THE RELATIONSHIP BETWEEN HIGHER-ORDER COGNITION AND PERSONALITY

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THE RELATIONSHIP BETWEEN HIGHER-ORDER COGNITION AND PERSONALITY

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To my family

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PREFACE

The few published studies on the relationship between working memory (WM) and personality have focused on narrow aspects of each construct, generalizing conclusions to the overall personality–cognition relationship. Furthermore, the studies examining working memory capacity (WMC)–personality relationship have primarily used single measures of WMC and personality rather than multi-indicator measures that would allow studying the relationship at the construct level. As a result, limited information exists to draw general conclusions about the overall nature of these relationships. In fact, it is possible that the association between personality and cognitive abilities is best grasped at a more general, construct or latent level. Moreover, cognitive task performance may vary not only as a function of specific personality traits but as their combination as structures that can be modeled via latent variable approach.

Empirical evidence strongly indicates that the constructs of WMC and gF, where gF represents the ability to solve novel problems and WMC represents the ability to control attention, and to actively maintain and update information, are highly related (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004). The literature demonstrates mostly weak relationship between aspects of personality and intelligence and aspects of personality and WM (Ackerman & Heggestad, 1997; Ashton, Lee, & Vernon, 2000; Furnham & Chamorro-Premusic, 2006; Gray & Braver, 2002; Jostmann & Koole, 2006; Moutafi, Furnham, & Crump, 2003; Rinderman & Neubauer, 2001).

The main goal of the present study was to understand the link between personality and higher-order cognition by including diverse cognitive and personality measures, with personality related to a person's general characteristic as well as specific personality attributes, including behavioral tendencies, future orientation, and previous experience. The study addressed three main aspects of the relationship within and between higher-order cognition and personality: (1) defining the WMC construct, (2) defining a latent personality structure and then its relation to WM and gF constructs, and (3) the notion of variability/stability across personality variables in individuals varying in WMC. The current research integrated the existing empirical evidence on this topic and shed light on the relationship between multiple aspects of personality on WM and gF on a broad scale, mostly ignored in the literature.

Two types of WM tasks were chosen to build two latent WM constructs to examine their relation to gF. The first WM latent factor included complex span tasks and the second WM latent factor comprised 3-back tasks. The results demonstrated that both WM latent factors highly relate with gF and with each other, yet are best described as two separate latent constructs. Based on the available empirical evidence, the diverse nature of the personality structure prompted exploration of two- and three higher-order personality factor models. Multiple personality measures were chosen based on the assumption that the examined aspects of personality possess a common characteristic to form a higher-order structure. The results suggested that a four-factor personality structure might provide an adequate representation of the measures used to form the constructs. The two- and three-factor structure found weak support as an adequate description of personality structure. The final cognitive and personality models were then

included in the model comprising personality, WM and gF latent constructs to examine whether the higher-order personality factors would differentially relate to WM and gF.

Multiple models support differential nature of the relationship between personality and higher-order cognition, where Approach (leading trait BAS-Fun Seeking characterized by change) and Restraint (leading trait Conscientiousness characterized by self-discipline) negatively related to all three cognitive constructs at a latent level. Two other personality constructs related positively to either WM construct only, which was Action characterized by open-mindedness with the leading trait Extraversion; or positively to gF construct only, which was Avoidance characterized by hesitation with the leading trait BIS.

Overall, the results show that specific personality characteristics at a general construct level might influence cognitive task performance. The main advance of the present study is including multiple measures to examine the relationship across multiple constructs and domains at a latent level. The results contribute to the interdisciplinary discussion about the influence of personality on cognitive task performance and contribute to an ongoing debate on (1) the nature of WMC and its tasks, (2) personality structure at a latent level, (3) the relationship between cognition and personality.

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LIST OF SYMBOLS AND ABBREVIATIONS

5-HT	Serotonin
A	Agreeableness
ACC	Anterior Cingulate Cortex
AOD	Action Orientation – Decision
AOF	Action Orientation – Failure
AOP	Action Orientation – Performance
BASD	Behavioral Activation Scale – Drive
BASF	Behavioral Activation Scale – Fun Seeking
BASR	Behavioral Activation Scale – Reward Responsiveness
BIS	Behavioral Inhibition Scale
C	Conscientiousness
CFA	Confirmatory Factor Analysis
DA	Dopamine
E	Extraversion
EFA	Exploratory Factor Analysis
N	Neuroticism
NE	Norepinephrine
O	Openness
PFC	Prefrontal Cortex
SEM	Structural Equation Modeling
WM	Working Memory
WMC	Working Memory Capacity
RSPAN	Reading Span Task

OSPAN	Operation Span Task
SSPAN	Symmetry Span Task
ACS-90	Action Control Scale
RFQ	Regulatory Focus Questionnaire
CABA	Context Appropriate Balance of Attention model
gF	Fluid Intelligence
gC	Crystallized Intelligence

SUMMARY

A latent variable approach was used to (1) examine the relationship between working memory capacity and fluid intelligence, (2) compare the relationship between fluid intelligence and two measures of working memory capacity (complex span and n-back), (3) identify higher-order personality factors and (4) determine the relationship between higher-order personality factors, working memory capacity and fluid intelligence. Confirmatory factor analysis followed by structural equation modeling described the complex span and n-back as highly correlated yet distinct constructs. Consistent with previous research, both measures correlated highly with fluid intelligence. Four higher-order personality factors best modeled the structure of personality. Moreover, these four factors had differential relationship to cognitive constructs. The current research provides a deeper understanding of the relationship between working memory capacity and fluid intelligence, including discrepancies considering the magnitude of the relationship between two types of working memory measures and fluid intelligence, and finally, the influence of a diverse personality structure on working memory capacity and fluid intelligence. Importantly, the study examined these relationships on a broad scale using multiple tasks at a latent level contributing to better understanding of the nature of working memory capacity – fluid intelligence relationship and the influence of personality on higher-order cognition.

CHAPTER 1

INTRODUCTION

Working Memory and Working Memory Capacity

Working memory (WM) plays a central role in active processing of goal-relevant and contextually appropriate information (Engle & Kane, 2004). Working memory is a construct related to maintenance, updating, and manipulation of information in active memory, important both in basic information processing and in higher-order cognition (Daneman & Carpenter, 1980; Engle et al., 1999; Conway et al., 2002; Kane & Engle, 2003; Unsworth, Schrock, & Engle, 2004). Working memory is essential for active processing, updating information flexibly according to the goal while resisting interference or discarding irrelevant information. In the present context, WM encompasses control of attention in pursuing a goal in the face of interference or temporarily irrelevant environmental cues (Engle, 2002; Engle & Kane, 2004; Kane, Bleckley, Conway, & Engle, 2001; Kane, Conway, Miura, & Colflesh, 2007).

In 1974, Baddeley and Hitch proposed an influential model of WM encompassing two systems responsible for maintenance and storage of phonological and visuospatial information (Baddeley & Hitch, 1974; Baddeley, 1996a, b) and a third system, the central executive (Baddeley, 2000; see also Unsworth, Redick, Heitz, Broadway, & Engle, 2009) responsible for control processes related to higher-order cognition and important in WM processes. Further research indicated an imperative role of the central executive in allocating resources to both the processing and storage components of WM and in controlling and directing attention to relevant information (Engle et al., 1999) (refer to Figure 1 below). Other models incorporating the control unit, such as supervisory unit (Norman & Shallice, 1986) or a control network (Chein & Schneider, 2005) further support the claim that the central executive is crucial in managing WM resources.

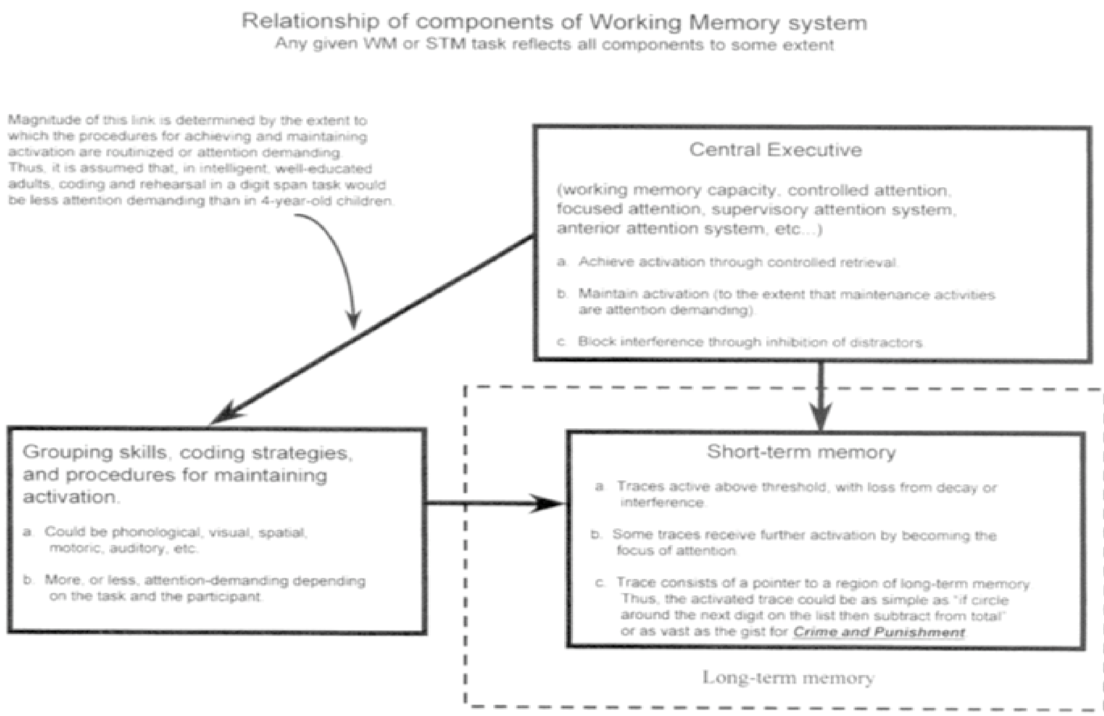

Figure 1. Components of the WM system (Engle, Tuholski, Laughlin, & Conway, 1999).

An important aspect of WM is its limited capacity. How much and how well a person is able to control attention, maintain and update information in active memory, is a source of individual differences. Various constraints in addition to capacity limits temporarily reduce the resources available for processing in WM, including interference, high cognitive load and anxiety (e.g. Ilkowska & Engle, 2010a, 2010b). A significant step in development and assessment of measures of working memory capacity (WMC) was devising a complex span task (the reading span task, RSPAN; Daneman & Carpenter,

1980) that assesses two important components of WM: storage (remembering words for recall at the end of a set) and processing (reading sentences). In the RSPAN, the number of sentence-word pairs presented to participants varies from two to seven, where more pairs in a set relate to higher demand put on WMC. The RSPAN has been followed by development of a wide range of complex span tasks, which are dual tasks structurally similar to the RSPAN that encompass various items serving as storage and processing components. Examples of other complex span tasks include operation span (OSPAN; with numerical processing component) and symmetry span (SSPAN; with spatial processing component; Turner & Engle, 1989; Unsworth, Heitz, & Engle, 2005). Figure 24 in Appendix A illustrates the OSPAN task procedure whereas Figure 25 in Appendix A compares different storage and processing components of the three complex span tasks just described.

Various aspects of cognitive processes differentiate persons scoring high (high spans) and low (low spans) on WMC tasks. High and low spans differ in the ability to control attention, namely, the ability to prevent attention being captured by representations not relevant to the task. High and low WMC individuals differ in how susceptible they are to distraction and how well they are able to resist interference or inhibit irrelevant information (Kane & Engle, 2003; Kane et al., 2007). In addition, high and low spans differ in perseveration, which is the rigidity in the way one solves a problem or responds when an old strategy or response is no longer appropriate but still pursued (Leiserson & Pihl, 2007). The flexibility and frequency of employing automatic and controlled processing further differentiates high and low WMC spans (Norman & Shallice, 1986; Schneider & Chein, 2003; Kane & Engle, 2003; Chein & Schneider, 2005). If high span individuals focus attention or inhibit irrelevant information better than low spans, then high spans could have a better ability to flexibly allocate available resources for moment to moment information processing, and to actively retrieve, maintain, and update information.

Temporary constraints on cognitive processes might cause facilitation of automatic responding regardless of whether a situation requires an automatic or controlled response. Low spans are especially prone to use automatic processing when demands or pressure put on WM are too high or when a task requires resisting prepotent responses over infrequent critical trials (e.g. Kane & Engle, 2003). There are situations, thought, that promote the automatic manner of responding or using simple strategies, which are frequently employed by low spans (Beilock, Kulp, Holt, & Carr, 2004; Beilock & Carr, 2005; Beilock & DeCaro, 2007). Beilock and DeCaro (2007) showed that individuals higher in WMC outperformed those low in WMC under a low-pressure condition, whereas underperformed low WM individuals under a high-pressure condition. On the other hand, performance of individuals low in WM was similar under both high and low pressure.

Why are individual differences in WMC important? Performance on complex span tasks predicts higher-order cognition, including reading comprehension, reasoning, fluid intelligence, and problem solving (Daneman & Carpenter, 1980; Kyllonen & Christal, 1990; Engle et al., 1999; Conway et al., 2002). Multiple studies indicate that WMC and fluid intelligence (gF) are highly related constructs (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Colom, Abad, Rebollo, & Shih, 2005; Colom, Rubio, Shih, & Santacreu, 2006; Conway et al, 2002; Conway, Kane, & Engle, 2003; Kane &

Engle, 2002; Kane et al., 2004; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Oberauer, Schulze, Wilhelm, & Süß, 2005). Fluid intelligence is important in reasoning, novel problem solving, in the ability to adapt flexibly to novel situations and in understanding the relationships between concepts (Cattell, 1943; Jensen, 1998). The Raven Progressive Matrices where the participant matches a missing picture based on the relationship the rest of the pictures in the set share with one another (Raven, Raven, & Court, 1998) is the most frequently used task to assess gF.

Working Memory and Personality

Working memory is a dynamic process, important in daily functioning, including cognitive processes, higher-order cognition, goal-directed behavior, and personality. Personality refers to a stable individual characteristic and describes typical patterns of behavior. As Johnson (1974) wrote, "There is a reason to believe that aspects of personality may be reflected in differences in the ability to remember", even though this link is complex (Johnson, 1974). Where this relationship could manifest? Johnson suggested that a good candidate to focus on for the cognition-personality relationship is a control system responsible for strategies and decisions for memory processes, such as encoding, selection, organization, transfer and retrieval of information from memory. Other researchers have focused on individual differences in multitasking (Lieberman, 2000), in prospective (Kuhl & Kazen, 1999) and retrospective (E.T. Higgins, 1997) goal orientation. The processes related to attention control seem to be especially important as they are tied to susceptibility to distraction, proneness to perseveration, and the ability to flexibly maintain and update information in active memory (Kane & Engle, 2003; Unsworth et al., 2004).

