

APPROACH/AVOIDANCE MOTIVATION AND GOAL MAINTENANCE: IMPLICATIONS
FOR MODELS OF EXECUTIVE FUNCTION

BY

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THESIS

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ABSTRACT

Trait motivational approach and avoidance tendencies have a differential effect on cognitive processing, at least in part via associations with affective traits. Positive and negative emotionality are fundamental components of these motivational dispositions and have been linked in some studies to a broadening (approach motivation) and a narrowing (avoidance motivation) of attention. Alternatively, other research has suggested that the level of motivation, not the positive or negative valence of emotionality, drives the narrowing of attention. To date, a shortcoming of the literature is that the relationships between trait motivation and cognition have most commonly been assessed using single measures of both constructs. The goal of the present study was to investigate the relationship between trait motivation and cognition more broadly at the latent factor level using multiple measures of both motivation and executive function. Structural equation modeling was used to estimate latent approach/avoidance variables from questionnaire measures and examine their relationship with latent models of executive functioning variables estimated from several neuropsychological tests in an undergraduate sample (N=103). The models of executive function that were used to guide analyses were the unity and diversity model (Miyake & Friedman, 2012) and the dual-network model (Dosenbach et al., 2008). Results indicated that higher levels of both approach and avoidance motivation were associated with better performance on executive function tasks associated with keeping task goals in mind across multiple trials. Findings supported the dual-network model and suggested that levels of motivation were more important than the valence of emotionality.

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CHAPTER 1

INTRODUCTION

Individual differences in cognitive and emotional processing influence the way people interpret their environment and execute goal-directed behavior. These differences have been attributed in part to personality and trait motivational tendencies (e.g., Elliot & Thrash, 2002; Roberts & Jackson, 2008; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). Trait approach/avoidance motivation (i.e., the tendency to approach or avoid) is defined as being preferentially sensitive to motivationally-congruent stimuli, with bidirectional influences on neurobiological, behavioral, and emotional responses to these stimuli (Elliot & Thrash, 2002; Elliot, 2006; Gray, 1990; Rothbart, Ahadi, & Evans, 2000). Although approach and avoidance processes involve different neurophysiological mechanisms, making it possible for a person to have both processes operating simultaneously, one system generally predominates (Elliot & Thrash, 2010).

The execution of goal directed behavior depends on the capacity to accomplish higher-order goals that require long-term mental representations of desired events or outcomes (e.g., Jurado & Rosselli). This capacity involves a subset of cognitive functions commonly called executive functions (EFs), such as the ability to hold information online, manipulate it in a flexible way, keep track of it despite distraction, and plan actions that promote achievement of a goal (e.g., Banich, 2009).

Research has consistently found relationships between motivation and EF (Gable & Harmon-Jones, 2008, 2010a, 2010b, 2010c; Pochon et al., 2002; Spielberg et al., 2011b, 2012; Taylor et al., 2004). For instance, in a series of studies that manipulated motivation using affective pictures (Gable & Harmon-Jones, 2008) it was found that increases in motivation

decreased attentional breadth as measured by a local-global task (Navon, 1977), which is thought to rely on the EFs of attentional control and inhibition of conflict (Andres & Fernandes, 2006). Moreover, decreases in attentional breadth were positively related to measures of trait motivation (study 3, Gable & Harmon-Jones, 2008). Neuroimaging work has also revealed that increases in trait motivation (Spielberg et al., 2011b) and experimentally manipulated motivation (via monetary incentives; Pochon et al., 2011) are related to more effective inhibition of conflict and increased brain activity in regions typically associated with EF (e.g., dorsolateral prefrontal cortex, medial prefrontal cortex, intraparietal sulcus). These results suggest that motivation plays a role in the effective deployment of EF.

A shortcoming of the literature to date is that the impact of motivation on EF has only been examined using single tasks measuring one component of EF (e.g., Gable & Harmon-Jones, 2008; Taylor et al., 2004; see Snyder et al., 2015 for a discussion of this issue). Relying on single tasks is problematic because EF tasks also rely on non-executive processes (e.g., visual-spatial vs. verbal skills; see Miyake et al., 2000, for a discussion of this “task impurity problem”) that may obscure relationships between EF and variables of interest, such as trait motivation. In order to address this problem, confirmatory factor analysis (CFA) and structural equation modeling (SEM) can be used to identify “pure” latent EF processes common to a group of related (e.g., inhibition) tasks. Another common problem in the EF literature is that single tasks are used without being connected to a larger theory that could inform predictions that go beyond those tasks (Miyake et al., 2000). The primary goal of the present study is to address these issues and understand the relationship between EF and trait motivation at the latent-factor level.

Although no complete theory of EF exists as of yet (Banich, 2009), several theorists have proposed models that attempt to organize the multitude of EF tasks into theoretical frameworks

using either observations of task performance (Baddeley, 2002; Baddeley & Hitch, 1974), connectivity among brain regions associated with EF (Dosenbach et al., 2008), or latent-factor analysis (Miyake et al., 2000; Miyake & Friedman, 2012). The advantage of working at the level of theoretical models, as opposed to using single tasks, is that they can be used to inform a wide range of predictions instead of predictions only relating to a single task (Snyder et al., 2015). Two compelling theoretical frameworks of EF that have emerged in recent years are the unity and diversity model (Miyake et al., 2000; Miyake & Friedman, 2012) and the dual-network model (Dosenbach et al., 2008). Both of these models have received support in the literature (see Sheffield et al., 2015 for an application of the dual-network model and Collette et al., 2006 for an application of the unity and diversity model), but their ability to capture the latent structure of a large battery of EF tasks has never been assessed within the same study. Given the uncertainty around which model of EF is best suited to investigate the relationship between EF and trait motivation, another goal of the present study is to compare the fit of these two models to the latent structure of a carefully-selected, theoretically-driven set of neuropsychological tasks intended to measure different domains of EF (e.g., updating, maintenance, etc.).

The unity and diversity model of EF suggests that there is a common EF that is used in the execution of a wide range of tasks and two more specific EFs, set-shifting (sometimes called just shifting) and working memory updating (sometimes called just updating; Miyake et al., 2000; Miyake & Friedman, 2012). Shifting refers to the process of keeping multiple tasks in mind and switching back and forth between them (e.g., changing the radio station while driving). Updating refers to the process of flexibly manipulating the contents of working memory (e.g., removing turns already taken from a set of driving directions). Common EF is needed for the other two EFs and is also largely responsible for inhibition-related ability (e.g., resisting the urge

to answer the phone while driving). This model does not encompass all possible EFs, but it provides a parsimonious way to begin describing a wide range of higher-order cognitive abilities.

The dual-network model is based on neural connectivity analysis and posits that the human brain contains two functionally connected networks that allow for both flexible and stable goal-directed behavior (Dosenbach et al., 2008). The flexibility system responds to moment-by-moment (or trial-by-trial) changes and allows an organism to adapt to rapidly changing demands. In contrast, the stability or maintenance system is slower to change and functions to keep long-term goals active over multiple trials allowing for complex, multi-stage goal-pursuit. The dual-network model has been supported by MRI functional connectivity studies that have observed connections between regions of the brain associated with maintaining goal pursuit (maintenance system) and between regions associated with flexibly adapting goals (flexibility system; Dosenbach et al., 2006, 2007, 2008; Seeley et al., 2007).

