word Interference Test; DFT = Design Fluency Test; TMT = Trail Making Test; TWT = Tower Test; VFT = Verbal Fluency Test. *Indicates a raw score. **Indicates the sum of two scaled scores. Correlations among psychopathology and among executive functioning factors were also estimated but not shown in the figure above.

Confirmatory Factor Analysis of ASR

A CFA of the predicted, three-factor model of dimensional psychopathology (i.e., internalizing, externalizing, and thought disorder symptoms) demonstrated a good model fit (CFI = 0.95; RSMEA = 0.09). This model was constructed using seven of the eight variables from the ASR, as well as the PDI. Factor loadings for both models can be found in Table 5.

Table 5. CFA Factor Loadings

Psychopathology	Loading	*SE*	*p*
Internalizing			
Anxious/Depressed	0.849	0.018	0.00
Withdrawn/Depressed	0.731	0.022	0.00
Somatic Complaints	0.618	0.027	0.00
Thought Disorder			
Thought Problems	0.842	0.035	0.00
PDI	0.519	0.034	0.00
Externalizing			
Aggressive Behavior	0.844	0.021	0.00
Rule-Breaking Behavior	0.681	0.026	0.00
Intrusive	0.482	0.033	0.00
Executive Functioning			
Inhibition			
CWIT: Inhibition*	0.617	0.046	0.00
CWIT: Inhibition/Switching*	0.612	0.046	0.00
TWT: Total Achievement	0.382	0.053	0.00
Shifting			
TMT: Switch Time*	0.389	0.047	0.00
DFT: Switch Dots*	0.463	0.049	0.00
ST Total Confirmed Sorts	0.505	0.063	0.00
Fluency			
VFT Letter Total Correct*	0.296	0.046	0.00
VFT Category Total Correct*	0.343	0.051	0.00
DFT Filled & Empty	0.829	0.091	0.00

Note. ST = Sorting Test; CWIT = Color-Word Interference Test; DFT = Design Fluency Test; PDI = Peters' Delusional Inventory; TMT = Trail Making Test; TWT = Tower Test; VFT = Verbal Fluency Test. *Indicates a value that was residualized of variance attributable to a control variable. Correlations among psychopathology and among executive functioning factors were also estimated but not shown in Figure 1.

Confirmatory Factor Analysis of the D-KEFS

The three-factor model of the D-KEFS indicated an inadequate fit (CFI = 0.85; RMSEA = 0.08). The modification indices within the model output noted that a residual correlation between two scores from the same subtest (design fluency) would improve model fit (M.I. = 45.48), suggesting they may have a relationship beyond what is accounted for by the individual factors. The use of a residual correlation for two scores from the same subtest is consistent with

the Karr et al. (2018) model which includes a residual correlation between the two verbal fluency scores. Therefore, an additional correlation between the two design fluency variables was included, which improved fit for the three-factor model (CFI = 0.90; RMSEA = 0.07) to an acceptable level.

In accordance with the analyses conducted by Karr and colleagues (2018), additional models were tested to determine if other factor structures provided an improved fit (see Table 6). Results of a three-factor model without including correlation residuals for verbal fluency demonstrated a much weaker fit (CFI = 0.80; RMSEA = 0.09) than either of the three factor models discussed above. Two factor models merging inhibition with shifting (CFI = 0.85; RMSEA = 0.08) or fluency (CFI = 0.79; RMSEA = 0.10) did not indicate a better fit, either. Similarly, when shifting was merged with fluency (CFI = 0.81; RMSEA = 0.09), goodness of fit did not exceed that of the original three factor model, nor did a unidimensional model (CFI = 0.79; RMSEA = 0.09). Of the models tested, a higher-order model demonstrated the second best fit (CFI = 0.85; RMSEA = 0.08), though this did not surpass the three-factor model structure. Lastly, a bifactor structure was tested in which all scores loaded onto a general executive functioning factor and one of three specific factors (i.e., inhibition, shifting, and fluency); however, it could not be estimated (i.e., the covariance matrix was not positive definite). Notably, the inclusion of a residual correlation between the two design fluency scores, as was done in the adjusted three factor model above, did not improve the fit of these models.