Previous research investigating the relationship between WM and personality have used a diverse set of personality instruments and cognitive tasks (Carver, 2005; Carver, Sutton & Scheier, 2000; Dweck & Leggett, 1988; Hoyle, 2006; Humpheys & Revelle, 1984; Luciano, Leisser, Wright, & Martin, 2004; Matthews & Dorn, 1995; Matthews & Gilliland, 2001; Mischel, 2004; Mischel & Shoda, 1995; 1999; Revelle, 1993; Sackett, Gruys & Ellingson, 1998). As such, the variety of incorporated tasks across studies makes it difficult to draw uniform conclusions at a general level. For example, Zinbarg and Revelle's study (1989) found that the interaction between anxiety and impulsivity affected the rate of learning in the Go/noGo task. Specifically, "high impulsives" with "low anxiety" individuals learned quickly how to achieve rewards, but could not learn to inhibit responses to avoid punishment. Conversely, "low impulsives" with "high anxiety" individuals quickly learned how to avoid punishment. The other two groups, high or low on both traits, were poor learners overall. In another study, Nugent and Revelle (1991; see Revelle, 1993) examined whether positive or negative feedback influence memory of impulsives and neurotics. "High impulsives" were able to remember better the words that followed a reward, whereas "low impulsives" better remembered the words that followed punishment. There was no effect of anxiety on memory performance when followed by punishment. The two studies (Zinbarg & Revelle, 1989; Nugent & Revelle, 1991) clearly illustrate the complexity of the link between personality and cognitive task performance.

Matthews and Dorn (1995) proposed that the nature of the relationship between cognitive task performance and personality depends on particular demands put on different cognitive processes, including attentional resources, executive control, and short-term memory (see also Hoyle, 2006).[1] Matthews and Dorn examined this hypothesis for individuals scoring high on trait Neuroticism, which is characterized by high anxiety, impulsiveness, negative affect, and poor coping with stress; and individuals scoring high on Extraversion, which is characterized by high reward sensitivity, excitement-seeking, positive affect, and sociability. The authors showed that individuals high in Neuroticism demonstrated poor executive control abilities and performed poorly across a variety of attentional tasks. However, no clear evidence was found for extraverts. Other studies have shown variation in cognitive task performance as a function of Neuroticism (Austin et al., 2002), Extraversion in differential brain activation across levels of WM task difficulty that depended on the level of the trait (Kumari et al., 2004; see also Figure 3), and finally, as a function of anxiety as a situational factor (Goff & Ackerman, 1992).

Both direct and indirect studies investigating the link between WM and personality are informative. The direct studies focus on various aspects of personality including affective personality traits (Gray, 2001; Gray & Braver, 2002; Gray et al., 2005) and intention related action-state orientation (Jostmann & Koole, 2006). Most of the available direct studies frame the relationship between WM measured primarily by the n-back task and personality within the approach and avoidance motivation or similar conceptualizations that assume duality of motivations, goal orientations, or affective sensitivities that drive behavior.

The indirect studies focus on the biological framework examining the role of genetics, brain pathways, and neurotransmitters (Carver & Miller, 2006; Carver et al.,

[1] Note, that attention control and resisting interference also differentiate performance of high and low WMC individuals.

2008; Cloninger, Dragan, Srvakic, & Przybeck, 1993; Cools et al., 2007; MacDonald, 2008; Zuckerman & Cloninger, 1996). Example neurotransmitters include dopamine (DA; Ashby, Valentin, & Turken, 1999; Ashby, Isen, & Turken, 2002; Depue, 1995; Depue & Collins, 1999; Reif & Lesch, 2003), serotonin (5-HT; Carver & Miller, 2006; Carver, Johnson, & Joormann, 2008) or the interplay between DA and 5-HT functioning (DeYoung, Peterson, & D.M. Higgins, 2002)[2].

Working memory performance is associated with DA functioning (Braver & Cohen, 2000; Kimberg, D'Esposito, & Farah, 1997; Luciana, Depue, Arbisi, & Leon, 1992). Reuter, Schmitz, Corr, and Hennig (2006) found significant dopamine D2 receptor gene DRD2 x COMT (Catechol-*O*-Methyltransferase) polymorphisms for the total BAS scores and its BASD and BASF subscales suggesting that individuals scoring high on the BAS scale exhibit high DA activity. Larsen and Augustine (2008) and Davidson, Jackson and Kalin (2000) showed the link between Extraversion and dopamine D4 receptor gene (DRD4) associated with activation of the left PFC and linked to the positive affect and BAS. Further relations between personality and neurotransmitters include association between DA and sensation- and novelty -seeking (DRD4, Dreisbach et al., 2005), which is interesting as novelty-seeking might be closely related to the qualities characteristic to Extraversion and BAS scales; and norepinephrine with alertness and reward seeking (Friedman and Schustack, 2006, p.187; see also Carver et al., 2008; Suhara et al., 2001). Other factors include rate of glucose metabolism in amygdala with activation of the right PFC, predicting high negative affect and BIS when following avoidance behaviors, and

[2] See Table 30, Appendix A for the role of neurotransmitters across personality traits.

finally, association of high Neuroticism with serotonin, avoidance motivation, negative affect, and BIS.

As just mentioned, serotonin has also been linked to personality in impulsivity (Carver & Miller, 2006) and Conscientiousness and, in the cognitive literature, serotonin has been implicated in effortful control acting on a response to changing behavioral context, akin to updating (Carver & Miller, 2006; Carver et al., 2008). Furthermore, MacDonald (2008) proposed a model connecting serotonergic system, self-regulatory behaviors, and effortful control, as shown in Figure 2 (left panel). This model has been expanded from the schematic proposed by Unsworth, Heitz and Engle (2005, p.37; here Figure 2, the right panel) that describes factors influencing individual differences in task performance. Note that the model proposed by Unsworth et al. includes various secondary factors, such as psychopathology, load, stress, and various socio-affective elements, that influence individual differences in task performance. These secondary factors serve as an additional load that shrinks the resources available for the task and disrupts maintaining and updating in WM.

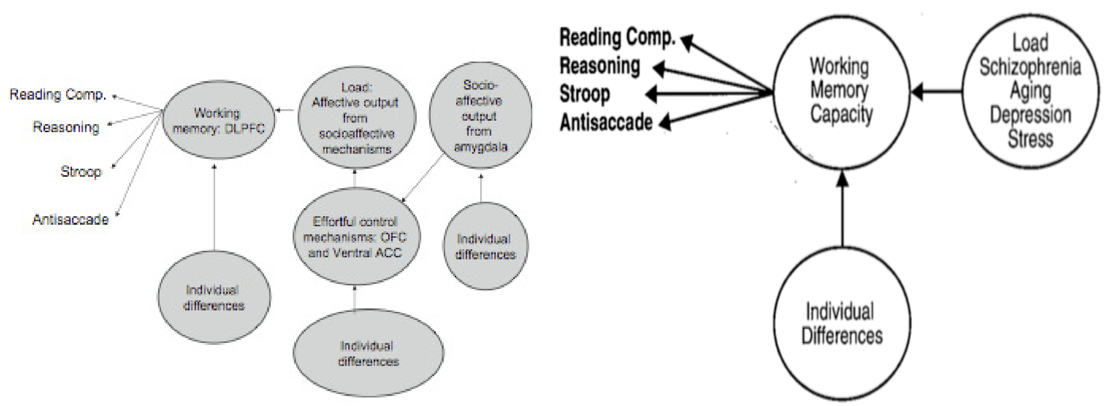

Figure 2. Relationships between socio-affective and effortful control mechanisms (MacDonald, 2008; left panel) and the baseline model (Unsworth et al., 2005; right panel).

Different brain activation patterns primarily include the prefrontal cortex (PFC) and anterior cingulate cortex (ACC; c.f. Kerns et al., 2004; Perlstein, Elbert, & Stenger, 2002). For example, varying levels of DA antagonist drugs influence performance on a WM task, and this effect was shown to vary by personality in traits Extraversion and impulsivity (Chavanon, Wacker, Leue, & Stemmler, 2007; Cools, Sheridan, Jacobs, & D'Esposito, 2007). Cools et al. (2007; see Figure 3) examined the role of DA in "flexible updating and stable maintenance of task-relevant information in WM". They showed that impulsive personality predicts DA dependent changes modulated by bromocriptine, a dopamine agonist, during WM processes. These changes are accompanied by modulations in brain activity caused by bromocriptine (see Wacker & Stemmler, 2006).

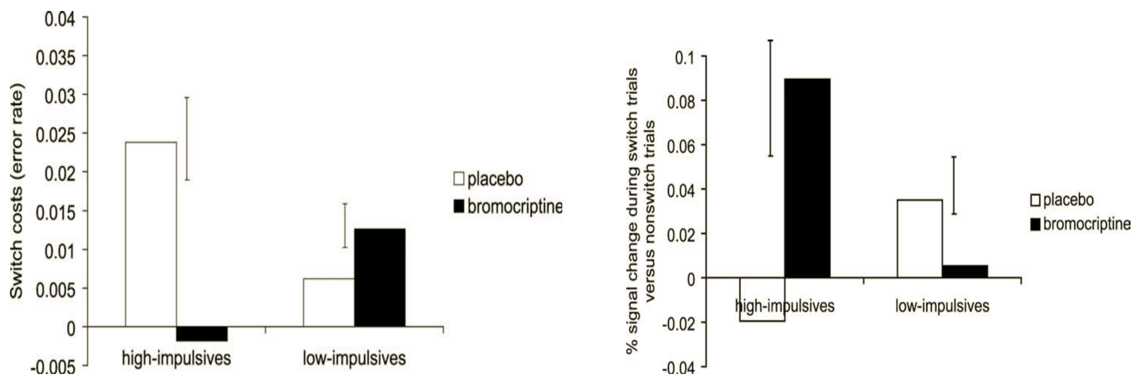

Figure 3. Results of Cools et al. (2007) study, as indicated in Fig.3 and 4 (p. 5509-5510).

Finally, disorders where impulsivity plays a leading role are marked by impairments in WM, changes in frontal brain areas and increased sensitivity to the effects of DA changes (Cools et al., 2007). Cools and colleagues predicted that individuals scoring high on trait impulsivity (high impulsives) would show greater effects of bromocriptine on WM, reflected by enhanced performance on a WM task, than individuals scoring low on trait impulsivity (low impulsives). Specifically, the bromocriptine would improve ability of high impulsives to switch and resist distraction. Cools also predicted that low impulsives would perform worse under bromocriptine. Administering bromocriptine to high impulsives indeed enhanced their performance on switching (flexible updating) in a delayed match-to-sample task. As the left panel of Figure 3 illustrates, high impulsives were better in attentional switching under bromocriptine than low impulsives.

As seen from the examples just described, the link between WM and personality might include particular aspects of both constructs and emerge in specific situations, as when a task requires high cognitive control, is highly demanding on WM resources, or involves multitasking (Eisenberger, Lieberman & Saptute, 2005; Lieberman, 2000; Lieberman & Rosenthal, 2001).

Working Memory and Personality: Example Studies from the Direct Evidence

This section describes specific studies examining the relationship between WM and personality. One may speculate, as personality bears motivational, strategic, and coping mechanisms potentially important in task performance, that personality might influence WM task performance. The first line of evidence suggests that affective dimensions of personality related to approach and avoidance influence cognitive control and brain activation patterns while performing a WM task (Cools et al., 2007; Gray, 2001; Friedman & Förster, 2005; Gray & Braver, 2002; Gray et al., 2005; Locke & Braver, 2008). Gray and colleagues reasoned that higher scores on behavioral activation scale (BAS) would be associated with better WM task performance (Gray & Braver, 2002; Gray et al., 2005). The BAS scale is a part of the behavioral activation and behavioral inhibition (BIS) scale (BIS/BAS; Carver & White, 1994; see also Table 30,

Appendix A) that assesses individual differences in arousal levels associated with emotional reactivity, namely, the sensitivity of responding to positive and negative events (Eysenck & Eysenck, 1985; Larsen & Ketelaar, 1991; Revelle, 1993). It has been shown that affective personality dimensions in neurotics and extraverts, and extraverts and introverts stem from differences in arousal levels (Eysenck, 1990). Gray and colleagues further hypothesized that the disparity during cognitively demanding tasks might be linked for the individuals high on the BAS scale with a lower activation in the caudal anterior cingulate cortex, a brain region known to be associated with error monitoring.

Gray and Braver (2002) used the n-back task to measure WM. A self-report BIS/BAS questionnaire served as a measure of affective personality. Extraverts with high BAS but low in BIS scores performed better on the 3-back task as measured by the *d'* (BAS r=.27*, $p=.0025$; BIS r=.06, $p>.29$) and had lower activation in the caudal anterior cingulate cortex during completion of the n-back task; that is, when high cognitive control was required. Gray et al. (2005) reported similar results even after controlling for individual differences in gF measured by the Raven Progressive Matrices. Gray et al. extended the previous results by analyzing performance on the 3-back task across trial types (targets, nontargets, and lures) showing that the effects were present for all trial types. Most importantly, the pattern was similar for the BAS and Extraversion, and BIS and Neuroticism, respectively. These results were also similar to Gray (2001) study that employed a less challenging, 2-back task. Interestingly, the three studies conducted by Gray and colleagues found no significant effects for individuals with high BIS scores, which they attributed to lack of anxiety-triggering manipulation.

In his 2001 study, Gray also found that performance on a *verbal* 2-back task was better in the approach (BAS) than in the avoidance state, whereas the avoidance state (BIS) facilitated performance on a *spatial* 2-back task. Gray considered this double dissociation a double dissociation between the approach and avoidance states in relation to performance on the WM task (n-back) an evidence for selective effects of emotions on cognitive control. He further reasoned that these selective effects might indicate the importance of particular aspects of cognitive control for different behaviors, such as verbal and sequencing type of processing for approach behavior, whereas spatial and sustained attention for withdrawal behaviors. Furthermore, Friedman and Förster (2005) found that approach and avoidance states affect attentional flexibility as measured by the Stroop and 2-back tasks, stating that in "approach, relative to avoidance, motivational cues facilitate task performance by enhancing the ability to shift the focus of attention in response to task demands" (Friedman & Förster, 2005, abstract).

In sum, the first line of evidence indicates that affective personality states related to approach and avoidance motivation differentially influence performance on the n-back task and the activity in the caudal anterior cingulate cortex. Thus, we may conclude that cognitive demands are likely a contributing factor to the personality – WM relationship.

In another study examining the influence of cognitive demands on personality, Kumari, Ffytche, Williams, and Gray (2004) compared performance on different variants of the n-back task (0 to 3-back) and brain activation patterns in relation to Extraversion, Neuroticism, and Psychoticism. Personality, particularly the levels of Extraversion, predicted activation in the dorsolateral PFC and the anterior cingulate cortex in response to cognitive demands. Activity over these brain regions differed across Extraversion levels with an increasing task difficulty in that individuals having higher Extraversion scores had higher signal change across the levels of the n-back task with higher demands producing higher signal change over both brain regions, as shown in Figure 4. That is, the strength of the Extraversion and Psychoticism scores determined the levels of activity over different brain areas. At the level of brain, the results provide further evidence for the relationship between personality and cognitive task performance.