There are both similarities and differences between the unity and diversity model and the dual-network model. These models are distinct from each other in their conception, with the unity and diversity model based mostly on theory and the dual-network model based on observations of connections within and between neural systems. Differences in origin may also lead to differences in which data they best predict. For instance, the unity and diversity model may predict behavioral data and outcomes (e.g., links between behavioral examples of trait motivation and performance on EF tasks). The dual-network model may be better suited to predicting the relationship between EF and trait motivation at the neural level. However, there is also conceptual overlap between these two models. Shifting and updating are both stimulus-driven processes that are similar to the processes associated with the flexibility system. Common EF is needed to inhibit irrelevant distractions in order to maintain focus on long-term task goals,

which is similar to the hypothesized function of the maintenance system. Current literature does not shed light on whether hypothesized latent components of one or both of these models (e.g., shifting and/or maintenance) are better suited to describing the relationship between EF and motivation.

Present hypotheses were driven by a review of several decades of research that suggests that experiencing positive affect increases attentional capacity, increases depth of processing, and fosters creative problem-solving (Isen, 2009; but see Dreisbach & Goschke, 2004, for the cost of high positive affect). Given that those with high levels of trait approach motivation are more likely to experience positive affect (Elliot & Thrash, 2002), it was hypothesized that higher levels of this trait would be related to more cognitive flexibility (reflected in either better shifting/updating or flexibility EF). Since approach and avoidance are hypothesized to be independent, it was not expected that those with higher levels of trait avoidance motivation would necessarily have a narrower attentional capacity, shallower processing, or worse problem-solving skills (but see Forster et al., 2006 for evidence of this relationship at the level of attention).

The research reviewed above is primarily concerned with the valence of motivation (approach, avoidance), which is a common focus of past research (e.g., Belayachi et al., 2015; Isen, 2009; Spielberg et al., 2011b). However, the present study will also consider the intensity (high, low) of trait motivation as it plays a role in the effects reviewed above and has been shown to interact with different aspects of EF independently of valence (e.g., Gable & Harmon-Jones, 2010a). Motivational intensity is defined as the degree to which an organism is driven to act to achieve a desired state, which is often, but not always, related to arousal. For example, amusement can be arousing and is generally viewed as a state associated with positive affect, but

amusement does not necessarily drive someone toward or away from a goal object (Bradley et al., 2001; Gable & Harmon-Jones, 2010b). Several studies have found that positive and negative affect that is also high in motivation leads to a narrowing of attention (Gable & Harmon-Jones, 2008), better recall for centrally vs. peripherally presented words (Gable & Harmon-Jones, 2010c), and a lower likelihood of accepting a somewhat poor exemplar of a category as a member of that category (e.g., a camel as a mode of transportation; interpreted as less cognitive breadth; Isen & Daubman, 1984; Price & Harmon-Jones, 2010). This was true of induced positive and negative affect and of trait positive affect (as measured by the BAS; Gable & Harmon-Jones, 2008). Evidence for the effects of trait negative affect on cognitive breadth is less well-established, but some authors propose that there is a link between depression (a disorder of low approach motivation; e.g., Henriques & Davidson, 1991; Spielberg et al., 2011a) and creativity (Andreasen, 1987; Ludwig, 1994) as well as breadth of memory (von Hecker & Meiser, 2005). On the basis of these findings, it was argued that the motivational intensity of affect, not its valence, was responsible for the observed effects on attention and cognition (Gable & Harmon-Jones, 2010b).

Therefore, an alternative hypothesis is that those with high levels of both approach and avoidance motivation will show better performance on tasks that benefit from persistent attention to and cognitive focus on goals (i.e., common EF; maintenance). Following findings by both Harmon-Jones and Gable and Isen, we also hypothesize that lower levels of each motivation will be associated with increased performance within the flexibility domain. The present study sought to test these hypotheses in order to better understand the relationship between trait motivation and theory-based latent factors of EF. If such a relationship exists at the latent-factor level, it

would suggest that the relationship between EF and trait motivation could have a number of far-reaching implications (e.g., development and treatment of psychopathology).

CHAPTER 2

METHOD

Participants

Participants were recruited through a two-stage procedure. The first stage used the psychology subject pool at the University of Illinois at Urbana-Champaign. Undergraduate students signed up for a group screening session that provided extra class credit. During these sessions, potential participants completed a series of questionnaires, including the Negative Affect (NA) and Positive Affect (PA) subscales of the Positive and Negative Affect Schedule (PANAS – Trait version; Watson, Clark, & Tellegen, 1988). The second stage involved using the scores from the PANAS to select participants to invite for further testing. In order to be eligible for the present study, they had to either (1) score at or above the 80th percentile (≥ 29) on the NA subscale of the PANAS and at or below the 50th percentile (≤ 34) on the PA subscale; (2) score at or above the 80th percentile (≥ 41) on the PA subscale and at or below the 50th percentile (≤ 22) on the NA subscale; or (3) score at or below the 50th percentile on the NA and PA subscales (≤ 22 on the NA subscale and ≤ 34 on the PA subscale). Percentile cutoff scores were determined using a large sample of college students ($N = 600$).

Individuals who agreed to participate after being contacted were given a laboratory tour, during which they completed various questionnaires and neuropsychological tasks. A total of 103 participants completed the neuropsychological task protocol (50% female, M age = 19.2, $SD = 1.4$). Findings using fMRI data from this sample are currently in preparation (Infantolino et al.). Functional MRI and neuropsychological data from this sample were also the subject of an unpublished dissertation (Crocker, 2014) addressing a different question that does not overlap

with the present report. All procedures were approved by the University of Illinois at Urbana-Champaign Institutional Review Board.

Questionnaires

The present study was part of a larger study that asked participants to complete a battery of questionnaires. Questionnaires of relevance to the present report included those used in Elliott and Thrash (2002) and Spielberg et al. (2011a) to obtain a measure of trait approach/avoidance motivation. Hence, participants completed the 12-item Extraversion (NEO-E) and the 12-item Neuroticism (NEO-N) subscales from the NEO-Five Factor Inventory (NEO-FFI, McCrae & Costa, 2004). On each subscale, participants rated how characteristic a series of descriptive statements was of themselves on a scale from 1 (strongly disagree) to 5 (strongly agree). The NEO-E scale consists of statements such as “I really enjoy talking to people,” and the NEO-N scale consists of statements such as “I often feel tense and jittery.”

Participants were also asked to complete the Behavioral Inhibition System/Behavioral Activation System scale (BIS/BAS, Carver & White, 1994). Like the NEO-FFI, each item asks participants how characteristic a series of descriptive statements is about themselves on a scale from 1 (very true for me) to 4 (very false for me). The 7-item BIS subscale consists of items such as “I feel pretty worried or upset when I think or know somebody is angry at me.” The 13-item BAS subscale includes statements such as “When I want something I usually go all-out to get it.”

Lastly, the Positive Temperament (GTS-PT) and Negative Temperament (GTS-NT) subscales of the General Temperament Survey (GTS, Clark & Watson, 1990) were included. This questionnaire asked participants to indicate how true or untrue each item was of them (1 = true or mostly true, 2 = false or mostly false). The 27-item GTS-PT consisted of statements such

as “I get excited when I think about the future.” The 28-item GTS-NT consisted of statements such as “I frequently find myself worrying about things.”