Table 6. Measurement model fit indices

Model	χ^2 (*p*)	*df*	CFI	RMSEA (90% C.I.)
ASR + PDI				
Three Factors (Int., Ext., TD.)	124.92 (0.00)	17	0.95	0.09 (0.07-0.10)
D-KEFS				
Three Factors (Inh., Shi., Flu.)	169.82 (0.00)	24	0.80	0.09 (0.08-0.11)

(table cont'd.)

Model	χ^2 (*p*)	*df*	CFI	RMSEA (90% C.I.)
Three Factors (Inh., Shi., Flu.), VFT corr.	136.06 (0.00)	23	0.85	0.08 (0.07-0.10)
Three Factors (Inh., Shi., Flu.), VFT, DFT corr.	97.45 (0.00)	22	0.90	0.07 (0.06-0.09)
Two Factors (Flu., Inh.=Shi.), VFT corr.	142.93 (0.00)	25	0.84	0.08 (0.07-0.10)
Two Factors (Shi., Inh.=Flu.), VFT corr.	180.64 (0.00)	25	0.79	0.10 (0.08-0.11)
Two Factors (Inh., Shi.=Flu.), VFT corr.	165.72 (0.00)	25	0.81	0.09 (0.08-0.11)
Unidimensional (Inh.=Shi.=Flu.), VFT corr.	181.38 (0.00)	26	0.79	0.09 (0.08-0.11)
Bifactor	Did not converge.			

Note. χ^2 = Chi-Square Test of Model Fit; CFI = Comparative Fit Index; Flu. = Fluency; Inh. = Inhibition; RMSEA = Root Mean Square Error of Approximation; Shi. = Shifting; VFT corr. = Verbal Fluency Test score errors correlated. DFT corr. = Design Fluency Test score errors correlated.

Structural Equation Model (SEM) Comparing ASR and D-KEFS

A structural equation modeling approach was used to determine the relationships between dimensions of psychopathology and the individual domains of executive functioning. Both executive functioning and psychopathology were modeled based on the results of the best-fitting CFA models above (see Table 7).

Table 7. Structural equation model comparing ASR and D-KEFS

Domain	Internalizing	Externalizing	Thought Disorder
Inhibition	0.36 (0.01)	-0.32 (0.02)	-0.12 (0.27)
Shifting	0.37 (0.03)	-0.13 (0.42)	-0.26 (0.06)
Fluency	-0.37 (0.01)	0.34 (0.01)	0.04 (0.73)

Note. χ^2 = Chi-Square Test of Model Fit; CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation. χ^2 (*p*) = 305.78 (0.00), df = 102, CFI = 0.93, RMSEA (90% C.I.) = 0.05 (0.05-0.06).

The first hypothesis examined if greater symptom severity was related to worse executive functioning performance. The standardized structural model fit predicting executive dysfunction from psychopathology demonstrated a good baseline structural model fit (CFI = 0.93; RMSEA = 0.05). Internalizing symptoms was the only dimension of psychopathology that was significantly related to all three executive functioning domains. Specifically, more severe symptoms were related to better performance on inhibition ($\beta = 0.36$, *SE* = 0.14, $p < .01$) and shifting ($\beta = 0.37$,

SE = 0.18, $p < .05$) tasks, but worse performance on fluency (β = -0.37, *SE* = 0.14, $p < .05$) tasks. Next, more severe externalizing symptoms was related to worse performance on inhibition (β = -0.32, *SE* = 0.13, $p < .05$) tasks and better performances on fluency (β = 0.34, *SE* = 0.13, $p < .01$) tasks. However, it was not related to shifting (β = -0.13, *SE* = 0.16, $p > .05$). While thought disorder symptoms was not significantly related to any of the three executive functioning domains, it trended towards more severe symptoms being related to worse performances on shifting (β = -0.26, *SE* = 0.14, $p = .06$) tasks.

The second hypothesis predicted that thought disorder symptoms would demonstrate more negative relationships with shifting and fluency performance, than externalizing and internalizing symptoms. Results of the Wald Test indicated that shifting performance was similarly influenced by thought disorder traits and externalizing traits (Wald chi-square [1] = 0.32, $p = .57$), but not thought disorder traits and internalizing traits (Wald chi-square [1] = 5.10, $p = .02$). As noted above, internalizing traits are positively related to shifting performance, while thought disorder traits are negatively related. Analyses also indicated that fluency performance was similarly influenced by thought disorder traits and externalizing traits (Wald chi-square [1] = 2.87, $p = .09$), as well as thought disorder traits and internalizing traits (Wald chi-square [1] = 3.59, $p = .06$).