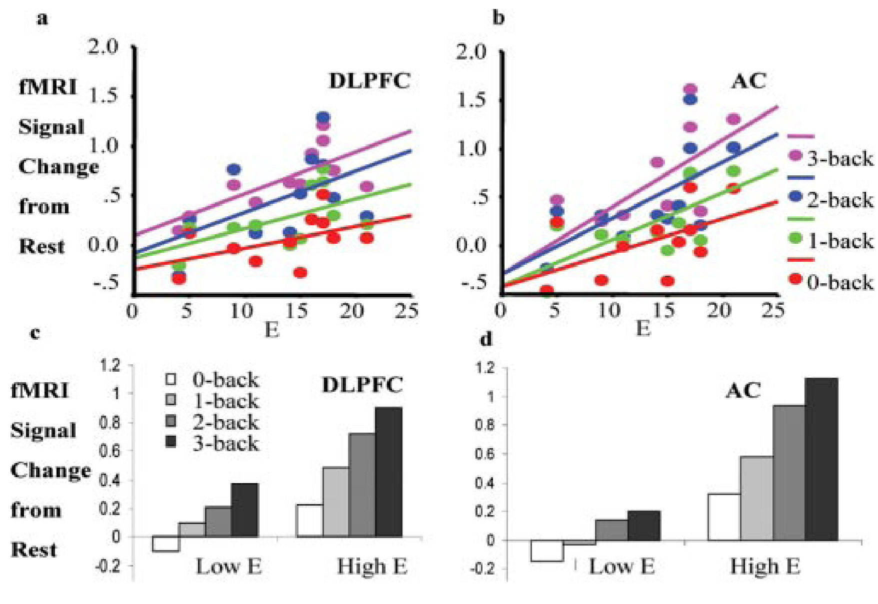

Figure 4. Relationship between Extraversion and n-back tasks varying in difficulty in relation to fMRI signal change across the tasks and levels of Extraversion (Kumari et al., 2004). DLPFC = dorsolateral prefrontal cortex; AC = anterior cingulate; E = Extraversion.

Jostmann and Koole (2006) took a different approach to investigate the influence of high demands on WM task performance and personality. They reasoned that a regulatory mode named intention-related action and state orientation might differentially influence WM performance under high and low demands. Action orientation characterizes promotion of change, decisiveness, and initiative (refer to Table 30,

Appendix A). These three features facilitate intentional action that promotes high goal efficiency. Importantly, individuals scoring high on action orientation under demanding situations employ regulatory resources, which subsequently results in better performance. In contrast, state orientation characterizes resistance to change, indecisiveness, and hesitation in taking action. Under demanding situations, this leads to perseveration and resistance to change, leaving fewer resources for an ongoing task, and subsequently leads to poor performance. Jostmann and Koole (2006) hypothesized that action-oriented individuals under high demands would outperform state-oriented individuals by employing self-regulatory mechanisms allowing for more on-task resources, whereas state-oriented individuals might perform better under rewarding contexts (see also Koole, Kuhl, Jostmann & Vohs, 2005).

In two experiments, Jostmann and Koole (2006) asked participants to imagine either a supporting person (rewarding condition) or a demanding person (demanding condition). Then, participants completed the decision-related (AOD) subscale of the Action Control Scale (ACS-90) and the OSPAN task (study 1). The ACS-90, a measure of action orientation, assesses dispositions towards particular orientation pertaining to the efficiency of acting towards a goal, strengthening motivation to employ self-regulatory behaviors, and shaping person's coping strategies (Kuhl, 2000; Kuhl & Beckmann, 1994). These qualities are especially important when making decisions under highly demanding situations, because enhancing self-regulation frees resources for the task. Enhancing self-regulation leads to successful maintenance of a current or prospective goal and enables efficient resource sharing between concurrent tasks. Indeed, in the demanding condition, action-oriented individuals outperformed state-oriented individuals on the OSPAN task. In contrast, in the supporting condition, state-oriented individuals performed better than action-oriented individuals did. Thus, Jostmann and Koole demonstrated that action orientation related to self-regulatory behaviors influences performance on the OSPAN task.

Another aspect of self-regulation – promotion and prevention focus – relates to anticipation of action and motivation. A short, self-report Regulatory Focus Questionnaire (RFQ) assesses two dimensions: promotion and prevention (E.T. Higgins, 1997; E.T. Higgins et al., 2001). E.T. Higgins (1997) defined promotion as a nurturance characterized by accomplishments, anticipation of pleasure, and aspirations, whereas prevention – as related to anticipation of pain, but also responsibilities and safety. Promotion focus is associated with cognitive flexibility and eagerness, and positively relates with two of the three BAS subscales, BAS-Reward Responsiveness and BAS-Fun Seeking. Prevention focus is associated with perseverance and vigilance, and negatively relates with the BAS-Fun Seeking (Baas, De Dreu, & Nijstad, 2008; E.T. Higgins et al., 2001). To date, no study has examined whether prevention or promotion focus has any influence on WM task performance.

Other authors investigated how individuals with different personality characteristics perform within reward and punishment contexts (E.T. Higgins, 1997; Leiserson & Pihl, 2007). For example, Locke and Braver showed that individuals differing in personality traits tied to reward expectation and reward sensitivity (measured by GRAPES and BIS/BAS scale, respectively) differed in WM task performance and brain activity. That lead the authors to conclude that proneness to incentives might influence cognitive control (Locke & Braver, 2008, p.108; see also Heitz, Schrock, Payne, & Engle, 2007). Yet other studies provide important information about the relationship between WM and personality by investigating cognitive task performance in personality disorders (Aycicegi, Dinn, & Harris, 2002; Aycicegi-Dinn, Dinn, & Caldwell-Harris, 2009; Coolidge, Segal, & Applequist, 2009).

Evidence also suggests that extraverts perform better in high competition situations as well as successfully inhibit prepotent responses (Bone, 1971; Howarth, 1969; Szymura & Nęcka, 1998). For example, Szymura and Nęcka (1998) examined the influence of multiple versions of a visual attention task on Extraversion. They found that introverts were faster and performed better in a non-demanding condition, whereas extraverts performed better in the demanding version of the task. These results are similar to Jostman and Koole (2006) where action-oriented persons performed better on a demanding task, whereas state-oriented persons performed better under rewarding conditions.

Several studies investigating personality described by the Big Five traits indicate that individuals scoring high on Conscientiousness express better control over prepotent responding, suggesting that Conscientiousness might relate to better WM task performance (D.M. Higgins, Peterson, Pihl, & Lee, 2007; John & Srivastava, 1999). Furthermore, Openness has been linked to successful self-control, better school performance (Jensen-Campbell et al., 2002; Jensen-Campbell, Knack, Waldrip, & Campbell, 2007) and better performance on various executive function tasks (DeYoung, Peterson & D.M. Higgins, 2005; Kaufman et al., 2010). Limited evidence exists also for Agreeableness (D.M. Higgins et al., 2007; Salthouse, Berish & Siedlecki, 2004). For example, Salthouse et al. (2004) reported Openness to be related moderately (r=.30) and

Agreeableness to be related slightly (*r*=.16) to an executive function construct characterized by fluency-related tasks, and Openness (*r*=.20) and Neuroticism (*r*=–.13) slightly related to the gF construct characterized by reasoning tasks. In another study, Revelle, Wilt, & Rosenthal (2010) presented participants with a set of personality questions of a similar structure as the Big Five, and ability tests (complex pattern recognition, spatial reasoning and standard ability) that were completed online in sets of random items. Revelle and colleagues reported moderate associations (*r* = .23 to .33) between cognitive abilities and the Openness factor of the Big Five. Finally, Smillie, Cooper, Tharp, and Pelling (2009) found that Psychoticism plays a role in cognitive control represented by set shifting/adaptation flexibility and response perseveration. Persons with higher WM and lower Psychoticism had a higher efficiency in set shifting in a version of the Wisconsin Card Sorting Test.

Taken together, the evidence indicates that individuals high on BAS, action orientation, and possibly Extraversion are superior in performance on WM tasks as indicated by better WM task performance of individuals having high BAS scores (Gray & Braver, 2002), better performance of those with high Extraversion scores in dual tasks and under demanding conditions (Szymura & Nęcka, 1998), WM tasks (Lieberman, 2000; Lieberman & Rosenthal, 2001), and better performance of those scoring high on action orientation under high demands (Jostmann & Koole, 2006). Furthermore, the evidence suggests the influence of personality on WM performance in specific situations, for example, when manipulating WM demands (Jostmann & Koole, 2006), reward contingencies (Chavanon et al., 2007; Finn, Mazas, Justus, & Steinmetz, 2002; Gevins & Smith, 2000), speed of stimuli presentation (Szymura & Wodniecka, 2003) or speed of responding (Lieberman, 2000). Research also shows different effects of suppression of irrelevant information, attentional flexibility (Szymura, Śmigasiewicz, & Corr, 2007) or perseveration (Leiserson & Pihl, 2007) on personality traits of impulsivity, novelty-seeking, and harm-avoidance (Carver et al., 2008; Finn et al., 2002). Finally, it is important to indicate the role of the processes important in WM across personality characteristics. These include the ability to resist interference (Gray, 2001; Gray & Braver, 2002), flexible adaptation to the changing environment, and susceptibility to distraction (Eysenck & Graydon, 1989) including distraction in dual task performance (Konig, Bühner, & Mürling, 2005; Lieberman & Rosenthal, 2001; Szymura & Wodniecka, 2003).

Fluid intelligence, working memory, and personality

Several empirical studies have investigated the relationship between personality, WM and intelligence. In general, studies report small to moderate correlations between WM and personality (Gray & Braver, 2002) and between intelligence and personality (Ashton et al., 2000; Rinderman & Neubauer, 2001) across personality traits and cognitive tasks (Ackerman, Beyer, & Boyle, 2005; Collins & Messick, 2001; Demetriou, Kyriakides, & Avraamidou, 2003; Furnham & Chamorro-Premusic, 2006; Furnham, Dissou, Sloan, & Chamorro-Premuzic, 2007; Kossowska & Necka, 1994; Maciel, Heckhausen, & Baltes, 1994; Matthews & Dorn, 1995; Razoumnikowa, 2003; Strelau, Zawadzki, & Piotrowska, 2001). Fluid intelligence (gF) represents reasoning ability to solve novel problems in contrast to crystallized intelligence (gC) representing knowledge acquired over the life-span, referred to as content (Cattell, 1971; Chamorro-Premuzic & Furnham, 2004). The distinction between fluid and crystallized intelligence proposed by

Cattell (1971) allowed researchers to examine two aspects of intelligence related to the ability to solve novel problems and learning (gF), and the ability to employ previous knowledge (gC). Literature agrees that gF and WM are highly related (Ackerman, Beyer, & Boyle, 2005; Colom et al., 2004; Conway et al., 2002; 2003; Engle et al., 1999; Kyllonen & Christal, 1990; Oberauer et al., 2005; but see Heitz et al., 2006). The interest of the present study is the relationship between WM and personality in relation to gF.

The evidence of the relationship between personality and gF has been largely mixed (Ackerman et al., 2005; Chamorro-Premuzic & Furnham, 2004; Collins & Messick, 2001; Demetriou et al., 2003; Furnham, 2007; Furnham & Chamorro-Premuzic, 2006; Goff & Ackerman, 1992; Kossowska & Necka, 1994; Maciel et al., 1994; Matthews & Dorn, 1995; Razoumnikowa, 2003; Szymura & Nęcka, 1998). Nonetheless, Chamorro-Premuzic and Furnham (2004; abstract) note the importance of the "theoretical integration of ability and nonability traits" in order "to explore causation and further develop theoretical approaches to understanding the relation between ability and nonability traits underlying human performance".

Following this premise, Chamorro-Premuzic & Furnham (2004) introduced a theoretical model of possible relationships between different aspects of intelligence (gF, gC, and subjectively assessed intelligence) and four of the five Big Five personality dimensions (Neuroticism, Extraversion, Openness to Experience and Conscientiousness).

The model served as an integrative framework and a starting point for further investigation, discussing separate paths of the relationships between the ability and personality.

Some studies show a weak but significant relationship between personality and performance on tasks assessing gF (Ackerman & Heggestad, 1997; Ashton et al., 2000; Goff & Ackerman, 1992; Holland, Dollinger, Holland, & MacDonald, 1995; Moutafi et al., 2003; Rinderman & Neubauer, 2001; Strelau et al., 2001). Specifically, Ashton et al. (2000) found correlations of r=.18 between gF and Openness/Intellect factor, as well as Harm Avoidance (r=-.19), Dominance related to Extraversion (r=.22) and Endurance (r=.15). Goff and Ackerman (1992) found evidence for small correlations between intelligence (reasoning composite) and Extraversion (r=.08) and Conscientiousness (r=-.16). Furthermore, Holland et al. (1995) examined the correlations between the subscales of the WAIS-R and the Big Five personality traits and reported correlations between Agreeableness and 4 out of 14 WAIS-R subscales (range from .21 to .32) and between Openness and 12 out of 14 WAIS-R subscales (range from .25 to .49). Four Openness facets (Aesthetics, Actions, Ideas, and Values) had correlations with multiple subscales. Moutafi et al. (2003) found correlations between Big Five traits and intelligence extracted from two ability tests (critical thinking and abstract reasoning). Moutafi et al. concluded that a profile comprising high Openness, low Neuroticism, low Extraversion and low Conscientiousness scores predicted intelligence, which suggests negative relations between intelligence and the three later traits. Finally, Austin et al. (2002) reported association of Openness with general ability (r=.34) finding also negative correlations of Neuroticism (from -.15 to -.19) and Psychoticism (from -.09 to -.14) with general ability, and a small correlation with Extraversion (r=.11; see also Chamorro-Premuzic & Furnham; 2004).

Overall, the literature demonstrates weak to moderate correlations between intelligence and personality (Collins & Messick, 2001; Strelau et al., 2001). Higher correlations are observed for abilities associated with general knowledge and gC (Chamorro-Premuzic, Furnham, & Ackerman, 2006; Furnham & Chamorro-Premuzic, 2006). Oftentimes, researchers ascribe the strength of this relationship to a multitude of additional factors, including the measures used to assess the examined constructs or situational factors (e.g. Strelau et al., 2001).

Dual and tripartite systems approach to personality

The following section introduces theoretical and experimental studies discussing categorization of personality into higher-order personality factors. A number of studies examining the relationship between personality and WM rely on common biological bases of personality and WM. This approach assumes overlapping biological underpinnings of WM and personality as well as their mutual dependence on similar genetic factors and neurotransmitter functioning (Eysenck, 1990; Matthews & Gilliland, 1999**;** Reif & Lesch, 2003; Revelle, 1993; Savitz, Solms, & Ramesar, 2006). Jeffrey Gray's theory of approach and avoidance motivation (Gray, 1970) and Hans Eysenck's theory of arousal (Eysenck, 1967; 1990) are the most influential theories in the present context. One way to examine an underlying structure and its characteristics shared across personality measures is a dual framework of approach and avoidance, the two constructs related to activation (approach) and inhibition (avoidance) (Gray, 1970)[3]. For example, Larsen and Augustine (2008) introduced a strong argument for dual systems approach to personality: "Although these two super traits may not encapsulate all of human

[3] For scales, traits, their characteristics and a categorization in accordance with a dual approach refer to Table 30, Appendix A.

personality, findings from social psychology, affective neuroscience, and genomic science all implicate the two constructs of dispositional approach and avoidance as central to our understanding of both the form and the function of personality". This statement implies that in order to understand the link between personality and higher-order cognition one should examine the most general characteristics described by multiple representations of both constructs.