Neuropsychological Task Protocol

The tasks used in this study were selected in part based on work done by Miyake and colleagues (2000, 2012) and were intended to assess the EF domains of inhibition (also subsumed under common EF), shifting, and updating. The order of neuropsychological tasks was counterbalanced according to the model proposed by Miyake et al. (2000) and by verbal and visuospatial domains. Tasks thus alternated between inhibition, shifting, and updating as well as between verbal and visuospatial domains (see Table 1, and see supplementary methods for a more detailed description of the present task battery). All tasks were administered according to a standardized protocol by clinical PhD graduate students who were trained in neuropsychological task administration.

In order to deal with the task impurity problem (see Snyder et al., 2015), many of the tasks included an assessment of basic cognitive processes required for performance on more complex executive function tasks. Based on a preliminary inspection of the correlation matrix, one task was not included (a computerized version of the Tower of London developed in conjunction with W.K. Berg (Berg & Byrd, 2002) and customized by S. L. Warren with input from collaborators W. Heller, & G. A. Miller). This task was intended to measure inhibition-related processing (Miyake et al., 2000), but it did not show significant relationships with other tasks in this domain or any other.

Data Analysis

Questionnaire and neuropsychological task data were examined for outliers. A trimming procedure that first identified scores three standard deviations above or below the mean assigned

those scores the value at three standard deviations. The normality of each distribution was also examined, and transformations were done when appropriate. All questionnaire measures were normally distributed. Several of the neuropsychological tasks needed to be transformed. The most common transformations were the square root and the square root of the arcsine, which are both used to correct for rightward skewness. Square root transformations were performed on the trail-making and the plus-minus tasks, which both have dependent variables measured in seconds. Square root of the arcsine transformations were performed on the keep track, letter memory, and spatial updating tasks, which have proportion correct measures as their dependent variables. Descriptive statistics, including skewness and kurtosis information, on post-transformed values are provided in Table 2.

Hierarchical clustering analysis was undertaken to explore the structure of the neuropsychological data. Associations between the tasks were visualized using a dendrogram (see Figure 1). The inverse of the correlation matrix (i.e., a dissimilarity matrix) of all neuropsychological tasks was used as the input into the linkage script in MATLAB (linkage.m, MATLAB and Statistics Toolbox Release 2014a, The MathWorks, Inc., Natick, Massachusetts, United States). Examination of the resulting dendrogram revealed two clusters of tasks that seemed to correspond broadly to the domains of maintenance and flexibility. Although this provided some support of the dual-network model (Dosenbach et al., 2008), tests of model fit are not possible with this approach. Confirmatory factor analysis (CFA) was used to more thoroughly address the question of whether a two- or three-factor solution was more appropriate, which was followed by SEM in order to examine the relationship between EF and motivation.

Trait approach/avoidance motivation latent factors were computed using the questionnaires and the factor structure used by Elliot and Thrash (2002) and Spielberg et al.

(2011a). For the three-factor unity and diversity model of EF, latent factors were computed using scores from tasks and a factor structure that conceptually following the methods of Miyake and Friedman (2012). Specifically, while different tasks were used in the present study, they were meant to fit into the three-factor structure of common EF, updating, and shifting proposed by Miyake and Friedman (2012). For the dual-network model, the same tasks as above were used but were designated as indicators of maintenance or flexibility based on the conceptually framework provided by Dosenbach et al. (2008).

CFA was performed using the lavaan (latent variable analysis; Version 05-15, Rosseel, 2012) package in R (Version 3.1.0; R Core Team, 2014). Robust maximum-likelihood estimation was used, and raw scores were the inputs for both models. This technique generates parameter estimates with standard errors and a mean-adjusted chi-square test statistic that are robust to non-normality. Lavaan transforms the raw scores into a correlation matrix and uses those standardized scores to estimate how well the model fits the data. Model fit was evaluated using multiple fit indices: the Model Chi-Square and its accompanying significance test (χ^2 ; Satorra & Bentler, 1988), the Comparative Fit Index (CFI; Bentler, 1990), the Tucker-Lewis Index (TLI; Tucker & Lewis, 1973), the Root Mean Square Error of Approximation (RMSEA, Steiger & Lind, 1980), and the standardized root mean-squared residual (SRMR). The χ^2 test assesses how much the structure of the data differs from the structure imposed by the model (Hu & Bentler, 1999). A significant result would imply that the data does not fit the proposed model. The CFI compares the χ^2 value to the χ^2 of the null model, where all measured variables are uncorrelated. This ratio ranges from 0 to 1, and values over 0.95 suggest good fit (Hu & Bentler, 1999). The TLI is similar to the CFI with respect to how it is calculated and its cutoff score (Hu & Bentler, 1999), but it also includes a penalty for model complexity. The RMSEA also accounts for model

complexity and reflects how well the model-implied covariance matrix fits the covariance matrix of the data. Hu and Bentler (1999) suggested that RMSEA values less than 0.08 indicate good model fit.

In the trait motivation CFA, NEO-E, BAS, and GTS-PT scores were used as indicators of approach motivation. NEO-N, BIS, and GTS-NT scores were used as indicators for avoidance motivation. This initial factor structure, proposed and confirmed by Elliot and Thrash (2002), was expanded by Spielberg et al. (2011a) to include several cross-loadings that improved model stability. The present study retained these cross-loadings for the same reasons. GTS-N and BIS were set to cross-load onto approach, and BAS was set to cross-load onto avoidance motivation. Given the relationship between approach and avoidance motivation theorized by Elliot and Thrash (2002), these two latent factors were allowed to covary freely. In order to set the scale of both of these latent variables, their variances were constrained to be one. Due to constraints imposed by sample size, approach and avoidance latent factor scores were extracted using the predict function in lavaan and used as exogenous variables in the SEM model with EF (described below).

The unity and diversity model of EF CFA used Plus-Minus, Trail-making, and Verbal Fluency tasks as indicators for the shifting factor, and Spatial Updating, Letter Memory, and Keep Track tasks as indicators for the updating factor. Following Miyake and Friedman (2012), general EF was estimated using a bi-factor model approach where stop-signal task and the inhibition and switching conditions of the Color-word interference task (primarily inhibition-related) were used as indicators of general EF along with all of the other tasks in the battery. Since this factor is thought to account for the variance shared among the three factors, no latent

factor correlations were modeled. Variances of latent factors were constrained to one in order to set the scale of both factors.

The dual-network model of EF CFA used the Stop-signal task, Plus-Minus, and the inhibition and switching conditions of the Color-word interference tasks as indicators of the maintenance factor and Trail-making, Spatial Updating, Letter Memory, Keep Track, and Verbal Fluency tasks as indicators of the flexibility factor. These two factors are based on hypothesized brain systems that are functionally interconnected (Dosenbach et al., 2008) and therefore were allowed to covary freely. Variances of latent factors were also constrained to one in order to set the scale of both factors. Testing the adequacy of fit of the two- and three-factor models was done through an inspection of fit indices.

SEM, also implemented using the lavaan package of R, was used to investigate the relationships between the latent approach and avoidance motivation variables and EF. Modification indices were examined, and theoretically sound correlations were added until the models were associated with excellent fit indices.

CHAPTER 3

RESULTS

The dual-network model of maintenance and flexibility was successfully estimated and was associated with indices indicating adequate fit. The model had a χ^2 value of 26.33, $p = 0.24$, and a Satorra-Bentler scaling correction factor of 1.113. Not all indicators were significant, but removing any of them reduced model fit to below acceptable standards. Indicators with less than significant loadings were the stop-signal task ($p = 0.17$), the switch condition of the Color-word interference task ($p = 0.06$), and the Trail-making task ($p = 0.06$). Fit statistics and measurement weights are summarized in Table 3.