The third hypothesis predicted that thought disorder symptoms and externalizing symptoms would demonstrating stronger, more negative relationships with inhibition than internalizing symptoms. Results demonstrated significant differences between internalizing traits and thought disorder symptoms (Wald chi-square [1] = 5.02, $p = .03$) and internalizing traits and externalizing traits (Wald chi-square [1] = 6.83, $p = .01$). As noted above, internalizing traits are

positively related inhibition performance, while thought disorder and externalizing traits are negatively related.

Supplemental Analyses

Dimensions of psychopathology were examined individually in separate models and compared to the three-factor model of executive functioning. Results indicated non-significant relationships between psychopathology and executive functioning performance, with the exception of externalizing symptoms and inhibition performance ($\beta = -0.12$, $p = .04$).

DISCUSSION

The clinical utility of executive functioning includes its potential to identify specific cognitive deficits in psychological disorders, provide a target for monitoring and improving treatment outcomes, and potentially enhancing diagnostic accuracy. However, inconsistencies within the current literature regarding a universal definition or a systematic method of quantifying this construct, limits advancement within this area of research. For example, the Unity and Diversity model (Miyake et al., 2000) is widely used in cognitive psychology and provides a structure for identifying the composition of domains within executive functioning. However, clinical studies often deviate from this model (Rabin et al., 2016), using varying assessment measures to evaluate executive functioning (Karr et al., 2018). Additionally, a majority of clinical studies use only one or a limited number of measures to assess executive functioning, leaving them susceptible to task impurity, or the measurement of non-executive cognitive processes that can confound performance-based measures (Snyder et al., 2015).

Similarly, although the current mental health classification system provides a structure for researching psychopathology, many have criticized the utility of the system, given high degrees of comorbidity between disorders, a lack of consideration for clinical presentation (i.e., symptoms, onset, stage of illness), heterogeneity of mechanisms within a disorder, categorical and diagnostic thresholds, and reification of disorders, or the idea of labeling a disorder based on an arbitrary criteria of symptoms (Carragher et al., 2015; Cuthbert & Insel, 2013; Hyman, 2010; Insel et al., 2010; Kotov et al., 2017). In order to address many of these concerns, researchers have sought to approach psychopathology using systems that quantify psychiatric classifications (Kotov, 2016), examining dimensions of psychological traits, as opposed to individuals that fit within a diagnostic criterion. Among other benefits, it has been argued that researching

psychopathology dimensionally provides more specific targets for treatments and interventions (Kotov et al., 2017), clarifies abstract concepts used to classify diagnoses (Cuthbert & Insel, 2013), and lesser degrees of psychopathology are less likely to be excluded from research (Kotov et al., 2017), which can improve diagnostic accuracy and highlight support needed for individuals with less severe symptoms.

Despite the limitations of exploring psychopathology using diagnostic criteria, the vast majority of prior work examining relationships between psychopathology and executive functioning has been conducted using diagnostic groups. In an attempt to overcome previous limitations within the literature, the present study sought to evaluate the relationships between the individual domains of executive functioning and psychopathology using a dimensional approach. Additionally, this study used multiple measures to assess each construct and implemented a previously developed scoring method, designed to reduce non-executive functioning variance (e.g., processing speed, verbal abilities). Additionally, this study further provides a unique contribution to the literature, in that no other studies have examined the relationship between these two models.

Factor Structure of Psychopathology and Executive Functioning

A CFA of the ASR and PDI model indicated an adequate fit as a three-factor model of dimensional psychopathology. It included two dimensional measures of psychopathology previously established by the ASR (Internalizing and Externalizing; Achenbach et al., 2017) and one original factor (Thought Disorders), which included the thought problems subscale from the ASR and the PDI. Consistent with previous literature (Anderson et al., 2015; Caspi et al., 2014; Kotov et al., 2010; Kotov et al., 2011; Markon, 2010), this model reflects three distinct factors of psychopathology. Inter-factor correlations were high between all three variables, with