The arousal theory (Eysenck, 1967; 1990) describes biological bases of personality related to individual differences in the Ascending Reticular Activating System, a part of the reticular formation in the brain stem. This system is a "drive-state" system responsible for maintenance of alertness and awareness, and involved in arousal and motivation. This system also prevents sensory overload by filtering out repetitive stimuli. The role of arousal in individual differences in personality has been widely acknowledged, particularly in Extraversion and Neuroticism. Overall, extraverts differ from introverts in their baseline levels of cortical arousal reflected by their lower activation of this system (Fink, Grabner, Neuper, & Neubauer, 2005). The second theory, Gray's motivational approach and avoidance systems, associates action control with motivation (Carver, Sutton, & Scheier, 2000; Gray, 1970; Matthews & Gilliland, 1999; 2001; Revelle, 1995). The two affective dimensions of approach and avoidance are tied to behavioral activation and inhibition systems. Activation and inhibition indicate individual differences in the sensitivity to cues of reward and punishment and characterize aspects of impulsivity (activation) and anxiety (inhibition) (Corr 2001; 2002; Jackson, 2003; Pickering, Corr & Gray, 1999; Rusting & Larsen, 1997; Zelenski & Larsen, 1999; Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993).

Various authors have proposed a dual processes approach across aspects of personality. Some authors suggest categorization within the dual system approach related to approach and avoidance motivation (Revelle, 1993; 1995; 2007; Revelle et al., 2010) or by using exploratory and confirmatory factor analyses within the dimensions of the Big Five (Digman, 1997; 1990). For example, Digman proposed that two higher-order factors that he named Alpha and Beta, as illustrated in Figure 5, might account for the five dimensions of the NEO-PI-R (for description refer to Table 31, Appendix A, and for NEO-PI-R facets refer to Table 30, Appendix A). The Alpha factor (socialization) linked to avoidance motivation, comprised traits bearing characteristics of negative affect (Neuroticism or its opposition Emotional Stability), avoidance of entities related to disorganization (low Conscientiousness) or avoidance of impolite actions (low Agreeableness; see also Larsen & Augustine, 2008). The Beta factor (personal growth) linked to approach motivation, comprised factors defined by the preference to approach new stimuli and situations, characterized by high Extraversion and high Openness/Intellect scores.

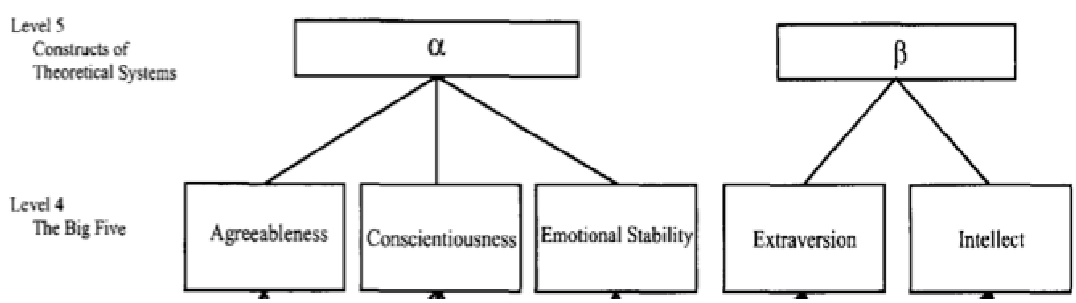

Figure 5. Higher-order personality traits Alpha and Beta. Part of a schematic (Digman, 1997).

The two factors replicate across samples and reflect the common genetic structure when examining heritability of the Alpha and Beta factors (Jang et al., 2006). Jang and colleagues defined the Beta factor identically to Digman as comprising Extraversion and Openness/Intellect. The Alpha factor comprised Conscientiousness and Neuroticism. Agreeableness was, at best, weakly associated with the Alpha factor. Confirmatory factor analyses consistently showed that the two factors best explained the covariance between the traits.

DeYoung et al. (2002) followed Digman's super-trait framework and renamed the two higher-order personality factors to Stability and Plasticity (Grossberg, 1987). DeYoung defined Stability (or Alpha) as a factor associated with overall stability across different spheres of life and with maintenance of information. Following Digman's (1997) hierarchy, Stability included three dimensions of the NEO-PI-R, Neuroticism (Emotional Stability), Agreeableness and Conscientiousness. The second supertrait named Plasticity (or Beta), characterized engagement, exploration, novelty, capability to adjust and process novel information, and flexibility across behaviors and cognitive processes. Plasticity comprised Extraversion and Openness/Intellect.

Interestingly, Liberman, Idson, Camacho, and E.T. Higgins (1999) proposed a similar terminology and the concept of Stability and Change within the framework of promotion and prevention focus. The authors categorized prevention focus as being associated with security and preference for stability, whereas promotion focus as being associated with openness and preference for change. The distinction between the prevention and promotion focus seems to relate to the processes important in WM. The citation below shows that, in addition to the distinction between flexible and stable processing, the role of adaptation to situational factors allows better utilization of cognitive resources. As Dreisbach (2006; p.17) notes:

> "(Maintenance capability) strongly depends on the current task demands whether a more flexible or a more stable processing mode is adaptive. A more flexible behavior is adaptive whenever we are confronted with unexpected events whereas a more stable behavior is required when intentions have to be maintained over time and shielded against distraction".

In a series of studies, Elliot and colleagues (Elliot, 2006; Elliot & Church, 1997; Elliot & Thrash, 2002; Zweig & Webster, 2004) examined the higher-order structure of approach and avoidance systems. In their model depicted in Figure 6, Elliot and Thrash defined two superordinate structures as general tendencies to approach or avoid rewarding or punishing situations. Based on confirmatory factor analyses, Elliot and Thrash proposed the Approach factor including Extraversion, BAS and positive affect, and the avoidance factor including Neuroticism, BIS and negative affect.

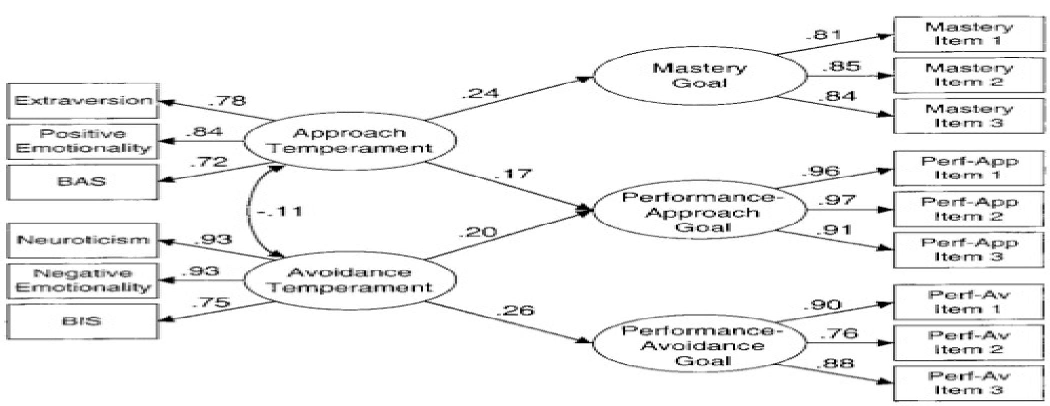

Figure 2. Full structural equation model linking approach and avoidance temperaments to achievement goals. Only theoretically central variables are included in the figure for presentation clarity. All parameters in the figure are significant ($p < .05$) except the covariance between approach and avoidance temperaments. Coefficients in the figure are standardized estimates. BAS = behavioral activation system; BIS = behavioral inhibition system; Perf-App = performance approach; Perf-Av = performance avoidance.

Figure 6. Structural equation model of approach and avoidance related to achievement goals (Elliot & Thrash, 2002).

Similar propositions of integration within the dual systems approach include various aspects of personality, attention, motivation, complex cognition (Derryberry & Reed, 2008; Kuhl & Koole, 2008). For example, one of the levels within a multilevel hierarchical model of personality proposed by Kuhl and Koole (2008) focuses on the valence of avoidance and approach components and higher-level systems as a basis of affect modulation related to approach and avoidance. To explain the relationship between avoidance and approach motivation, affect and cognitive processing, Kuhl and Koole suggest a further distinction defined as progression (higher-order control) and regression (prepotent or habitual responding). Revelle (1993) proposed analogous categorization across multiple levels of predispositions and responses of affective and behavioral reactions within the approach and avoidance system (Revelle, 1991; Zinbard & Revelle, 1989). Likewise, Rusting (1998) and Larsen and Augustine (2008) integrated personality, mood, and cognitive processing by incorporating the BAS, Positive Affectivity, and Extraversion into a construct related to approach motivation, and the BIS, Negative affectivity and Neuroticism into a construct related to avoidance motivation. Huebeck, Wilkinson, & Cologon (1998) proposed categorization through a set of confirmatory factor analyses revealing the two second-order factors as the best model, Positive Personality and Negative Personality. The Positive Personality factor included Extraversion, Positive affect, BAS Drive and BAS Fun Seeking subscales of the BIS/BAS (Carver & White, 1994). Three indicators defined the factor named Negative Personality: Neuroticism, BIS and Negative Affect. Including BAS Reward Responsiveness significantly worsened the model fit (Huebeck et al., 1998; p.795) and thus, this scale was subsequently dropped from the model for being an "ambiguous" scale.

Hofmann, Friese and Strack (2009; see also Hofmann, Friese & Wiers, 2009; Strack & Deutsch, 2004) introduced a dual-systems perspective to automatic and controlled processing, represented by two personality variables Impulse and Self-control. In this framework, Hofmann et al. proposed that WMC is a moderator such that, "Reflective precursors of behavior should predict behavior better for individuals high rather than low in working memory capacity. The opposite should hold for impulsive precursors" (Hofmann, Friese and Strack, 2009; p.170) as the impulsive mode does not require high cognitive capacity (Hofmann, Friese & Wiers, 2009) and allows for quick responses to the changing environment. Reflective precursors, on the other hand, fulfill self-regulatory goals and are associated with controlled processes, flexibility, and higher-order cognition. This framework seems to be similar to the concept of regression and progression proposed by Kuhl and Koole, 2008. An interesting feature of the model proposed by Hofmann and colleagues is the assumption that both systems are not exclusive. That is, both compete to become dominant, leading to a chosen overt behavior. Assuming that the reflective system requires cognitive capacity, one could hypothesize that persons low in WMC might adapt the impulsive mode as a dominant system.

Carver and colleagues proposed a similar approach adapting two modes of self-regulation named Action and Restraint (Carver et al., 2008; see also Carver, 2005; Carver & Miller, 2006) to contrast two modes of processing: reflexive (automatic) and effortful (reflective or deliberative) that might stem from either restraint or action, as Figure 7 shows. In their framework, Carver and colleagues proposed that the reflexive system is important for processes related to rewards, emotional salience and impulsive reactions, whereas the effortful control mode counterbalances the effects of inhibitory and impulsive reactive systems.

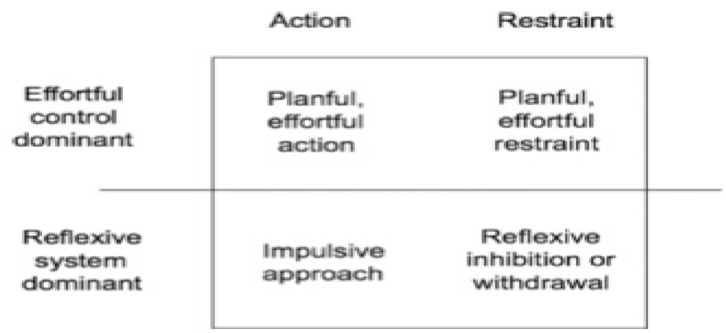

Figure 2. Either a dominant reflexive system or a dominant effortful control system can ultimately result in either restraint or action.

Figure 7. The relationship between modes of processing, effortful control and reflexive system (Carver et al., 2008).

An alternative approach considers categorization of personality dimensions into a structure comprising three higher-order factors. A number of studies suggest that a three-factor distinction might be plausible and worth investigating. For example, Carver and Miller (2006) proposed Approach, Avoidance, and Constraint factors build from multiple personality measures (NEO-PI, MPQ, ZKPQ, and the BIS/BAS). The authors defined Approach by positive affect, BAS-Drive and BAS-Reward Responsiveness (refer to Table 1) and characterized by its common feature – incentives. The second system, Avoidance, related to threat, included Neuroticism, negative affect, and the BIS scale. The third system, Constraint related to restraint of behavior, defined as either inhibition of an incentive (a threat response) or as ability to plan and exhibit better executive control, comprises impulsive sensation seeking, impulsiveness, and BASF (Carver & Miller, 2006, p.10).

Table 1. Illustration of personality categorization into three factors as described in Carver and Miller (2006; upper panel) and Zelenski and Larsen (1999; lower panel).

Carver & Miller (2006)	*Personality scales included in the respective factors*		
1. Approach	Extraversion	Positive Affect	BASD, BASR
2. Avoidance	Neuroticism	Negative Affect	BIS
3. Constraint	Sensation Seeking	Impulsivity	BASF

Zelenski & Larsen (1999)	*Personality scales included in the respective factors*			
1. Approach (Reward) Sensitivity	Reward Expectancy	Persistence	Extraversion	BASD BASR
2. Avoidance (Punishment) Sensitivity	Punishment Expectancy	Harm Avoidance	Neuroticism	BIS
3. Impulsivity	Impulsivity	Novelty Seeking	Psychoticism	BASF

Zelenski and Larsen (1999) proposed conceptually similar model to Carver and Miller (2006) with three higher-order personality factors formed from multiple personality measures (EPQ, TCI, GRAPES, I7, and BIS/BAS): Reward Sensitivity, Punishment Sensitivity, and Impulsivity (see also Larsen & Augustine, 2008, p.159; Dweck & Leggett, 1988, p.262; Elliot & Thrash, 2002) where the first factor, approach sensitivity, comprised Reward Expectancy, Extraversion, BAS-Drive, and BAS-Reward Responsiveness; the second factor, avoidance sensitivity, comprised Neuroticism, Harm Avoidance, and the BIS scale; the third factor was described by Impulsivity-related scales and Psychoticism. Table 1 compares the two personality structures proposed by Carver and Miller (2006) and Zelenski and Larsen (1999). As seen in the table, similar or even the same scales (e.g. BIS/BAS) define the constructs of Approach and Avoidance. The third factor consists of comparable scales although named differently across the two studies. Importantly, the two studies used different personality scales except the BIS/BAS, yet three comparable higher-order personality factors emerged.

Finally, three higher-order personality factors have been also suggested within the biological approach (Eysenck & Eysenck, 1975; Goldberg, 1990). An aspect of Cloninger's psychobiological model of temperament and character (TCI) ascribes specific personality traits to functioning of neurotransmitters. Cloninger argues that Novelty Seeking likely emerges from having a low baseline dopamine activity; Harm Avoidance emerges from low serotonin, and Reward-Dependence from low levels of norepinephrine (Cloninger et al, 1993; De Fruyt, De Wiele, & Van Heeringen, 2000; Hansenne, 1999; Kose, 2003; Paris, 2005; Suhara et al., 2001; Zuckerman & Cloninger, 1996).

It is important to acknowledge that McCrae and colleagues have argued that to achieve the most from different personality characteristics researchers should remain at the level of the primary traits, e.g. Extraversion (McCrae et al., 2008; see also Jang et al., 1998; Jang et al., 2006). Furthermore, according to McCrae and colleagues, higher-order factors, such as the Big Two (Digman, 1997) do not depict specific enough characteristics to model variations in personality (but see Jung et al., 2006).