The three-factor unity and diversity model of EF proposed by Miyake and Friedman (2012) was not successfully estimated. However, this is likely due to the present sample size ($N = 103$) and the number of parameters this model needs to estimate (Bentler & Yuan, 1999). In order to fully investigate the unity and diversity model, we also attempted to estimate an earlier version of it (Miyake et al., 2000) that contained inhibition, shifting, and updating with correlations between all tasks instead of a common EF factor. This model was misspecified and resulted in negative variances and covariance in addition to error matrices that were not positive definite. An inspection of the output further confirmed that this model did not fit the data well, as all fit indices were below what is considered adequate. These results suggest that the two-factor model is a better fit for this data set, and therefore this model was used to investigate the relationship of EF to trait motivation.

The CFA for trait motivation was successfully estimated. The model was associated with a χ^2 value of 8.22, $p = 0.15$ (see Figure 2). Fit statistics indicated adequate fit to the data. All measurement weights were significant at $p < 0.05$, with the exception of two indicators that were

cross-loaded on the trait approach and avoidance latent factors. Specifically, GTS-NT, which was cross-loaded on approach motivation, was associated with a p -value of 0.07, and BAS, which was cross-loaded on avoidance motivation, was associated with a p -value of 0.08. When these cross-loadings were removed and the model refitted, none of the fit statistics met criteria for adequate fit. Further, the χ^2 values of each model were compared using an analysis of variance test (ANOVA), and the initial model was found to fit significantly better (χ^2 difference = 9.52, $p = 0.02$). Therefore, the cross-loadings were retained in the final model. Approach and avoidance were also significantly correlated ($r = -0.73$, $p < .01$). Measurement weights and fit statistics are summarized in Table 3.

For the SEM model relating EF to trait motivation, means, standard deviations, skewness, and kurtosis statistics are provided in Table 2 for each of the scales and tests indicating each of the latent factors. Almost all skewness and kurtosis values were at or below 1 (absolute value) with the exception of the kurtosis for the trail-making task (1.671). Multivariate normality was assessed using the Mardia (1970) test for skewness. This test yielded an insignificant result for the motivation model and the EF model, suggesting that all data were multivariate normal.

In this larger SEM model, the measurement weight for the stop-signal task was the only insignificant loading. When this indicator of maintenance was removed, the model was still associated with excellent fit. Specifically, it had a χ^2 value of 29.35, $p = 0.34$. All other measurement weights were significant at $p < 0.05$. Measurement weights and fit statistics are summarized in Table 3. The two EF variables were also significantly correlated ($r = 0.72$, $p < 0.01$). The relationship between EF and motivation was explored through a set of simultaneous regressions with approach and avoidance functioning as exogenous independent variables and maintenance and flexibility functioning as dependent variables (see Figure 3). Only the

regression weights between maintenance and motivation were significant. Approach and avoidance motivation both positively predicted maintenance scores (approach $\beta = 0.45$, $p = 0.03$; avoidance $\beta = 0.41$, $p = 0.04$). No relationship between motivation and flexibility was observed (approach $\beta = 0.01$, $p = 0.95$; avoidance $\beta = 0.11$, $p = 0.58$).

CHAPTER 4

DISCUSSION

A common issue in the study of EF and trait motivation is the difficulty in interpreting the meaning of their relationship due to the impurity of single-task measures of EF and subsequent difficulty in connecting these tasks to broader theories of EF. This study aimed to address this issue by using a theory-driven SEM approach to understand the relationship between trait motivation and EF at the level of latent factors. Results confirmed that the factor structure of the personality and temperament data can be best explained by trait approach and avoidance motivation (Elliot & Thrash, 2002; Spielberg et al., 2011a, 2011b, 2012a, 2012b). In addition, the EF data were best described by a two-factor solution that closely resembled the dual-network model characterized as maintenance and flexibility (Dosenbach et al., 2008). Approach and avoidance motivation predicted performance within the latent EF domains of maintenance and flexibility in a way that partially supported hypotheses. Specifically, performance on tasks requiring the maintenance of goals across many trials improved as levels of trait approach and avoidance motivation increased. No effect of motivation was observed for tasks that were more dependent on flexibility of attention and cognition.

The superior fit of the dual-network model over the unity and diversity model, evidenced by performance of the two- vs. three-factor SEM, to the present data does not necessarily reflect an underlying truth regarding the structure of EF. The most likely reason for the difference in model fit is that the present EF battery included many complex tasks (those from the D-KEFS and the spatial updating task) that were not in the original battery that was best described by the three-factor unity and diversity model (Miyake et al., 2000; Miyake & Friedman, 2012). It is possible that the complexity of the present EF battery resulted in shifting processes being needed

during updating tasks (and vice versa). This complexity likely caused the broader latent factor of flexibility to be a more appropriate characterization of the processes needed for tasks typically labeled as shifting and updating (e.g., Miyake et al., 2000). However, the dual-factor model could also represent a general structure of EF that is applicable to a more diverse set of tasks, which could provide a unifying theory for future research. More work is needed in order to determine whether the dual-factor model or the unity and diversity model is more broadly applicable or whether these models are simply suited to describe different sets of EF tasks.

As stated above, present results indicated that motivation was related to tasks that primarily required the maintenance of goals across trials and not the flexible monitoring of the environment. Furthermore, these effects did not differ as a function of the valence of motivation, but rather depended on the intensity of motivation. The present relationship found between motivational intensity and maintenance EF is in line with work investigating affect varying in motivational intensity and its influence on selective attention and conflict inhibition, referred to as cognitive focus (e.g., Gable & Harmon-Jones, 2008). In a series of studies investigating cognitive focus, increasing levels of approach motivation were induced using either pictures or films (Gable & Harmon-Jones, 2008; 2010a, 2010b; Price & Harmon-Jones, 2010). Tasks used to measure cognitive focus were the Kimchi and Palmer (1982) global-local visual processing task and the Navon (1977) letters task. The consistent finding across these studies was that cognitive focus decreased in breadth as a function of experimentally manipulated and trait approach motivation. This decrease in breadth was hypothesized to aid in goal attainment when approach motivation was high by reducing the influence of irrelevant stimuli (e.g., focusing on approaching food when hungry or, relevant to the present study, being motivated to do well on a test of cognitive abilities in an evaluative context). This interpretation is in line with present

results that show that trait approach motivation plays a role in improving the deployment of the broad EF construct of maintenance, which is thought to be involved in focusing on long-term goals despite distraction.