internalizing and externalizing demonstrating the strongest relationship (r = 0.81), followed by internalizing and thought disorders (r = 0.73), and externalizing and thought disorders (r = 0.68). Prior work has shown a high degree of variability in the relationships between internalizing, externalizing, and thought disorders factors. For example, small to moderate correlations (r = 0.10 to 0.25, Kotov, Chang, et al., 2011; r = 0.23 to 0.41, Kotov, Ruggero, et al., 2011) have been observed in some studies. In contrast, moderate to high correlations have also been observed in other studies (e.g., r = 0.41 to 0.70, Markon et al., 2010) with one study finding the relationship between internalizing and thought disorder so strong (r = 0.87) that thought disorder was then modeled as a factor within internalizing symptoms (Keyes et al., 2013). The majority of studies examining the factor structure of psychopathology use data from structured clinical interviews and have been conducted with clinical samples. One study using dimensional measures (i.e., scores on the Minnesota Multiphasic Personality Inventory-2-Restructured Form and Personality Disorders Inventory for DSM-5) to model internalizing, externalizing, and thought disorder factors found small to moderate correlations (r = 0.23 to 0.37). Compared to the available literature, the relationships in the current sample are on the higher end of what has been observed and this may reflect the use of a non-clinical sample and shared variance associated with using subscales primarily from a single measure.

A CFA of the executive functioning model proposed by Karr et al. (2018) did not replicate within this sample. While the original model accounted for residual correlation values between two verbal fluency measures, results from this sample indicated a need to include a similar correlation between the two design fluency scores as well. Once this additional residual correlation was added the model demonstrated an adequate fit. Inter-factor correlations were high between shifting and inhibition (r = 0.81) and shifting and fluency (r = 0.72), but not

between inhibition and fluency (r = 0.43). These results are consistent with Karr et al. (2018), who demonstrated similar relationships between their factors.

Overall, the results of this study contribute to the current literature examining how dimensional psychopathology influences aspects of executive functioning. The two models analyzed are consistent with previously supported theories within their fields of research and contain unexamined elements that expands upon past results. For example, the dimensional psychopathology model contains a Thought Disorders factor that is unique to the two-factor ASR model of internalizing and externalizing. Additionally, the popular Unity and Diversity model of executive functioning was examined using a recently proposed model for scores from a popular clinical measure (i.e., the D-KEFS) (Karr et al., 2018). While three factor models of executive functioning are commonly used within adult samples (Karr et al., 2018; Klauer et al., 2010; Latzman et al., 2010; Miyake et al., 2000), these models do not always have a good fit across studies (Karr et al., 2018a), and may explain why an adjustment was necessary within the current study to obtain adequate model fit.

Associations Between Executive Functioning and Dimensions of Psychopathology

Contrary to hypothesis 1, severity of psychopathology was not always related to worse performance. Specifically, more severe internalizing symptoms interfered with fluency performance, but were also related to improved performances on both shifting and inhibition tasks. Additionally, externalizing symptoms demonstrated an opposite relationship with these measures, as individuals performed worse on inhibition tasks but better on fluency tasks. These results deviated from previous literature that consistently described mental health symptoms as impeding cognitive performance, so additional post-hoc tests were conducted.

Supplemental analyses investigating individual relationships between all six factors (3 psychopathology and 3 executive functioning domains) provided clarity for some of these initial findings. Results indicated that individual dimensions of psychopathology alone did not predict worse cognitive performance, with the exception of a weak relationship between externalizing and inhibition. Although notably, the direction of these non-significant relationships were consistent with the results from the initial SEM. Taken together, this suggests that the relationships found within these model comparisons may be subject to a suppression effect, where the relationship between two variables is strengthened by the presence of a third variable (Cheung et al., 2008). For example, internalizing or externalizing symptoms alone may not significantly impact cognitive performance. However, when all dimensions of psychopathology are considered within a single model, the unique variance provided by either internalizing or externalizing uniquely influences aspects of executive functioning performance.

Overall, results indicated that executive functioning performance was differently influenced by levels of psychopathology. Specifically, individuals with more internalizing traits performed better on inhibition tasks. This may be explained by theories about symptoms from internalizing disorders, which suggest that state anxiety may increase arousal and motivation (Eysenck et al., 2007) and facilitate cognitive performance (Lupien et al., 2007; Yerkes-Dodson Law, 1908). Another study also demonstrated that individuals who ruminate more, a trait commonly observed amongst individuals with depression, committed less disinhibition errors (Altamirano et al., 2010). Prior work finding a negative association between internalizing disorders and inhibition have identified cognitive speed as a potential confound in interpreting inhibition scores (Edwards et al., 2005; Snyder et al., 2013; Visu-Petra et al., 2013; Wood et al.,

2001) and, in the current study, the influence of speed on inhibition scores was reduced through the use of residualized scores controlling for baseline response speed.