The present study

The present study examined the relationship between a higher-order personality structure, WM and gF cognitive constructs at a latent level by sampling across multiple aspects of personality and cognitive tasks. In particular, the study investigates a higher-order personality structure across a broad sample of personality inventories to derive general personality aspects, of which the relationship to WM and gF was examined at a latent level. The main assumption for that is the existence of a common characteristic of particular personality dimensions that can be represented by higher-order factors. The main motivation for the study was that the literature lacks a comprehensive study that would include multiple measures of cognitive and personality constructs and examine them at a latent level, although new studies have began to emerge (Unsworth, Spillers, & Brewer, 2010; Read et al., 2010). Most available studies comprise singular tasks. Moreover, tasks vary across studies making it difficult to draw conclusions at a more general level.

The specific aim was, first, to examine whether defining latent WM constructs by two distinct set of tasks would differentiate the relationship of WM to gF and to personality constructs. Most of the research in the area of personality and WM has used variations of the n-back task as a measure of WMC. On the other hand, the controlled attention view of WM emphasizes different processes of the construct and uses mostly complex span tasks as a measure of WMC processing and storage components. The n-back and complex span tasks differ substantially in the task structure although both tasks putatively measure WMC (Kane et al., 2007). Thus, it was important to examine whether the relationship between cognition and personality depends on the kind of WM task used. The second specific aim was to investigate a higher-order personality structure derived from multiple personality measures. The third specific aim was to relate the higher-order personality structure to WM and gF via latent variable approach. The final question concerned the nature of the personality structure in individuals varying in their levels of ability.

The present study incorporated multiple measures of WM, gF and personality widely used in the cognitive, social, and neuroscience literature. As individual dispositions might be viewed from different perspectives and scopes (Mischel & Shoda, 1998; Revelle, 1993; 1995; Funder, 2001; Ozer & Reise, 1994; see also Fleeson, 2001), the current study examined various aspects of personality. A broad scope of personality measures allowed for comprehensive sampling across different yet related measures representing a wide range of personality dimensions pertaining to motivation (prevention/promotion), affect sensitivity (avoidance/approach), goal intentions (state/action orientation), and a person's general behavior (the Big Five traits). It should be noted that even though all these measures represent a given aspect of personality, and most of them have been shown to form reliable latent factors, as reviewed in the previous section, not all of the traits might be similar enough to form a strong higher-order personality structure within the present setting. Furthermore, several of the personality dimensions included in this project are sensitive to situational manipulations, such as induction of anxiety or threat. In turn, the sensitivity of a particular personality dimension influencing cognitive task performance might not be of the same magnitude as when such manipulation would have been included. However, the present study have focused on the stable, trait aspects of personality, not the state-like characteristics. As such, the present study does not include situational manipulations.

The majority of the analyses in this study are based on structural equation modeling technique. Structural equation modeling, or a latent variable approach, tests specific patterns of relationships among latent variables, examines how underlying factors influence each other and investigates their relative contributions in explaining variation in other factors. This approach allows testing for general latent constructs, unique contributions of their components and a measurement error (Hull, Lehn, & Tedlie, 1991). In the present context, a latent variable approach enabled us to evaluate the relationship between personality variables and assess the relative contribution of WM and personality in explaining variation in gF. In terms of assessing the strength and the nature of this relation, the proposed methodology in comparison to the studies currently available offers approach that is more comprehensive.

A latent variable approach has been successfully applied in the WM and personality literatures (Finch & West, 1997; Hoyle & Lennox, 1991; Mumford, Baughman, Uhlman, Costanza, & Threlfall, 1993; Ormel & Rijsdijk, 2000; Smit, Kelderman, & van der Flier, 2003). The WM construct has been examined in relation to gF, short-term memory, and processing speed (Conway, et al., 2002; Engle et al., 1999; Kane et al., 2004; Miyake et al., 2000; Oberauer et al., 2005), and as a joint investigation of WM and personality (DeYoung et al., 2005; Elliot & Thrash, 2002; Kaufman, et al., 2010; Salthouse et al., 2004; Unsworth et al., 2010; Zweig & Webster, 2004). Unsworth and colleagues (2010) incorporated this technique to explore the relationship between executive functions represented by four latent variables: WM, Fluency, Response Inhibition, Vigilance, along with gF, personality measured by the NEO-PI-R and BIS/BAS, and personality disorders. The authors performed confirmatory factor analyses for each personality measure, and then investigated separately the relationship among executive functions and personality traits. Relevant to the present study, gF correlated negatively with Neuroticism (r=-.22) and BIS (r=-.24), whereas WM represented by the OSPAN task related negatively to Extraversion (r=-.19) and Agreeableness (r=-.18). Interestingly, the BAS and Conscientiousness, contrary to previous studies (Gray & Braver, 2002; D.M. Higgins et al., 2007) were not related to any of the executive function latent factors. In another study, Salthouse et al. (2004) reported the correlations between cognitive ability constructs and Openness (ranging from .19 to .31), lower correlations for Extraversion, Agreeableness, and Neuroticism (.15 to.18), and none for Conscientiousness.

The present study: Aspect 1 and Hypothesis

The first aspect examines the nature of the WM tasks by investigating the latent structure of two types of WM tasks – complex span and n-back – and their relationship to gF. Two sets of tasks, complex span and n-back (all 3-back), defined two latent WM factors. In the first set, three complex span tasks: the automated Operation span (OSPAN), Symmetry Span (SSPAN) and Reading Span (RSPAN) tasks (Conway et al., 2005; Engle & Kane, 2004; Turner & Engle, 1989) constituted a set of observed variables describing the WM complex span construct named WMcs. The three tasks measure active maintenance and updating of information, and temporary storage for ordered retrieval (Conway et al., 2005; Unsworth et al., 2009). The complex span tasks have a similar task structure, good validity and reliability (Conway et al., 2002; 2005; Engle et al., 1999). Performance on complex span tasks is a metric for categorizing participants into groups differing in the capacity of WM, usually into those having high or low WMC. In most situations and over multiple contexts and domains, individuals scoring high on WM tasks (high WMC individuals or high spans), outperform those scoring poorly (low spans) on a variety of other tasks employing cognitive control, and even simple attentional tasks, such as the Stoop or antisaccade. The common features of the cognitive control tasks include ability to restrain from automatic/habitual responding during critical trials and to resist distraction or interference.

In the second set, three 3-back tasks constituted a set of observed variables defining the WM n-back construct named WMnb. The n-back task (Jonides et al., 1997) is frequently used to assess WM or construct of cognitive control. The structure of the n-back task differs from the structure of the complex span tasks. The n-back task is not a dual task and primarily measures the ability to update representations of consecutive items mentally within a block of trials. According to Jonides et al. (1997), the n-back incorporates seven processes: encoding, storage, rehearsal, inhibition, response execution, temporal ordering, and matching. Participants constantly compare an item presented on the screen with the item n-items back, where n=0,1,2, or 3. The participant's task is to indicate whether the items on screen and n-items back are the same or different. Table 32 (Appendix A) lists different n-back tasks used in most of the direct studies examining the relationship between WM or cognitive control and personality. As seen from the table, multiple versions of the n-back task were used, from the easiest 0-back to more difficult 3-back. Individual differences related to WM performance become apparent in the more difficult 2- and 3-back versions, which tap heavily on the executive processes. Item presentation is fast (usually 1.5-2.5 sec) so that a minimal amount of time is devoted to make decisions and responding. In the 3-back task, the participant sees a stimulus, compares it to the one three stimuli back and indicates whether they are the same or different. Figure 26 (Appendix A) illustrates the 3-back procedure used in the present study, where participants completed three n-back tasks: 3-back verbal, 3-back spatial, and 3-back numerical. The three types of stimuli in the three tasks were developed to match the types of stimuli from the three complex span tasks.

Even though the complex span and the n-back tasks both measure WM, some authors speculate that the two types of WM tasks might not represent identical constructs (Jaeggi, Buschkuehl, Perrig, & Meier, 2010; Kane et al., 2007; see also Owen, McMillan, Laird, & Bullmore, 2005). Moreover, as the n-back has a different structure than the complex span, one may assume that the relationship of two different WM latent variables with personality might differ, since the two sets of measures at least partially tap different sets of processes related to attention control. For example, the n-back is a single task focusing on the continuous updating of a stream of items, whereas the complex span task is a dual task, where the to-be-recalled items are at the end of the set. Incorporating both tasks into the present study allows for a direct comparison between the two types of tasks in their degree of similarity and assessment of how the two sets of tasks relate to personality and gF at a latent level. Moreover, using two types of WM tasks enables a more direct comparison with the existing studies examining the relationship between personality and WM.

Additional analyses evaluated the relationship between personality and n-back trial types (Gray et al., 2005) by correlating personality and three trial types: targets, nontargets and lures, to examine whether the three trial types show differential correlation patterns with specific aspects of personality. The three trial types convey contrasting information about performance on a trial-by-trial basis. Targets are trials with the response “yes”, nontargets are those with the response “no”. Lures are of a special importance since they represent a matching item, but in the incorrect slot for comparison, for example 2-items back instead of 3-items back; thus, the trial requires a “no” response as opposed to more automatic or familiarity-based incorrect response “yes” (Barch et al., 2009; Kane et al., 2007; Öztekin & McElree, 2010).

Hypothesis 1. *I expect the two WM latent variables to be highly correlated but best described by two latent constructs. If the complex span tasks and n-back tasks capture different aspects of the WM construct (e.g. Kane et al., 2007), the two WM latent variables should differ with respect to the relationship to the remaining latent variables. If, on the other hand, as might be suggested by high correlations between the n-back and complex span tasks, the two tasks represent the same construct, then the relationships within the models should not differ.*

The present study: Aspect 2 and Hypothesis

The second aspect examines a higher-order structure of personality by testing various personality variables at a latent level. The resulting cognitive and personality models constituted a basis to examine the joint relationship between higher-order personality structure, WM, and gF. The aim of the second aspect was to integrate personality measures into a higher-order structure and examine the relationship between the resulted structure and WM and gF to determine what is the relationship between cognitive and non-cognitive variables. First, fourteen personality traits from four questionnaires have been subjected to confirmatory factor analyses to examine the patterns proposed and inferred from empirical and theoretical studies and determine the best structure, assuming that personality dimensions possess a common characteristic described by higher-order factors. Two-factor model assumed Action and Restraint to express the duality of the human nature. An alternative account assumed three-factor model defined by Action, Restraint, and Constraint. The Constraint factor emerged primarily from dividing the Restraint factor from the two-factor model into two related yet distinct factors with a premise that this structure might better define the differential characteristics within the Restraint factor related to the avoidance concept, assuming that a behavior resulting from any of the two factors leads to a similar outcome. For example, not making a response might be a result of either blocking or suppressing the response. Furthermore, this additional division might capture potential differences in cognitive mechanisms operating within the Restraint and Constraint factors, such as focus, narrow down and suppress for Constraint and block or stop for the Restraint factor. Furthermore, two mechanisms leading to a similar outcome, such as non-action, might derive from two different lines of thinking or reasoning patterns resulting from a specific combination of personality traits. Specifically, one pattern might relate to a blocking mechanism and another pattern might relate to a suppressing mechanism. Consider the example that the same behavioral outcome might be to omit a response or deliberately not responding, yet the reasons a person chooses to implement particular behavior or action might differ. Finally, Constraint and Restraint might differentially relate to WM and gF. Table 2 lists the characteristic features of the two factors[4]. Table 3 lists the characteristic features of the three higher-order factors, where:

Constraint (restriction, limitation; focus, narrow down, from the environment; suppression)
Restraint (self-control, discipline; stop; from yourself; blocking or stopping)

Hypothesis 2. *Personality dimensions will form two higher-order factor structure. Alternatively, personality dimensions will form three higher-order factor structure. I expect that the two models will fit the data based on a confirmatory factor analysis.*

[4] Table 31 in Appendix A presents an integrated framework across personality dimensions and biological factors supporting dual-approach.

Table 2. Characteristic features of the higher-order personality factors Act and Restraint.

ACTION	RESTRAINT
Anticipation of pleasure Reward approach Approach motivation Active goal pursuit strategies / action Preference for novel information / creativity / divergent thinking / intellectual curiosity Flexibility / plasticity / preference for change Openness to change / promotion of change Impulsivity Updating Decisiveness Dynamics High self-regulatory resources High performance under high demands Positive emotionality Dopamine (limbic and motor system, ACC, PFC)	Anticipation of pain Punishment approach Avoidance motivation Passive / safety-related goal pursuit strategies Avoidant / reserved / prefers stability Stagnation / hesitation for action or change / Constraint Stability / high control of impulses Perseverance and rigidity but also persistence Neatness, determined, reliable Maintenance Indecisiveness Inhibition Anxiety / depression / helplessness / poor self-regulation Poor coping with stress Negative emotionality Serotonin (limbic system, basal ganglia)

I expect that the two factors named Action and Restraint would bear characteristics similar to approach and avoidance systems, respectively, as described in Table 2. The promotion focus, AOP, AOD, AOF (from the ACS-90), BAS Fun Seeking, BAS Reward Responsiveness, BAS Drive, Extraversion, and Openness would define the Action construct. The BIS scale, prevention focus, Agreeableness, Conscientiousness, and Neuroticism would form the Restraint construct. The left panel in Figure 8 illustrates the hypothesized two higher-order personality model with indicator variables defining the two latent constructs, Action and Restraint.

In addition, I expect that the three factors named Action, Restraint and Constraint would bear characteristics similar to approach, avoidance and constraint/impulsivity systems (Carver & Miller, 2006; Zelenski & Larsen, 1999; see also Table 3). I predict that the BAS Drive, BAS Fun Seeking, promotion focus, AOF, AOD, Extraversion, and Openness would load into the Action construct. The prevention focus, BAS Reward

Responsiveness, and Conscientiousness would load into the Restraint construct. Finally, Neuroticism, Agreeableness, and the BIS scale would load into the Constraint construct. The right panel in Figure 8 illustrates the hypothesized model with three higher-order factors and the indicator variables defining the three latent constructs, Action, Restraint and Constraint. The models will be compared by the $\chi^2_{\text{difference}}$ test and the Akaike Information Criterion (AIC) fit statistic.

Table 3. Characteristic features of the higher-order factors Act, Constraint, and Restraint.