While the research reviewed above has dealt with approach motivation, the present study found that avoidance motivation had similar effects on EF. These effects are in line with the motivational dimension model (Gable & Harmon-Jones, 2010b), which posits that high levels of motivation of either valence will decrease the breadth of cognition, specifically within the domain of attention. In support of this model, it was demonstrated that pictures that induced sadness (classified as low-intensity avoidance motivation) increased attentional breadth relative to a neutral comparison condition. In contrast, disgust (classified as high-intensity avoidance motivation) decreased attentional breadth relative to a neutral comparison condition (Gable & Harmon-Jones, 2010a). The results of the studies reviewed above are consistent with present findings that the intensity of both trait approach and trait avoidance motivation has an impact on cognition. Furthermore, the present findings extend the motivational dimension model (Gable & Harmon-Jones, 2010b) beyond the breadth of attention and show that higher-order cognitive processes such as EF can also be affected by trait motivational intensity (also see Spielberg et al., 2011b; 2012a; 2012b). This relationship suggests that psychological disorders characterized by low levels of approach or avoidance motivation (e.g., depression, mania, respectively, Henriques & Davidson, 1991; Nigg, 2000) could exert effects on EF that could lead to impairments in living. Furthermore, while high levels of approach and avoidance led to improved performance within the maintenance domain, it is possible that within the context of disorder, EF could be used toward maladaptive goals (e.g., mania is also associated with hyperactive approach processes that lead to risky decision-making, Nigg, 2000).

The specificity of the effect of motivational intensity to EF tasks measuring maintenance, as opposed to flexibility, may be explained by examining the cognitive processes theoretically associated with this domain of EF. Optimal performance on maintenance-related tasks depends in part on the ability to focus on a single goal and ignore irrelevant information (the environment, distracting thoughts, etc.). In contrast, performance within the domain of flexibility depends on monitoring the environment for constantly changing stimuli. This monitoring benefits from a broader attentional focus. Therefore, it follows from the evidence presented here (e.g., Gable & Harmon-Jones, 2008) that increased trait motivational intensity would be associated with better performance of tasks measuring maintenance as a result of reductions in the breadth of attention.

However, optimal performance on maintenance-related EF tasks requires a variety of cognitive processes in addition to the focusing of attention (e.g., inhibition of automatic responses, keeping a single goal in memory across many trials, etc.). Results from the present study suggest that the intensity of motivation affects cognition beyond the simple focusing of attention as tasks within the EF domain of maintenance theoretically require more complex mental operations, such as keeping long-term goals in mind despite distraction from irrelevant stimuli. Prior work provides support for this link between motivation and more complex cognition. In a study assessing the effect of motivation on memory, high-intensity approach motivation improved the later recall of words that were presented nearer the focal point of attention (Gable & Harmon-Jones, 2010c). Focusing on and remembering the stimuli salient to goal attainment would be essential in successful performance on a wide range of tasks, including those within the EF domain of maintenance. Together with the present results, these studies suggest that the influence of motivational intensity goes beyond attention and show that it can

influence the performance of higher-order cognitive processes (see also, Price & Harmon-Jones, 2010).

Indeed, all studies reviewed above demonstrate that high-intensity approach and avoidance motivation may serve to focus cognition. Therefore, it is possible that participants high in trait approach and avoidance motivation in the present study were better able to ignore distracting information because they were more driven to do well than those low in trait motivation. This would assist in performance on tasks within the EF domain of maintenance, which all benefit from the focused cognition associated with high-intensity motivation. The importance of the observed link between EF and trait motivation is that it is a potential mechanism in the development of psychopathology that could be amenable to intervention. However, it remains unclear how trait motivation of different valences can produce similar performance on tasks in this domain, as observed in the present and other studies (e.g., Spielberg et al., 2011b), and yet still be associated with different symptom profiles in depression and anxiety (Spielberg et al., 2011a).

One possible reason for similar performance but different outcomes is that, although similar intensity of trait motivation may lead to similar levels of EF performance in the maintenance domain, its valence may lead to differential use of those skills (for a review, see Spielberg et al., 2013). One example of approach and avoidance motivation being related to similar performance of a maintenance-type task while also being related to different deployment of resources was found in a study by Spielberg and colleagues (2011b). It was found that trait motivation was related to activity in different parts of the dorsal lateral prefrontal cortex (DLPFC) during performance of the classic color-word Stroop (replicating other studies, e.g., Milham, Banich, & Barad, 2003). Despite these neural differences, higher levels of motivation

were associated with better performance, with both approach and avoidance accounting for unique variance in behavior. These data suggest that, although there are seemingly similar benefits to performance as a function of trait motivation, there are different neural pathways to this performance. This provides support for the hypothesis that high levels of either motivation may aid in the execution of goal-directed behavior (via recruitment of EF resources) in the short-term. However, differences in the way EF is used as a function of trait motivation (reflected in differential neural activity) may lead to the divergent associations that approach and avoidance have with depression and anxiety (Elliot, 2006; Spielberg et al., 2011a).

Expanding on the above, it may be that approach motivation fosters the use of maintenance skills in the service of positive long-term goals that ultimately lead to greater satisfaction and well-being. In contrast, avoidance motivation may predispose people to use maintenance skills to ruminate on past negative events in their lives and to focus their attention away from resolving the feelings that those negative events generate. Both of these forms of avoidance have been strongly implicated in the development of depression and anxiety (e.g., Jacobson, Martell, & Dimidjian, 2001; Nolen-Hoeksema, 2000). Another possibility is that trait avoidance motivation is a risk-factor for depression and anxiety for reasons independent of EF. Finally, the relationships between psychopathology and EF (e.g., Gotlib & Joorman, 2010; Levin et al., 2007; Snyder, 2012) may manifest only after the onset of psychopathology (Snyder et al., 2015). Further research is needed in order to test the causal relationship between trait motivation and EF and how this affects the development of psychopathology.

A primary limitation of this study was sample size, which was smaller than what is typical of studies employing SEM. However, the validity of present results is supported by previous studies that have used SEM for similar purposes with similar sample sizes (Spielberg et

al., 2011b, 2012a, 2012b). Furthermore, there is little difference between the factor loadings of each of the indicators of approach and avoidance motivation in the present sample ($N = 103$) and in the much larger sample used by Spielberg et al. ($N = 1,114$; 2011a). Sample size did constrain the ability to compare statistically the two- and three-factor models of EF. As noted above, it is possible that higher complexity of the current EF battery than that of Miyake and colleagues (2000, 2012) made the two-factor model a more parsimonious fit. Another limitation of the present study is that it is cross-sectional in nature. Although there is strong theoretical and observational evidence that highlights the influence of trait motivation on the development of EF (e.g., Anderson, 2002; Elliot, 2006; Elliot & Thrash, 2002; Jurado & Rosselli, 2007; de Luca et al., 2003; Rothbart, Ahadi, & Evans, 2000), the nature of the present study does not allow it to speak to the temporal or causal relationship between motivation and maintenance.

Despite these limitations, a relationship emerged between both trait approach and avoidance motivation and the broad EF latent factor of maintenance. Furthermore, a connection was made between the theoretical frameworks of trait motivation and the dual-network model of EF, which can help inform future research and hypotheses about how these two constructs interact. This connection is significant given how important such tasks are for daily functioning. However, more research is needed to understand how trait motivation and EF interact and if that interaction has a causal relationship to the development of psychopathology. Understanding how trait motivation affects EF could improve current and influence future interventions. For instance, the reason behavioral activation is an effective intervention could be that it helps those suffering with psychopathology to overcome their motivational tendencies and to use their EF adaptively (Jacobson, Martell, & Dimidjian, 2001). By understanding how a person with high levels of trait approach or avoidance motivation is most likely to deploy their EF resources,

clinicians and theorists may be better able to teach and develop strategies that could counter maladaptive or ineffective uses of EF.