Results also indicated a negative relationship between more internalizing symptoms and fluency performance. Notably, the fluency factor within the Karr et al (2018) model of executive functioning is comparable to updating, which includes "effective gating of information and controlled retrieval from long-term memory" (Myake & Friedman, 2012). Working memory, or updating deficits are commonly associated with clinical populations from internalizing psychopathology, including depression (Berggren & Derakshan, 2013; Owens et al., 2013) and anxiety (Snyder et al., 2010; Snyder et al., 2013). Hankin and colleagues (2016) propose poor cognitive control as a transdiagnostic factor that increases stress, which in turn increases rumination. Multiple theorists have suggested that worry and rumination, common symptoms of internalizing disorders, are negatively associated with performance on updating tasks (Beckwe et al., 2014; Joormann & Gotlib, 2008; Pe et al., 2013). Together, these theories may explain why individuals with more internalizing symptoms demonstrated greater difficulties with fluency measures.

These two findings are also consistent within the child literature, which suggests that moderate levels of anxiety may improve inhibition, but disrupt other processes, such as updating, or working memory, tasks (Jarrett et al., 2012; Tannock, 2009). Other child and adolescent studies have demonstrated that children with internalizing psychopathology perform worse on verbal fluency tasks (Brocki & Bohlin, 2006; Kusche et al., 1993; Nigg et al., 1999), while one study examining anxiety found that individuals, even at a young age, exhibit verbal updating impairment in both efficiency and accuracy (Visu-Petra et al., 2011). Together, these findings suggest that fluency performance is similarly influenced from childhood into adulthood.

Internalizing psychopathology was also positively related to shifting performance. This finding is inconsistent with findings from previous literature examining anxious and depressive samples, which noted worse performances on shifting measures (Airaksinen et al., 2005; Cohen et al., 1996; Mantella et al., 2007; Snyder, 2013; Snyder et al., 2015). Replication of these results may be needed in order to determine if this finding is unique to this study.

Regarding externalizing psychopathology, results indicated that individuals with more externalizing traits performed worse on inhibition tasks. This is in line with prior studies using both dimensional and categorical approaches to psychopathology. For example, Nigg et al. (2017), found that adults with greater externalizing symptoms performed worse on inhibition tasks even when factoring out processing speed. Meta-analyses examining clinical populations with externalizing symptomology such as Wright et al. (2014) and Lipszyc & Schachar, (2010) have also found inhibition deficits (Smith et al., 2014). Similarly, meta-analyses within the child literature indicate that children with greater externalizing symptoms demonstrate worse performances on standard Stroop Tasks (Homack & Riccio, 2004; Shoemaker et al., 2013).

Improved fluency performance was related to increased externalizing psychopathology. This was inconsistent with previous studies, which demonstrated a negative relationship between externalizing psychopathology and verbal fluency in both adults (Caspi et al., 2014) and children (Morgan & Lillianfeld, 2000). Additionally, a non-clinical, cross-sectional study examining lifespan traits commonly associated with externalizing symptomology (e.g., impulsivity) demonstrated no relationship with verbal fluency (Sutin et al., 2011). However, results from Reske et al. (2011) demonstrated that non-dependent, occasional stimulant users generated more words during verbal fluency tasks as compared to a non-user control group. Notably, the user-group also produced a significantly higher error rate. Together, this may suggest that individuals

with more externalizing symptoms sacrifice accuracy for fluency and, because the fluency tests used in this study offer minimal penalty for incorrect responses, individuals with more externalizing psychopathology may have performed better than individuals with other psychopathology. However, further study is needed to better understand this finding.

Inconsistent with the initial hypothesis, thought disorder symptom severity was not significantly related to executive functioning performance within any of the three domains. This result deviates from the previous literature, as individuals with more severe thought disorder symptoms typically perform worse on cognitive tasks than other types of psychopathology. However, this result may also be unique to our sample, in that more severe thought disorder traits are typically associated with severe mental illnesses, which was an exclusion criterion for the NKI study. Therefore, this suggests that the results from previous studies examining individuals with severe mental illness (e.g., schizophrenia) may reflect a more impaired population than was enrolled in this study.