ACTION	CONSTRAINT	RESTRAINT
Active goal pursuit Flexibility Openness Preference for change Impulsivity, Dynamics e.g. Openness, Extraversion	Restriction Limitation Suppress, focus, narrow down From the environment (external) e.g. Agreeableness	Self-control Discipline Block, stop From yourself (internal) e.g. Conscientiousness

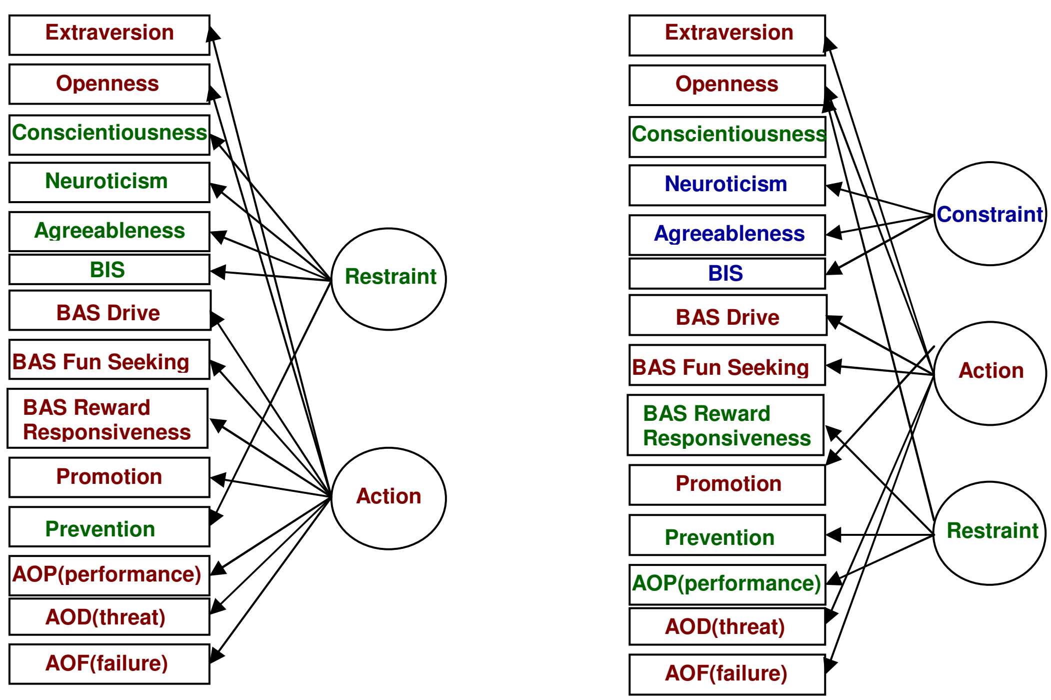

Figure 8. Hypothesized two- and three-factor CFA models of personality dimensions. The circles define latent constructs, whereas the rectangles represent indicator variables.

The motivation for an alternative model is that although strong evidence exists for the dual approach, one might argue that the two higher-order personality factors (especially the Restraint factor) are not sufficient to categorize personality dimensions into underlying characteristics (McCrae et al., 2008; see also Jang et al., 1998; 2006). In addition, ample literature supports both two- and three higher-order personality factors. Thus, it is of importance to account for and compare both possibilities within one study.

The present study: Aspect 3 and Hypothesis

The third aspect examines the resulting structure to test whether the relationship between personality, WM, and gF differs with ability at a latent level defined by scores on complex span tasks. This aspect examines also variability-stability of individual dispositions to investigate whether people high and low in WMC differ in their personality structure. The variability/invariance phenomenon across and within personality has been addressed in multiple studies (Costa & McCrae, 1986; Liberman et al., 1999; Szymura et al., 2007; McCrae, 1993; Szymura & Wodniecka, 2003; Terracciano, Costa, & McCrae, 2006). For example, Bonaccio and Reeve (2006) applied an analysis of equivalence/invariance and a latent variable approach to examine the influence of levels of Neuroticism on cognitive abilities (verbal, numerical, spatial, symbolic reasoning and speed). They hypothesized that factor scores assessing cognitive performance of those scoring high on Neuroticism would differ from those scoring low. The authors implied that “neuroticism interferes with performance on cognitive ability tests (p.405).” Contrary to Austin et al. (2002), Bonaccio and Reeve did not find differential relationship between levels of Neuroticism and cognitive abilities, described below.

Although this study assumes the existence of a certain personality structure, the individual scales also represent their unique characteristics related to prospective, past experience, typical, and motivational aspects. If we assume that a person possesses stable personality traits, motivational and behavioral predispositions to act and react to changes in the environment including problem solving and cognitive task performance, then some individuals might be more consistent in their behaviors than others might be across aspects of personality captured by measures related to motivation, planning and execution of behaviors. Thus, the personality measures used in this study could potentially inform about the stability of prospective, retrospective, motivational, typical, and affective personality traits.

If personality influences cognitive functioning, personality should make a difference in how a person actively processes incoming information in WM and how the person prepares to respond. The present study hypothesizes that different relations in terms of variability/stability might exist in individuals differing in their WMC. In other words, if low WMC spans are more variable than high WMC spans, then disparate patterns across personality dispositions might be expected for two groups. This implies that the high and low spans may hold differential relationship for personality and higher-order cognition[5]. Austin et al. (2002) is an example of a study examining differential relationship between personality (primarily Neuroticism and Openness) across the levels of ability. Austin and colleagues found that whereas correlations between Extraversion and Conscientiousness remained unchanged, correlations between Neuroticism and

[5] The following citation would argue in favor of such prediction, "Ability effects on the correlation between Extraversion and Conscientiousness have been the focus of particular interest, with the suggestion that the less able might perceive a combined E+C dimension, whilst the more able would perceive E and C as distinct" (Austin et al., 2002, p. 1404).

Psychoticism differed across ability levels. Specifically, correlations between Neuroticism and Psychoticism weakened with greater ability, whereas the correlations between gC and gF were greater with higher levels of Neuroticism.

Invariance and variability accounts for behavior choices related to personality predispositions across situations and time. Assessment of variability/stability of person's typical behaviors and dispositions allows one to examine whether a consistent pattern of behaviors exist as a trait-like characteristic. According to the context appropriate balance of attention (CABA) model proposed by Newman and colleagues (MacCoon, Wallace, & Newman, 2004; Patterson & Newman, 1993), attention-balanced individuals might allocate their attentional resources equally to reward and punishment cues. In contrast, individuals that are imbalanced might selectively allocate attention facilitating one type over the other, facilitate response conflict, or prefer the prepotent response. The CABA focuses on the role of a limited capacity of selective attention and the interplay between choosing a dominant or non-dominant response in pursuing the goal state. Thus, the CABA reflects choosing the response suited for the requirements of a task, solving response conflict, and the ability to adapt to changing situations. The categorization into dominant and non-dominant responding is akin to automatic or prepotent and controlled processing, automatic being similar to dominant responses, whereas controlled being similar to processes leading to the choice of non-dominant responses when desired.

In sum, the notion of individual's stability across aspects of personality and situations touches on a widely discussed debate concerning stability and variability of a person's behaviors across situations and dispositions (Mischel, 2004; Mischel & Shoda, 1998; 1999). Suhara et al. (2001; p.891) calls attention to the stability aspect of an individual, ”although personality can be influenced by environmental and occupational settings, the basic pattern would be one of stability over time”. Alternatively, individuals can be motivated differently and change their approach to the goal. For example, they may behave inconsistently at various points in time on task, for example, before the task (prospective aspect or motivation), during the task (while dealing with a trial-by-trial changes and consequences of choosing a particular response), or while assessing past performance for the future reference.

Hypothesis 3. *Low WMC individuals differ more across different aspects of personality than high WMC individuals.*

This hypothesis relates to the studies by Austin et al. (2002) and Bonnacio & Reeve (2006) and to the Newman’s balanced attention model (MacCoon et al., 2004; Patterson & Newman, 1993) since attention control contributes to WM (Engle, 2002). As an analogy to Newman and colleagues, low WMC individuals are considered imbalanced since they use the prepotent responding as a default strategy while performing a highly demanding task. In contrast, high WMC individuals are considered balanced individuals that are able to allocate flexibly their attentional resources accordingly to the task or situation requirements.

CHAPTER 2

METHOD

Participants

Three hundred and seventeen, 18-30 years old Native English speakers (144 females, 173 males; average age 21.48) were recruited from Georgia Tech student population (167; 52.7%) and community volunteers (150; 47.3%). Participants were recruited for two individual sessions lasting about 1.5 hours each and were compensated for each session with either 1.5 course credit or a $20-check. Working memory, gF tasks and personality measures were administered in the same order for all participants. WM and gF measures were computer-administered, whereas the personality questionnaires were paper-and-pencil. Participants were tested in groups of 1 to 5 per session. Prior to signing up, participants were examined for the following exclusion criteria: (1) currently suffering from any illness (2) taking medications that may affect attention or memory (3) being a non-English native speaker (4) poor visual acuity.

Working memory measures

Operation Span (OSPAN). This dual task measured storage and processing components of WMC. Each trial consisted of 3 to 7 equation-letter pairs that involved mentally solving math problems and remembering letters for a later recall (Turner & Engle, 1989; Unsworth, et al., 2005). Participants solved simple mathematical equations indicating each time whether the solution was True or False, and remembered letters presented for 800ms after each math equation for an ordered recall. At the end of each trial, participants were to select letters from 12 available letter-boxes, in a correct serial order. The task comprised 75 pairs with three trials of each list length. The dependent variable was the number of letters recalled in the order that they had been previously presented.

Symmetry Span (SSPAN). Structurally similar to the OSPAN, this task introduced vertical symmetry decision on an 8 x 8 figure of a black and white squares (processing component) and memory for location of squares on a 4 x 4 matrix (storage component). Participants decided whether a figure is symmetrical by clicking a button marked “Yes” or a button marked “No”, then for 650ms they saw matrix with a red square in one of 16 locations. Half of the time the pattern was symmetrical. Locations of each square had to be remembered in a serial order for recall at the end of each trial (Turner & Engle, 1989; Unsworth, et al., 2005). At the end of the trial, the participant was presented with a 4x4 grid of white squares, and chose the respective locations of the red squares in a correct serial order. The task comprised 42 total symmetry-matrix pairs and varied within a trial from 2 to 5. The dependent variable was the number of correct square locations recalled in a correct order.

Reading Span (RSPAN). Similar in structure to the OSPAN and SSPAN tasks, the RSPAN trial comprised a sentence followed by a letter (Daneman & Carpenter, 1980). The participant judged whether a sentence made sense and memorized a letter for a serial recall at the end of a trial. The task comprised 75 sentence-letter pairs in a series of 3 to 7 pairs. The dependent variable was the number of letters recalled in the correct order.

Verbal 3-back. Participants compared and responded to a letter appearing on the screen. They indicated whether the letter is the same or differs from the letter three screens back (Gevins & Cutillo, 1993; Jonides et al., 1997; Kane et al., 2007). Each trial required response. The task comprised 2 blocks of 48 trials per block. Participants performed half of the real trials (block 1), then, after a 15-second break, the second half of the real trials (block 2). The 96 trials comprised 16 targets, 66 non-targets, and 14 lures. Participants received feedback only for the 20 practice trials (10 non-targets, 5 targets, and 5 lures). In case of an incorrect response, the word "INCORRECT" written in a red ink appeared for a 250 ms. Each trial consisted of a fixation cross (500 ms) and a stimulus (2500 ms). Participants answered either "same" or "different" by pressing either "f" (labeled "s") or "j" (labeled "d") keys on a computer keyboard. A set of ten letters was chosen for the practice (C,D,J,L,N,P,S,V,Y,Z) and a different set of eight letters for the real trials (B,F,H,K,M,R,Q,X). The letters were phonologically distinct from each other. The dependent variable was the measure of sensitivity *d'*. The number of correct responses to targets, non-targets, and lures was also recorded. The three n-back tasks had the same procedure and timing of events. Each n-back task was constructed to match the stimulus kind with the respective complex span task with the premise to make the two types of WM tasks as comparable as possible.

Spatial 3-back. The structure and procedure was the same as the 3-back task with letters, with 20 practice trials and 2 blocks of real trials with 48 trials per block. Participants compared and responded to a position of the red square on a 4x4 matrix indicating whether the location of the square was the same or differed from the square three items back. Participants answered either "same" or "different". Eight locations were chosen for practice trials and another eight locations, distinct from the locations of the red square on the practice trials, were chosen for the real trials. After practice, participants performed half of the real trials (block 1), then, after a 15-second break, the second half of the trials (block 2). The dependent variable was the measure of sensitivity *d'*. The correct responses to targets, non-targets, and lures were also recorded.

Verbal 3-back. The structure and procedure was the same as the 3-back with letters and locations. The task comprised 20 practice trials and 2 blocks with 48 trials per block. Participants compared and responded to each number indicating whether the number was the same or differed from three numbers back. Participants answered either "same" or "different". The numbers chosen for practice (20,30,40,50,60,70,80,90) differed from the numbers chosen for real trials (1,2,3,4,5,6,7,8). After 20 practice trials, participants performed half of the real trials (Block 1), then, after a 15-second break, the second half (Block 2). The dependent variable was the measure of sensitivity *d'*. The correct responses to targets, non-targets, and lures were also recorded.

Ability measures

Raven's Advanced Progressive Matrices (Raven). Participants selected one of eight alternatives to complete a set of pictures organized in a 3x3 matrix of geometric patterns. Participant's task was to choose the picture that best completes the overall pattern (J.C. Raven, J.E. Raven & Court, 1998). The rules were becoming more complicated as the task progressed. The dependent variable was the number of correctly completed patterns out of 18 total within 10 minutes.

Number series. Participants completed series of number patterns, by discovering the underlying rule of the pattern and choosing one of five alternatives across 15 items. Dependent variable was the number of correct patterns completed within 4.5 minutes (Thurstone, 1938).

Letter sets. Participants determined which item from the series of five letters did not belong (Ekstrom, French, Harman & Dermen, 1976). The dependent variable was the number of correct series out of 20 total completed within 5 minutes.

Shipley's Institute of Living Scale (Shipley). Participants completed the Abstraction subtest measuring abstract reasoning. Twenty problems comprised series of letters, numbers, and words. The task was to type the answer to complete the series with an item that best follows the pattern (Shipley, 1940). The dependent variable was the number of correct series completed within 5 minutes.

Personality measures[6]

NEO-PI-R. The NEO-PI-R self-report measure comprises 240 questions answered on a 5-point scale (from *strongly agree* to *strongly disagree)*. The NEO-PI-R assesses a person's "emotional, interpersonal, experiential, attitudinal, and motivational styles" (Costa & McCrae, 1992; p. 14). The NEO-PI-R measures typical person behavior categorized into five broad domains: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness, each described by 6 facets scales (see Table 30, Appendix A; Costa & McCrae, 1992).

BIS/BAS. The Behavioral Inhibition/Activation scale (Carver & White, 1994) is a 24-item self-report questionnaire assessing behavioral inhibition (7 items) and activation systems (13 items). The BAS scale is further divided into three subscales: BAS-Drive (4 items), BAS-Fun Seeking (4 items), and BAS-Reward Responsiveness (5 items). Remaining 4 items are filers.

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[6] Refer to Table 31, Appendix A for description of personality measures used in the current study along with their theoretical bases.

Action and state orientation. The ACS-90 self-report questionnaire comprises 36 questions (Kuhl & Beckmann, 1994). Participants choose one of two alternatives as an answer to a question, framed to represent either action or state orientation. The ACS-90 scale consists of three 12-question subscales: decision-related (AOD), failure-related (AOF), and performance-related (AOP). The higher scores indicate greater action orientation.

Promotion and prevention focus. The 11-item self-report measure, the Regulatory Focus Questionnaire (RFQ, E.T. Higgins, 1997; 2001) asks how frequently an event occurs or has occurred in the past. Participants choose one of five alternatives on the scale from *never or seldom* to *very often*; *never true* to *very often true*; or *certainly false* to *certainly true*. Six items describe promotion and five items describe prevention focus. The scale yields two scores, one for promotion and the other for prevention focus.

Procedure

During the first session, participants read and signed a consent form, completed the demographics form and then the series of WM complex span tasks (the OSPAN, RSPAN, and SSPAN) and three gF tasks (the Ravens, number series, and letter sets). Participants came back for a second session that included 3-back tasks (the letter, number, and spatial), a gF task (Shipley), and the four paper-and-pencil personality questionnaires (the BIS/BAS, ACS-90, RFQ, and NEO-PI-R). The order of the tasks was the same across participants to prevent confounding of a task order (Salthouse & Babcock, 1991). Both sessions were group-administered, in groups of one to five persons per session in a room with separated spaces and computers for each participant. The experimenter was present at all times during each session. Upon completion, each participant received a short debriefing form, was compensated and thanked for participation in the study.