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FIGURES AND TABLES

Table 1 Neuropsychological Task Battery

| Task Name | Executive Function Assessed | Dependent Variable | Reference |
|--|--|--|---|
| Keep Track task | Updating verbal information in working memory | Proportion of words remembered | Yntema, 1963 |
| Letter Memory Task | Updating verbal information in working memory | Proportion of letters remembered | Morris & Jones, 1990 |
| Spatial Updating Task | Updating spatial information in working memory | Proportion of box presentation sequences recalled correctly | Warren, Towers, Miller, & Heller, unpublished |
| Trail-making Task | Shifting between sequencing alphabetically and numerically | Time to complete shifting condition minus time to complete baseline conditions | Delis et al., 2001 |
| Verbal Fluency Task | Shifting between verbal categories | Number of successful switches between categories | Delis et al., 2001 |
| Plus-minus Task | Shifting between simple mathematical operations | Time to complete shifting condition minus time to complete baseline conditions | Jersild, 1927; Spector & Biederman, 1976 |
| Stop-signal Task | Inhibiting a dominant motor response | Average reaction time to stop-trials minus average reaction time to go-trials | van den Wildenberg et al., 2006 |
| Color-word Interference Task, Inhibition Condition | Inhibiting a dominant verbal response | Time to complete inhibition condition minus time to complete baseline conditions | Delis et al., 2001 |
| Color-word Interference Task, Inhibition/Switching Condition | Inhibiting a dominant verbal response and shifting between rule-sets | Time to complete inhibition/switching condition minus time to complete baseline conditions | Delis et al., 2001 |

Table 2 Descriptive Statistics

| Variable | Mean | SD | Skewness | Kurtosis |
|---|-----------|-------|----------|----------|
| BIS | 20.60 | 4.53 | -0.33 | -0.52 |
| BAS | 41.37 | 5.19 | -0.22 | 0.25 |
| GTS-NT | 10.96 | 7.94 | 0.38 | -1.04 |
| GTS-PT | 17.81 | 6.39 | -0.51 | -0.75 |
| NEO-N | 30.37 | 10.50 | 0.37 | -0.28 |
| NEO-E | 42.03 | 9.01 | -0.26 | -0.69 |
| Stop-signal Task* | -218.04ms | 31.87 | 0.29 | 0.57 |
| Color-word Interference Task – Inhibition Condition* | -21.28s | 6.72 | -0.41 | 0.97 |
| Color-word Interference Task – Inhibition/Switching Condition* | -25.24s | 7.81 | -0.12 | 0.35 |
| Trail-making Task* | -5.24s | 1.29 | -0.66 | 1.67 |
| Verbal Fluency Task | 13.82 | 3.23 | 0.02 | 0.12 |
| Plus-minus Task* | -4.11s | 1.23 | -0.20 | -0.37 |
| Keep-track Task | 1.10 | 0.10 | 0.013 | 0.14 |
| Letter-memory Task | 1.03 | 0.21 | -0.10 | -0.06 |
| Spatial-updating Task | 1.02 | 0.20 | -0.20 | -0.55 |

* = tasks whose variables were reversed so that higher scores represented better performance. Units are provided for timed measures – all other units are arbitrary. *BIS* behavioral inhibition system, *BAS* behavioral activation system, *GTS-NT* general temperament survey negative temperament, *GTS-PT* general temperament survey positive temperament, *NEO-N* NEO neuroticism, *NEO-E* NEO extraversion.

Table 3 CFA and SEM model fit and factor loadings

| Dual-network CFA model | | Trait Motivation CFA Model | |
|--|-----------------------|-----------------------------------|-----------------------|
| <i>Fit statistic</i> | <i>Value</i> | <i>Fit statistic</i> | <i>Value</i> |
| CFI | 0.95 | CFI | 0.99 |
| TLI | 0.92 | TLI | 0.98 |
| RMSEA | 0.04 | RMSEA | 0.08 |
| SRMR | 0.06 | SRMR | 0.02 |
| Maintenance | | Approach | |
| <i>Variable</i> | <i>Factor Loading</i> | <i>Variable</i> | <i>Factor Loading</i> |
| Stop-signal task | 0.18 | BAS | 0.72** |
| Plus-minus task | 0.73** | GTS-PT | 0.87** |
| Color-word Inhibition task | 0.51** | NEO-E | 0.91** |
| Color-word Switching task | 0.31 [†] | BIS | 0.26* |
| Flexibility | | GTS-NT | 0.18* |
| Trail-making task | 0.25 [†] | Avoidance | |
| Spatial Updating task | 0.60** | BIS | 0.94** |
| Letter Memory task | 0.66** | GTS-NT | 1.04** |
| Keep Track task | 0.51** | NEO-N | 0.94** |
| Verbal Fluency task | 0.27* | BAS | 0.25 |
| Dual Network-Trait Motivation SEM model | | | |
| <i>Fit statistic</i> | <i>Value</i> | | |
| CFI | 0.97 | | |
| TLI | 0.96 | | |
| RMSEA | 0.03 | | |
| SRMR | 0.07 | | |
| Maintenance | | | |
| <i>Variable</i> | <i>Factor Loading</i> | | |
| Plus-minus task | 0.75** | | |
| Color-word Inhibition task | 0.46** | | |
| Color-word Switching task | 0.30* | | |
| Flexibility | | | |
| Trail-making task | 0.24* | | |
| Spatial Updating task | 0.57** | | |
| Letter Memory task | 0.66** | | |
| Keep Track task | 0.52** | | |
| Verbal Fluency task | 0.26* | | |

† = 0.06

* < 0.05

** < 0.005

BIS behavioral inhibition system, *BAS* behavioral activation system, *GTS-NT* general temperament survey negative temperament, *GTS-PT* general temperament survey positive temperament, *NEO-N* NEO neuroticism, *NEO-E* NEO extraversion