Limitations

First, this study examines psychopathological traits within a non-clinical sample. Although recruitment from the NKI study is demographically and socioeconomically designed to emulate the general population of the U.S., decreased symptom severity may limit the generalizability of these findings to clinical samples. Similarly, exclusion criteria prevented individuals with severe mental illness from taking part in this study, which may have limited findings regarding the thought disorder symptoms factor. Moreover, data collection also limited analyses because the sorting test was administered to fewer participants than any of the other measures included within this study. Future studies may benefit from a more balanced distribution of variables.

Another limitation of this study came from using scores derived from the same measure. Regarding the D-KEFS model, two of the three scores that comprise the inhibition and fluency factors are from the same subtest. Therefore, the factors are more likely to load onto a single factor, due to shared method variance. Additionally, scores from multiple, different measures are recommended to minimize task impurity (Snyder et al., 2015), which is also limited by using multiple scores from the same subtest. However, in an attempt to correct for task impurity and mitigate non-executive functioning variance, residual scores were used for subscores from similar tests (e.g., processing speed for the inhibition scores). Similarly, psychopathology was measured using data primarily taken from the ASR, which may have increased shared variance between factors. Moreover, the variables that make up the Thought Disorders factor do not capture the breadth of positive symptoms that can be associated with severe mental illness (i.e., visual or tactile hallucinations).

Future Directions

Executive functioning is a transdiagnostic feature of psychopathology (Hankin et al., 2016; Snyder et al., 2015); however, more research is needed on the relationship of individual domains of executive functioning with psychopathology. Specifically, future research would benefit from an approach which integrates both advances in the measurement of executive functioning, using multiple measures that identified shared variance within similar executive functioning tasks to obtain a more "pure" score of individual domains, and advances in the measurement of psychopathology, examining dimensional models that avoid diagnostic restrictions, within-disorder heterogeneity, and comorbidity (Hankin et al., 2016; Snyder et al., 2015). This study approaches the topic using a publicly available, non-clinical sample with scores primarily derived from a single test. Future studies would improve upon the current

literature by using a clinical sample and multiple measures from different tests to assess the individual domains of executive functioning.

Despite the benefits of using latent factor models to explore the relationships between psychopathology and executive functioning, only a handful of studies have examined dimensions of psychopathology (rather than specific disorders) and how those dimensions relate to executive functioning. McGrath and colleagues (2016) targeted specific psychopathology traits in children, examining their relationships to executive functioning domains, and demonstrated a modest relationship between psychopathological traits and common executive functioning. Similarly, other studies examining dimensional psychopathology have demonstrated significant relationships between psychopathology and cognition, including executive functioning (Bloemen et al., 2016; Hatoum et al., 2018; Huang-Pollock et al., 2017). Together, these findings suggest that executive dysfunction is present within dimensional psychopathology, but further research may be needed, especially within adults, to understand potential risk factors and underlying mechanisms.

Using another dimensional approach, some studies have examined the general psychopathology factor, "p Factor", and found associations with global functioning impairments, including executive functioning deficits (Caspi et al., 2014). Specifically, Martel and colleagues (2017) demonstrated that the p Factor is associated with objective measures of global executive dysfunction amongst children. Similar findings were supported in a neuroimaging study, which found that general psychopathology was related to hypoactivation within the executive network, which includes: frontal pole, ACC, anterior insula, and precuneus, regions which have been implicated in the frontoparietal network necessary for carrying out goal-directed tasks (Duncan, 2010). Additionally, more specific executive functioning deficits have been identified in child

and adolescent studies, which suggest that updating is associated with both general psychopathology and externalizing disorders (Caspi et al., 2014; Huang-Pollock et al., 2017), but not internalizing disorders (Huang-Pollock et al., 2017).

Although the direction of this research seems promising, there is currently a dearth of literature examining the systematic use of latent-variable models to compare cognitive mechanisms within mental health samples (Goschke, 2014), especially within adult psychopathology. There is room to grow when understanding the role of executive functioning and when considering methodological suggestions for implementing more consistent measures. With the current research indicating significant relationships between executive functioning and dimensional psychopathology within child and adolescent samples, there is an opportunity for this work to expand within the adult literature. Together, previous research offers an improved methodological approach towards enhanced understanding of executive functioning, within the context of latent-variable models of adult psychopathology.

APPENDIX: COPYRIGHT INFORMATION

Relationships between multiple dimensions of executive functioning and resting-state networks in adults

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