Data Analysis

The first steps in data analysis involved data screening, descriptive statistics and first-order correlations. Next, a series of confirmatory factor analyzes were constructed to verify the correctness of measurement models for the personality structure and separately for the cognitive constructs, followed by modifications to improve fit. Finally, a series of structural equation models were constructed to examine the relationship between the latent constructs. The fit of the models was established through several fit statistics including chi-square, normed fit index (NFI), non-normed fit index (NNFI), comparative fit index (CFI), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), root-mean-square error of approximation (RMSEA), and standardized root-mean-square residual (SRMR; Byrne, 2006; Finch & West, 1997; Hull et al., 1991; Jöreskog, 1993; Raykov, Tomer, & Nesselroade, 1991; Tabachnick & Fidell, 1996). The chi-square metric informs about the difference between the reproduced and observed covariance matrices, thus, non-significant statistics reflects a good fit, but a significant chi-square may also mean the sensitivity to sample size, such that a model may have a good fit despite the significant chi-square test in large samples (Hu & Bentler, 1995). A good fit reflects a value < 2 for the ratio of the chi-square to the number of degrees of freedom (df). The other fit statistics inform about the proportion of variance explained by the model (Jöreskog, 1993). Values grater than .90 indicate acceptable fit, and values greater than .95 indicate a close fit. The SRMR reflects the averaged squared difference between observed and reproduced variances. The values $< .05$ indicate acceptable fit and values <

.09 indicate a close fit. Finally, values of RMSEA less than .08 reflect acceptable fit, and values less than .05 indicate close fit (Hu & Bentler, 1995; Schumacker & Lomax, 1996; Loehlin, 2004). The fit across the models was compared using chi-square difference tests to yield the best fitting models. If not otherwise specified, the analyses were conducted using the LISREL software. EQS software calculated the Mardia's metric.

Design

To examine the first aspect of the study, series of confirmatory factor analyses were performed that investigated the nature of the WM tasks and their relation to gF. The first latent factor, WMcs, was defined by the three complex span tasks (SSPAN, RSPAN and OSPAN), whereas the second, WMnb, was defined by set of the 3-back tasks (number, letter, and spatial). Four tasks were the indicators of gF: the Raven, number series, letter sets, and Shipley. The CFA models examined whether a three-factor model with simple structure (each variable loading only on one factor) fits the data or whether a two-factor model with WM joint latent factor fits the data better. The best fitting models were retained for further analyses and model modifications.

The second aspect addressed the integration of personality traits into a higher-order structure to examine whether a two-factor CFA model with simple structure (each variable loading only on one factor) fits the data and compare to a three-factor model to assess which of the hypothesized structures fits the data better. In a baseline model with two latent factors, personality was represented by Action and Restraint. In a three latent factors model, personality was represented by three latent factors Action, Restraint, and Constraint. The best fitting model after modifications was retained for further analyses. The best resulting personality and cognitive CFA models were then subjected to CFA and

SEM analyses that tested the relationship between personality, WM, and gF constructs (see Jöreskog, 1993).

The third aspect addressed the notion of changes within the personality structure within the level of ability via the latent variable approach and cluster analysis. Finally, additional analyses were performed to obtain more detailed picture of the examined associations. The analyses investigated (1) relations between personality and the three n-back trial types (targets, nontargets and lures), (2) relations between cognitive variables and the three n-back trial types, and (3) correlations between the NEO-PI-R facets and cognitive variables.

CHAPTER 3

RESULTS

Participants

Eight of the total 317 participants were excluded from analyses. Two did not fill out responses to too many questions across the personality questionnaires, above the cutoff point of 5% of missing values within each questionnaire, and six participants yielded no recorded scores across all or most of the trials in at least one of the n-back tasks. That left the total sample of 309 participants (141 females and 168 males; average age 21.50), including Georgia Tech students (165) and community volunteers (144).

Missing data

The data were examined for accuracy of data entry, missing values, and outliers. Thirty-two of the 309 participants had missing data in one or more personality questionnaires. The majority of the participants with missing personality data did not answer only one or two questions in one of the four questionnaires. A mean replacement method was used in dealing with these missing data. The mean of each subscale with a missing score was treated as a replacement score for a missing value for each participant. All the participants with missing personality values were retained for analyses.

Three participants had missing scores in working memory complex span measures that resulted from a computer error. Two participants lacked the OSPAN scores and one participant lacked the SSPAN scores. Multiple imputation method in PRELIS with an Expectation Maximum algorithm for multiple imputation of missing values was used to insert missing data for the three participants, with the to-be-imputed values taking into account all other variables available from each participant (Schafer & Graham, 2002; Tabachnick & Fidel, 1996).

Data screening

Individual scores from any variable that were more than three standard deviations from the mean were defined as univariate outliers. Nine values out of all questions from the four personality questionnaires and eighteen values out of all cognitive tests were found to be univariate outliers according to this criterion, and were replaced with a value corresponding to 3 standard deviations from the appropriate mean (Kline, 1998; Tabachnick & Fidell, 1996). Next, the data were screened for univariate normality. Table 4 lists descriptive statistics. All variables had skewness less than 2 and kurtosis less than 4 suggesting normally distributed data (Kline, 1998; Finch & West, 1997).

Mardia's coefficient and normalized estimate (Byrne, 2006; Mardia 1970; 1974; Tabachnick & Fidel, 1996) was computed using EQS 6.1 for all the variables. Mardia's normalized estimate > 5 indicates non-normally distributed data (Byrne, 2006, p.131). The Mardia's normalized estimate for this sample did not exceed 5 and was equal to 4.57 for all variables suggesting that data are within the upper limits of multivariate normality. Cook's D statistic (Cook, 1977) was used to identify multivariate outliers. Cook's D is a measure of how a value for one variable influences the relations with other variables. Values > 1 indicate possibility of having multivariate outliers. None of the Cook's D values was higher than 0.06, suggesting no multivariate outliers in the data.

The variance of inflation (VIF) and the Tolerance metric were used to examine multicollinearity. The VIF > 10 and the Tolerance < .1 indicate multicollinearity (Cohen, et al., 2003). None of the values exceeded these thresholds. In addition, none of the variables had extremely high first-order correlations (>.80). The highest first-order correlations (.683) was between the OSPAN and RSPAN tasks, followed by the n-back tasks (ranging from .663 to .622), the number series and letter sets (.634), the Ravens and Number series (.628), then Neuroticism and BIS (.623). Overall, the ranges of zero-order correlations indicated a suitable fit to subject the data to structural equation modeling analysis. With the 309 participants retained for analyses, the ratio of participants to all observed variables exceeded 10:1.

To establish the final data set, a raw data set with missing values was compared to the set with applied missing data solutions. Negligible if any differences were observed between the models derived from the two data sets in terms of the loadings of observed variables to the latent variables and in the magnitude of the relations between latent variables; also apparent in identical values of fit indices. The models reported here used the data with imputed missing data for cognitive tasks and mean replaced data for personality questionnaires.

Table 4. Descriptive Statistics for Working Memory, Reasoning, and Personality Measures.

Variables	Mean	S.D.	Skewness	Kurtosis	Range	Min	Max	Possible range	Reliability
1. BIS	19.80	3.93	-.21	-.25	20	8	28	0 – 28	.770 [a]
2. BASD	11.36	2.46	-.13	-.18	12	4	16	0 – 16	.765 [a]
3. BASF	12.29	2.57	-.52	-.20	12	4	16	0 – 16	.759 [a]
4. BASR	17.61	2.02	-.56	-.55	8	12	20	0 – 20	.692 [a]
5. PRO	22.26	3.62	-.37	-.01	20	10	30	6 – 30	.609 [a]
6. PRE	16.75	4.22	-.28	-.29	20	5	25	5 – 25	.754 [a]
7. AOF	6.15	2.94	-.07	-.82	12	0	12	0 – 12	.731 [a]
8. AOD	6.74	3.15	-.07	-1.03	12	0	12	0 – 12	.785 [a]
9. AOP	8.92	2.21	-.66	-.03	10	2	12	0 – 12	.596
10. N	89.61	23.42	.28	.24	140	29	169	0 – 19	.831 [b]
11. E	119.29	20.66	-.25	.26	124	44	168	0 – 192	.784 [b]
12. O	121.24	20.07	.26	.10	121	52	173	0 – 192	.715 [b]
13. A	112.33	19.26	-.02	-.17	111	57	168	0 – 192	.733 [b]
14. C	117.03	22.43	-.23	.08	132	33	165	0 – 192	.846 [b]
15. Shipley	14.25	2.98	-1.04	1.50	17	2	19	0 – 20	.763 [c]
16. Ravens	9.70	3.96	-.40	-.58	17	0	17	0 – 18	.829 [c]
17. Lsets	10.52	3.37	-.05	-.48	18	0	18	0 – 20	.761 [c]
18. Nseries	9.14	3.19	-.27	-.44	14	1	15	0 – 15	.789 [c]
19. OSPAN	56.91	13.51	-1.14	1.26	68	7	75	0 – 75	.842 [d]
20. SSPAN	28.04	8.76	-.69	-.06	42	0	42	0 – 42	.841 [d]
21. RSPAN	52.80	14.80	-.95	.39	67	8	75	0 – 75	.888 [d]
22. Nlett (d’)	0.73	.95	-.74	2.01	6.48	-3	3.48	-4.65 – 4.65	.757 [e]
23. Nnumb (d’)	1.40	1.05	.05	1.08	6.95	-2.30	4.65	-4.65 – 4.65	.767 [e]
24. Nspat (d’)	1.50	1.19	.26	-.08	6.42	-1.77	4.65	-4.65 – 4.65	.815 [e]

[a] Reliability calculated for each subscale and computing Cronbach’s Alpha from each item within the subscale; [b] Reliability calculated for each trait based on the Cronbach’s Alpha across the six facet scores; [c] Reliability calculated for each item and computing Cronbach’s Alpha; [d] Reliability calculated by summing up the first, second, and third presentation of each list length and computing Cronbach’s Alpha across the three scores; [e] Reliability calculated for d’ obtained for each block (A and B) and computing Cronbach’s Alpha across the two scores; BIS = behavioral inhibition scale, BAS = behavioral activation scale, where BASD = Drive subscale, BASF = Fun Seeking, BASR = Reward Responsiveness; PRO = promotion focus; PRE = prevention focus; AO = action orientation, where AOF = failure related, AOD = decision, AOP = performance; N = Neuroticism, E = Extraversion, O = Openness; A = Agreeableness; C = Conscientiousness; Lsets = Letter sets; Nseries = Number series; OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; Nlett = 3-back letters; Nnumb = 3-back numbers; Nspat = 3-back spatial.

Correlations

As Table 5 shows, zero-order correlations were within the range acceptable for a latent variable analysis. As expected, WM measures were highly correlated, which is consistent with the literature (e.g. Kane et al., 2004). Zero-order correlations ranged from .447 to .683 implying a strong WM complex span latent construct. Similarly, correlations between the 3-back tasks ranged from .622 to .663, implying a strong WM n-back latent construct. Correlations between the complex span tasks and the 3-back tasks ranged from .279 to .488 suggesting that the complex span tasks and the n-back tasks measure likely similar constructs yet are distinct. The gF measures were highly correlated, implying a strong gF construct, with correlations ranging between .516 and .634. The correlations between gF tasks and the six WM tasks ranged from .308 to .545 implying strong associations between gF and WM as suggested in the literature.

In the personality domain, the three BAS scales correlated moderately with each other (.364 to .474) and the BASR scale correlated positively with the BIS subscale (.222), which is consistent with the literature (Carver & White, 1994; Smits & Boeck, 2006). Surprisingly, the two other BAS scales also correlated, though weakly, with the BIS scale (-.116, -.186, respectively). Promotion and Prevention were not significantly correlated (.089), implying that they are independent traits, which is consistent with the description of the Prevention and Promotion scales by E.T. Higgins (1997; see also Molden, Lee, & E.T. Higgins, 2008). The AOF (threat related) and AOD (demand related) scales from the Action Control Scale (ACS-90) correlated moderately (.369), and had a low correlation with the AOP scale (performance related; -.043 and .194, respectively). Most of the NEO-PI-R correlations were weak (-.210 to .086), with the exception of modest correlations between Extraversion and Openness (.307) and between Neuroticism and Conscientiousness (-.394). Note also a high correlation between the BIS and Neuroticism (.623). Overall, the magnitude and directions of correlation patterns were consistent with the literature (e.g. Carver & White, 1994; Smits & Boeck, 2006; DeYoung et al., 2005; Digman, 1997; De Fruyt et al., 2000; Revelle et al., 2010). The pattern of correlations also indicated a good convergent and discriminant validity, namely, that the measures used to form a construct have greater correlations than the measures intended to form separate constructs.

The correlations between personality and WM, and personality (especially BASD, BASR, AOD, AOP, and Conscientiousness) and gF tasks were consistently low to moderate and negative[7]. Importantly though, when examining the signs, the personality measures with the same direction of correlation would form the same respective hypothesized higher-order personality factors. One exception was Conscientiousness, which matched the predictions in terms of the classification but not the sign. Although the results of the direct studies described earlier (e.g. Gray & Braver, 2002 with the BIS/BAS) indicate that the sign of the correlation is expected to be positive, some researchers report weak but negative correlations between reasoning, WM, and selected personality scales (Austin et al., 2002; Unsworth et al., 2010). For example, weak negative correlations have been reported between gF and Neuroticism, gF and BIS, between WM and Extraversion, WM and Agreeableness (Unsworth et al., 2010), and between ability and Neuroticism (Austin et al., 2002). Especially puzzling in the present study is a negative correlation between the BAS scales, WM and gF, while other studies report otherwise (Gray & Braver, 2002).

[7] The two exceptions were Prevention focus and Agreeableness.