Figure 1 Neuropsychological Task Dendrogram

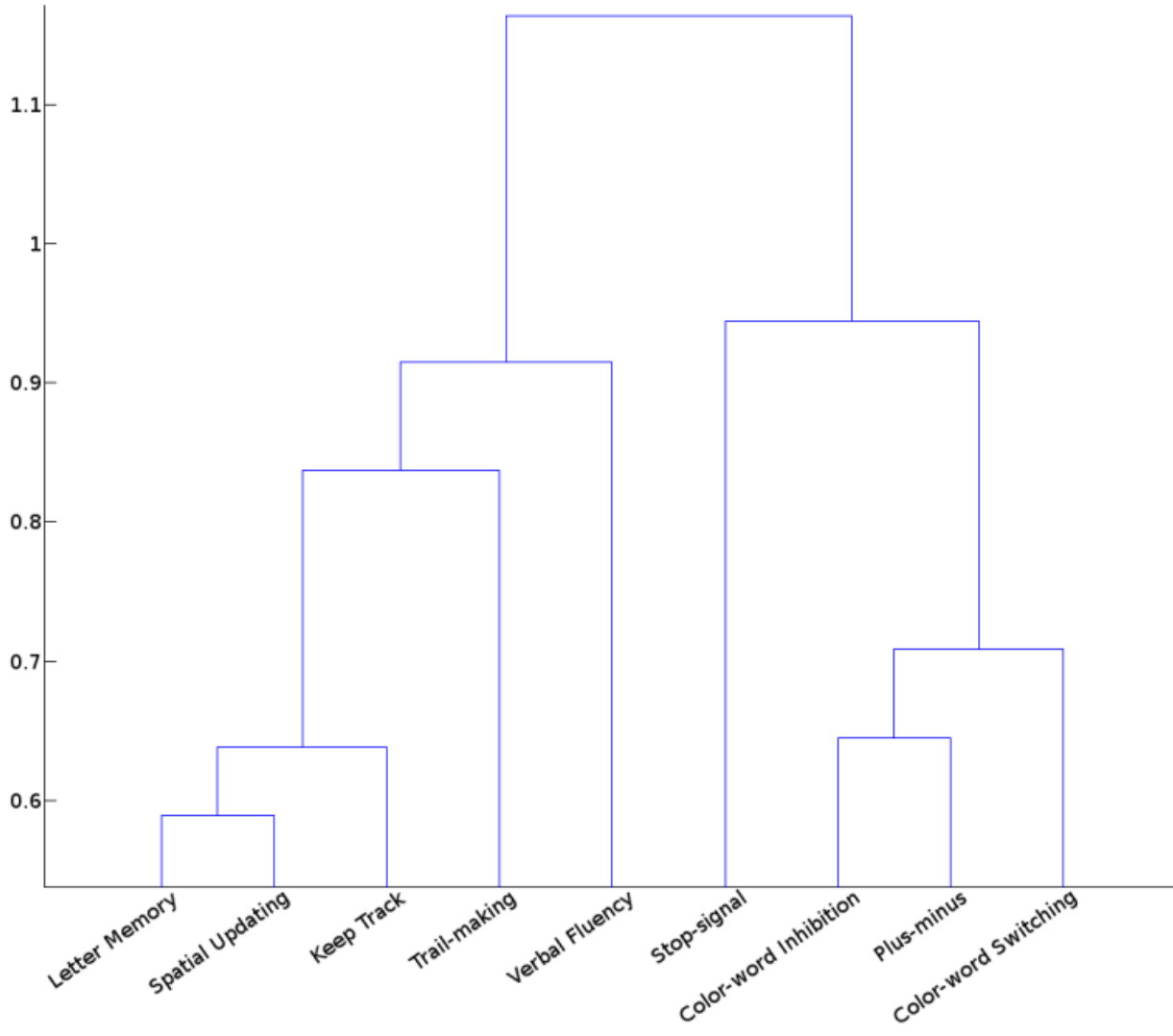
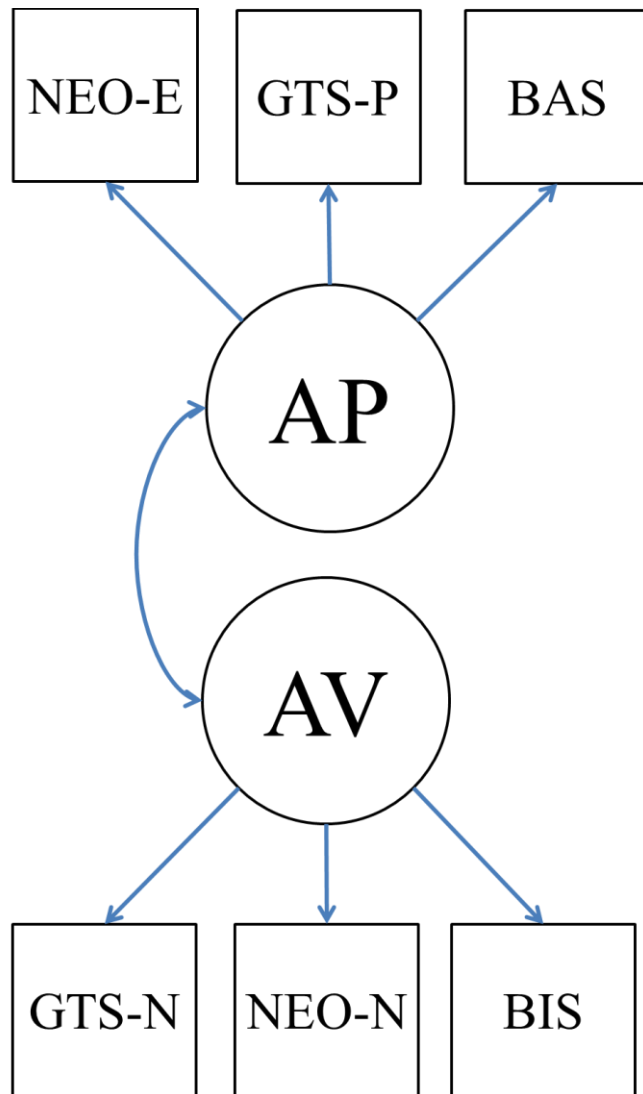
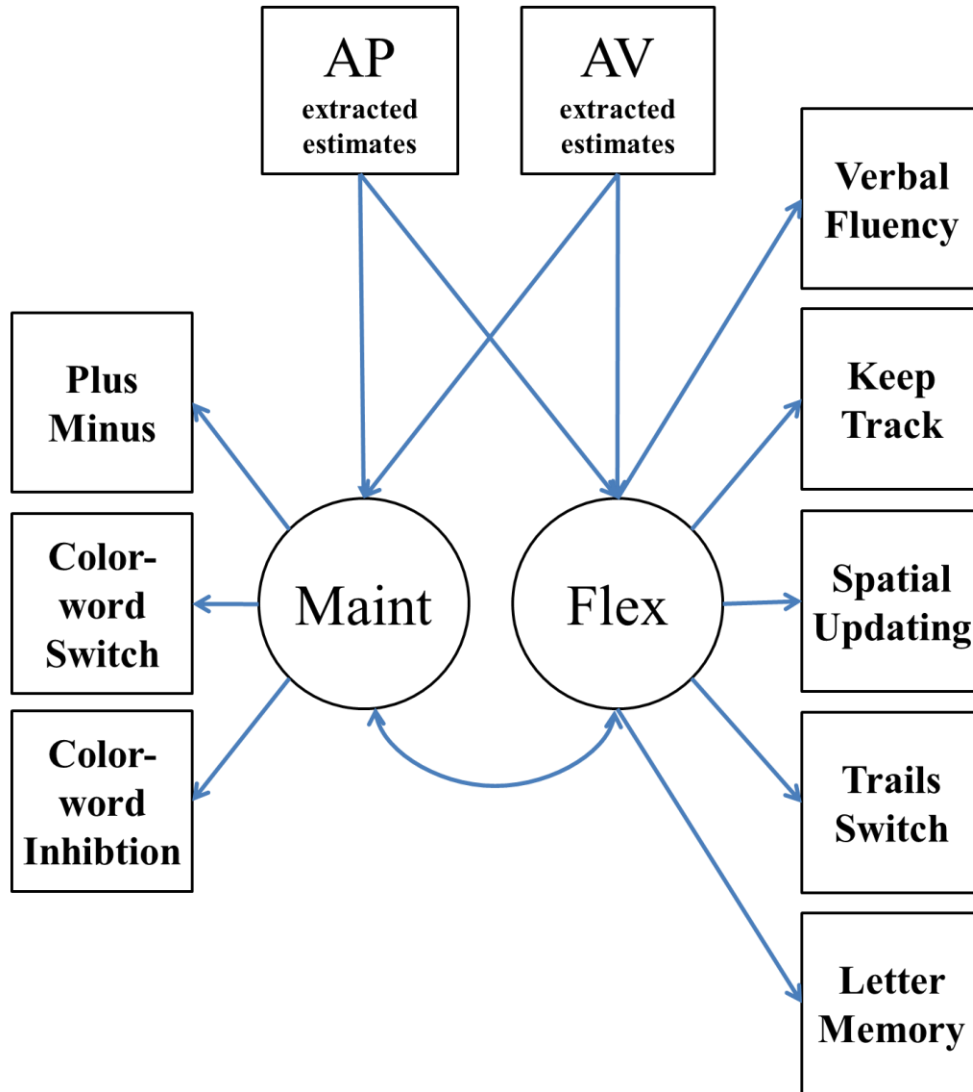


Figure 2 Trait Motivation Model



BIS behavioral inhibition system, *BAS* behavioral activation system, *GTS-NT* general temperament survey negative temperament, *GTS-PT* general temperament survey positive temperament, *NEO-N* NEO neuroticism, *NEO-E* NEO extraversion, *AP* trait approach motivation, *AV* trait avoidance motivation.

Figure 3 SEM of the Dual-network Model and Trait Motivation



AP trait approach motivation, *AV* trait avoidance motivation (both extracted from the trait motivation CFA), *Maint* latent EF variable of maintenance, *Flex* latent EF variable of flexibility.

APPENDIX A: METHOD SUPPLEMENT

Specific neuropsychological tasks

Keep track task (Yntema, 1963). This task assesses the ability to update information held in working memory on a trial-by-trial basis. On each trial, participants were shown two to five target categories out of six possible categories (animals, colors, countries, distances, metals, and relatives) at the bottom of the computer screen. The target categories remained at the bottom of the screen while individual words belonging to the six possible categories were presented serially for two seconds each. The amount of individual words presented in each trial ranged from 15 to 24 words. Participants were instructed to recall the last word from each of the target categories shown on the bottom of the computer screen and state them out loud at the end of each trial. Participants performed two practice trials and then 16 task trials, recalling a total of 56 words. The dependent measure was the proportion of words recalled correctly for the task trials.

Letter memory task (Morris & Jones, 1990). This task is similar to the keep track task in that it required participants to continually update information in working memory on a trial-by-trial basis. Each trial consisted of 9, 11, or 13 letter strings presented individually and serially on the computer screen for three seconds each. The task was to recall the last four letters presented in the list in the order presented. Participants were instructed to continually rehearse out loud the last four letters by adding the most recent letter and dropping the fifth letter back and then saying the new string of four letters until the end of the list. The number of letters presented (9, 11, or 13) on each trial varied randomly so that participants did not know how long each list was and had to continuously update their working memory representation until the end of each trial. After three practice trials, participants performed 12 task trials for a total of 48 letters recalled. The dependent measure was the proportion of letters recalled correctly.

Spatial updating task. The spatial updating task was developed in our laboratory (Warren, Towers, Miller, & Heller, unpublished manuscript) as a visuospatial analog of the letter memory task and is similar to the spatial portion of the Hebb-Corsi test (Corsi, 1972; Nelson et al., 2000). Participants viewed a screen with a spatial array of 21 small boxes in which a sequence 9, 11, or 13 boxes were darkened in a random order one at a time. Participants had to use a strategy similar to that used in the letter memory task, in that they needed to forget the location of the square five trials back and add the location of the square that was just presented to memory. Participants were instructed to select the last four boxes that darkened in the proper sequential order after each presentation of a square using the mouse. After two practice sequences, participants performed 12 task sequences for a total of 48 boxes recalled (the last four boxes for each trial). The dependent measure was the proportion of boxes recalled correctly.

Trail-making task. The trail-making task from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) was used to assess visual-motor sequencing and the ability to flexibly shift between sequencing numbers and letters. Two baseline tasks of simple number sequencing and simple letter sequencing were administered. All three conditions consisted of two pages of numbers and letters interspersed across the page and contained within circles. During the first baseline task, participants were instructed to draw a line connecting the numbers in numeric order. The second baseline task required that participants draw a line connecting the letters in alphabetical order. During the switching condition, participants were instructed to switch between drawing a line connecting the numbers and letters in the appropriate order (A-1-B-2, etc.). The dependent measure was calculated by subtracting the average of the times to complete the simple number and letter sequencing conditions from the time to complete the switching condition.

Verbal fluency task. This task (D-KEFS; Delis et al., 2001) assesses fluent verbal production and shifting. Basic ability is first assessed (i.e., speeded word generation constrained by a rule). During category switching, participants were instructed to generate words, alternating between two different semantic categories (fruits and furniture) as quickly as possible. The dependent measure was switching ability as measured by the number of successful switches. Basic ability was not included in scoring because preliminary analyses indicated it did not influence the results.

Plus-minus task. This task assesses the ability to switch between simple mental operations (Jersild, 1927; Spector & Biederman, 1976). Participants are presented with three lists of 30 two-digit numbers (the numbers 10-99 pre-randomized without replacement). The first two tasks separately establish a baseline for addition and subtraction ability. The third task measures how well participants can switch back and forth between the two operations. Participants were told to complete each list quickly and accurately. The dependent measure was the cost of shifting between the operations of addition and subtraction, computed by subtracting the average of the time to complete the addition and subtraction lists from the time to complete the alternating list.

Stop-signal task. The stop-signal task (van den Wildenberg et al., 2006) was used to measure the ability to suppress a dominant or automatic response. The dominant response was established over the course of 50 initial trials during which participants were instructed to indicate the direction of a green arrow that appeared on a computer screen with corresponding arrow keys. They then had to perform the same task again but had to withhold their response every time the arrow turned red (the stop signal). The time at which the arrow changed color was adjusted for each participant so that they were able to withhold a response on about 50% of the color-changing trials. There were 48 practice trials followed by 3 blocks of 80 trials in which

25% of the trials in each block were stop trials. Participants were instructed to maintain a consistent response speed and not to slow down to see whether the arrow changed color. The inter-trial interval between offset of one trial and the onset of the next ranged from 750 to 1250 ms, and participants were allowed up to 1000 ms to respond while the arrow was on the screen. The dependent measure was the stop-signal reaction time (SSRT), calculated by subtracting the average stop-signal delay across the 3 blocks from the median of the distribution of reaction times for the correct go trials.

Color-word interference task – inhibition condition. This task assesses the ability to inhibit automatic responses (D-KEFS; Delis et al., 2001). The two baseline conditions consisted of a set of 50 colored squares (red, green, blue) and a set of 50 color names (red, green, blue). Participants were instructed to name the colors of the squares as quickly and accurately as possible and to read the color names as quickly and accurately as possible. These conditions accounted for variation in color discrimination and word reading ability. The inhibition condition consisted of 50 color names (red, blue, green) that were printed in incongruent ink colors (e.g., the word red in blue ink). Participants were instructed to say the ink color the words were printed in, and not read the color names, as quickly and accurately as possible. The dependent measure was the time it took participants to perform the inhibition condition minus the average of the color naming and word reading conditions.

Color-word interference task – inhibition/switching condition. This task assesses the ability to inhibit automatic responses and switch between rule-sets (D-KEFS; Delis et al., 2001). This condition of the color-word interference task was similar to the inhibition condition described above. The primary difference was that some words were printed inside boxes, whereas others looked just as they did in the inhibition condition. Participants were instructed to

read the words if they were printed in the boxes but to say the ink colors the words were printed in if they were not in boxes. The dependent measure was time to complete the inhibition/switching condition minus the time to complete the color naming condition. This measure was selected over one where the average of the color naming and word reading was removed because it was more highly correlated with the other measures putatively tapping similar processes.