Table 5. Correlation Matrix for Personality, Fluid Intelligence, and Working Memory Measures.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. BIS	—															
2. BASD	-.186**	—														
3. BASF	-.116*	.474**	—													
4. BASR	.222**	.402**	.364**	—												
5. PRO	-.144*	.267**	.155**	.228**	—											
6. PRE	.063	-.310*	-.337**	-.041	.089	—										
7. AOF	-.540**	.094	.134*	-.132*	.186**	-.014	—									
8. AOD	-.281**	.281**	-.011	.083	.378**	.138*	.369**	—								
9. AOP	.099	.037	-.048	.170**	.282**	.114*	-.043	.194**	—							
10. N	.623**	-.115*	-.054	.051	-.354**	-.235**	-.511**	-.416**	-.080	—						
11. E	-.058	.370**	.464**	.399**	.394**	-.080	.078	.265**	.086	-.210**	—					
12. O	.033	.062	.354**	.152**	.179**	-.188**	.022	-.046	.077	.099	.307**	—				
13. A	.178**	-.313**	-.177**	.012	.087	.376**	.061	.106	.154**	-.148**	.123*	.086	—			
14. C	-.072	.131*	-.234**	.218**	.395**	.355**	.072	.590**	.264**	-.394**	.158**	-.205**	.186**	—		
15. Shipley	.192**	-.299**	-.077	-.069	.078	.243**	-.104	-.134*	.209**	.090	-.030	.105	.149*	-.084	—	
16. Ravens	.092	-.340**	-.173**	-.228**	.020	.221**	-.018	-.111	.131*	.047	-.069	.072	.109	-.134*	.606**	
17. Letter sets	.071	-.273**	-.122*	-.074	.084	.215**	-.080	-.092	.107	.068	-.028	.051	.084	-.062	.516**	
18. Number series	.101	-.226**	-.161**	-.149**	.032	.171**	-.129*	-.156**	.144*	.121*	-.087	-.024	.036	-.124*	.564**	
19. Oper	.030	-.122*	-.023	-.097	.066	.072	-.036	-.130*	.032	.039	-.011	.051	.075	-.139*	.356**	
20. Symm	-.055	-.211**	-.096	-.158**	.029	.034	-.022	-.075	.117*	-.034	-.032	.049	.009	-.133*	.372**	
21. Read	-.012	-.163**	-.006	-.138*	.134*	.097	-.007	-.117*	.109	-.008	-.008	.101	.067	-.119*	.475**	
22. Nlett	.093	-.235**	-.085	-.089	.071	.123*	-.018	-.085	.062	.039	.052	.104	.125*	-.133*	.434**	
23. Nnumb	.044	-.183**	-.033	-.095	.068	.139*	.072	-.067	.074	-.017	-.021	.109	.122*	-.123*	.400**	
24. Nspat	.073	-.311**	-.151**	-.188**	.084	.180**	-.051	-.102	.115*	.019	-.069	.106	.116*	-.115*	.464**	

Variable	16	17	18	19	20	21	22	23	24
16. Ravens	—								
17. Letter sets	.554**	—							
18. Number series	.628**	.634**	—						
19. Oper	.425**	.308**	.412**	—					
20. Symm	.543**	.441**	.475**	.447**	—				
21. Read	.490**	.439**	.431**	.683**	.548**	—			
22. Nlett	.438**	.482**	.433**	.279**	.353**	.366**	—		
23. Nnumb	.367**	.392**	.396**	.362**	.347**	.389**	.626**	—	
24. Nspat	.492**	.453**	.545**	.376**	.488**	.479**	.622**	.663**	—

BIS = behavioral inhibition scale, BAS = behavioral activation scale, where BASD = Drive subscale, BASF = Fun Seeking, BASR = Reward Responsiveness; PRO = promotion focus; PRE = prevention focus; AO = action orientation, where AOF = failure related, AOD = decision, AOP = performance; N = Neuroticism, E = Extraversion, O = Openness; A = Agreeableness; C = Conscientiousness; Oper = Operation span; Symm = Symmetry span; Read = Reading span; Nlett = 3-back letters; Nnumb = 3-back numbers; Nspat = 3-back spatial. Significant correlations are marked * ($p < .05$) and ** ($p < .01$).

Models

The analyses involved the CFA and SEM models comprising (1) only the cognitive measures, (2) only personality measures to establish the best measurement model that fits the data, (3) both cognitive and personality measures. Modifications of the models aimed at improving fit were performed with the premise to remain both parsimonious and in agreement with the theoretical and empirical accounts. LISREL 8.80 package with the maximum likelihood (ML) estimation method was used to estimate all models.

Cognition only models

Confirmatory Factor Analysis of Working Memory Latent Factors

The first set of confirmatory factor models (CFA) examined the relationship between two WM latent factors. The following pattern of results was observed in a series of CFA analyses described throughout this section in more detail. The two WM latent factors were highly correlated, yet distinct, suggesting that indeed they represent similar properties of the WM construct, but are best described as two separate entities. This conclusion was supported by a series of confirmatory factor analyses contrasting one- and two-factor models. Table 6 lists fit statistics for the first set of the CFA models with two WM latent factors; Figure 9 displays four measurements models (CFA1 to 3a).

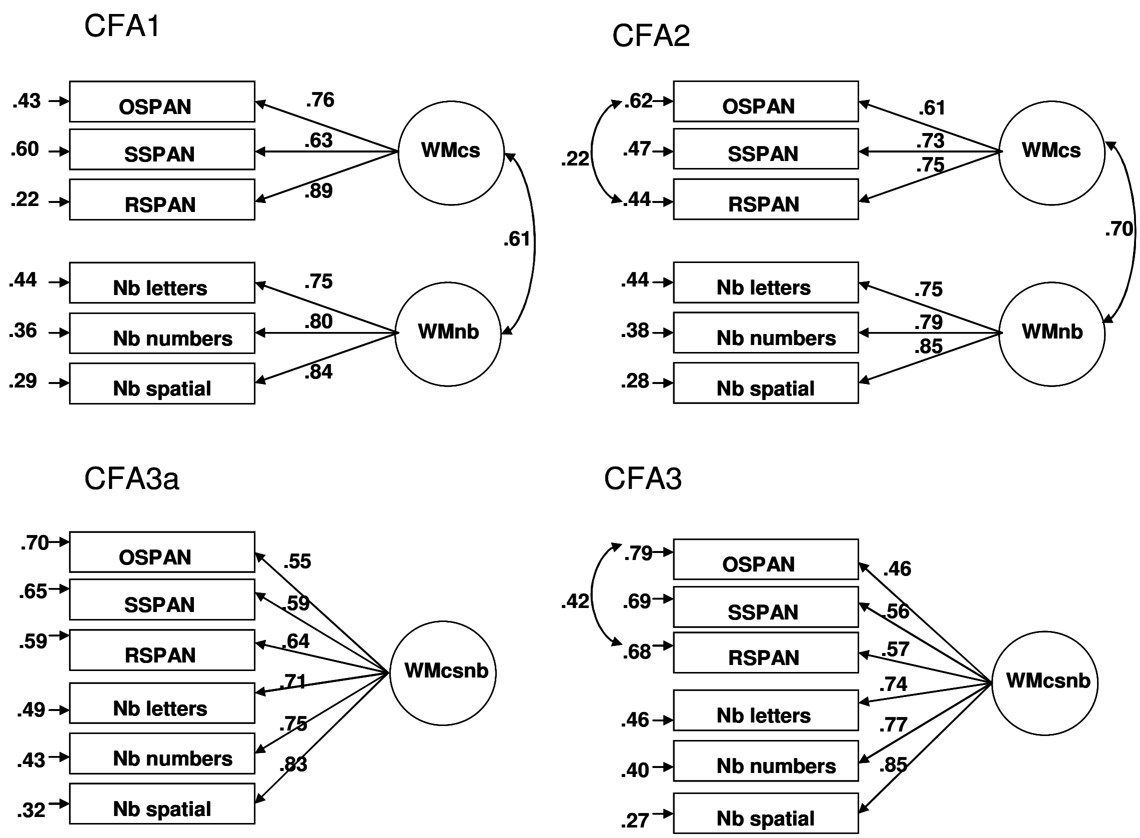

Figure 9. Confirmatory Factor Models for Working Memory Variables (N=309). Panel A and B contrasts two WM factors with and without a correlated error between the OSPAN and RSPAN complex span tasks. Panel C and D contrasts a single WM factor with and without one correlated error. OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; Nb = n-back; WMnb = working memory n-back latent variable; WMcs = working memory complex span latent variable; WMcsnb = joint working memory latent variable comprising n-back and complex span tasks.

The first measurement model (CFA1) included three complex span tasks that loaded into the WM complex span latent factor (WMcs). In this model (and all the following models), circles reflect the latent variables, whereas rectangles reflect the indicator variables that define latent constructs. The three n-back tasks loaded into the WM n-back latent factor (WMnb). The two factors were allowed to correlate and no residual correlations were allowed. The task loadings to their respective latent factors were very high, ranging from .63 to .88. The fit of the CFA1 was very good, despite the significant χ^2 test (p<.01), with χ^2 (8) = 27.94, NFI = .97, CFI = .98, RMSEA = .09, and AIC = 53.94. The second model, CFA2, was identical to the CFA1 with one modification allowing the errors between the OSPAN and RSPAN tasks to correlate.

Table 6. Confirmatory Factor Models Involving Working Memory Latent Factors (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A*. Two WM, no correlated errors											
CFA1	**8**	**27.94**	**3.49**	**.97**	**.96**	**.98**	**.97**	**.92**	**.090**	**.046**	**53.94**
B. Two WM, one correlated error											
CFA2	**7**	**16.24**	**2.32**	**.99**	**.98**	**.99**	**.98**	**.95**	**.065**	**.025**	**44.24**
C. One WM, one correlated error											
CFA3	8	62.61	7.82	.94	.91	.95	.94	.83	.149	.073	88.61
D. One WM, no correlated errors											
CFA3a	9	193.54	21.50	.84	.74	.85	.83	.60	.258	.10	217.54
One gF factor											
CFA6	2	8.03	4.01	.99	.97	.99	.99	.94	.099	.021	24.03

* Models in bold were retained for further analyses.

The correlated errors (or correlated residuals) indicate variance shared specifically between the two tasks. This modification was justified by the similarity in a method variance, identical part involving letter recall in both tasks and the presence of the correlated error in previous studies (e.g. Kane et al., 2004). This modification improved model fit significantly, which was visible by a smaller AIC value, non-significant χ^2 test, and overall better values of fit indices, χ^2 (7) = 16.24, NFI = .99, CFI = .99, RMSEA = .065, and AIC = 44.24.[8]

[8] When comparing models, smaller AIC values indicate better fit and a more parsimonious model.

Since the two sets of WM tasks represent related WM constructs, the next two models (CFA3 and CFA3a) examined whether one WM factor comprising the three complex span tasks and the three n-back tasks would fit better than the two-factor model. The CFAs with a unitary WM factor were compared to the CFAs with two WM latent factors. Both one-factor models had significantly worse fit in comparison to two-factor models, as seen in Table 10. The difference test for the two models without the correlated error, the CFA1 and CFA 3a, was $\chi^2_{difference}(1, N=309) = 165.6, p<.0001$, and for the two models with correlated error $\chi^2_{difference}(1, N=309) = 46.37, p<.0001$[9]. The CFA1 and CFA1a were concluded as the best models and retained for further analyses. Based on the

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[9] Modification indices in LISREL suggested that by allowing more errors to correlate, the model fit would improve even more. The correlated errors might arise from different reasons, for example, from task or procedure similarity, stimulus similarity, and content or domain similarity. Any error correlations taken into account were justified by either similarity of the procedure (e.g. OSPAN and RSPAN) or stimuli (e.g. SSPAN and n-back spatial). Two correlated errors were added in another model, the n-back spatial with SSPAN that reflected the stimulus similarity, and an error correlation between the n-back letter and n-back number task. The fit was excellent, $\chi^2(5) = 5.01$, NFI = 1.00, CFI = 1.00, RMSEA = .002, and AIC = 37.01. Even though the model fit improved ($\chi^2_{difference}$ between this model and CFA2 $(2, N=309) = 11.23, p=.0036$), a potential problem arises when interpreting what the correlated errors mean. Overall, the same applies to the models examined later. Correlated errors, in addition to making model interpretation more difficult, may potentially adjust the relationship with other factors already in the model as well as those added later in the analysis. In addition, a better fit might stem from having a smaller number of degrees of freedom per se. This might cause model to fit better but the model may suffer in parsimony and/or clarity of interpretation. Another point that would suggest leaving out the modification indices that propose correlated errors for the present data is that, in the current models, the values of correlations between the errors were mostly small in magnitude. Only some error correlations were significant as indicated by t-test, and even that was changing with the number of correlated errors applied to the model, e.g. between the SSPAN and n-back spatial, letter and number, or OSPAN and RSPAN. Thus, initially and then throughout the reminder of the analyses, only structures of the CFA1 and CFA2 models with none or one error correlation were retained and compared to examine whether the residual correlation between the OSPAN and RSPAN changes any relationship between the variables and latent factors.

two sets of CFAs with one and two WM latent factors, a better fit of the two-factor model suggests that two separate WM factors with two different types of WM tasks represent the WM construct better than a unitary WM latent factor, with these particular tasks and the present sample. This result also suggests that the complex span tasks and n-back tasks are related but distinct and better described separately than together.

Confirmatory Factor Analyses of Working Memory and Fluid Intelligence

After establishing the model with two WM latent factors, the next step examined their relation to gF. The following pattern of results was observed in a series of CFA and SEM analyses comprising the three cognitive latent factors, gF, WMcs, and WMnb, described throughout this section in more detail. Both WMcs and WMnb appeared to have a strong relationship with gF, yet the magnitude of the relationship differed slightly between the WMcs and WMnb factors. These differences became more pronounced when a correlated error was added between the OSPAN and RSPAN. Furthermore, despite the fact that all cognitive tasks had strong representations within verbal, spatial, and numerical domains, the domain CFA model did not fit the data well, suggesting that the construct division better describes the relationships within the cognitive tasks than the domain-specific model. It also means that even though (a) the n-back tasks were created to be identical to the complex span tasks in the stimulus type, (b) the indicator tasks for the gF construct had a strong representation of the three different domains, having separate WM and gF constructs still better describes the data.

A gF latent factor (CFA6; see Table 6) composed of four gF tasks (Ravens, Shipley, letter sets, and number series) was added to the models CFA1 and CFA1a to examine whether the two WM latent factors have different relationship with gF. All latent factors were allowed to correlate freely. Table 7 shows the complete fit statistics for this set of CFA models. The first model in this series, CFA7c, comprised two WM latent variables with one correlated error between the OSPAN and RSPAN tasks, and a gF latent factor (refer to Figure 10). The loadings of the tasks to their respective latent factors were high, and ranged from .61 to .86 (CFA7c). The fit of this model was very good, χ^2 (31) = 71.51, NFI = .98, CFI = .99, RMSEA = .065, and AIC = 119.51. The second model, CFA7ca, was the same as CFA7c with an exception of leaving out a correlated error between the OSPAN and RSPAN tasks. The fit of the CFA7ca model with no correlated errors was very good but slightly worse than the fit of the CFA7c model, χ^2 (32) = 95.96, NFI = .97, CFI = .98, RMSEA = .081, and AIC = 141.96, $\chi^2_{difference}$ (1, N=309) = 24.45, p<.0001. Both models were retained for further analyses.

Table 7. Confirmatory Factor Models with Working Memory (WM) and Fluid Intelligence (gF) Factors (N=309). Models in bold were retained for further analyses.

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A. Two WM, one gF, one correlated error											
CFA7c	**31**	**71.51**	**2.30**	**.98**	**.98**	**.99**	**.96**	**.92**	**.065**	**.032**	**119.51**
B. Two WM, one gF, no correlated errors											
CFA7a	**32**	**95.96**	**2.99**	**.97**	**.97**	**.98**	**.94**	**.90**	**.081**	**.047**	**141.96**
C. Three content domain, one correlated error											
CFA9	31	245.31	7.91	.93	.91	.94	.86	.76	.150	.065	293.71
D. Three content domain, no correlated errors											
CFA9a	32	313.19	9.78	.90	.87	.91	.83	.71	.169	.076	359.19
One WM, one gF, one correlated error											
CFA8	33	161.42	4.89	.95	.95	.96	.91	.84	.112	.064	205.42
One WM, one gF, no correlated errors											
CFA8a	34	271.50	7.98	.92	.91	.93	.85	.76	.151	.069	313.50

Since a predominant content domain distinctly characterized all ten cognitive tasks, three latent factors: Spatial, Numerical, and Verbal, were formed based on the content domains of the six WM and four gF tasks[10],[11]. Two alternative content domain measurement models CFA9 with one correlated error and CFA9a with no correlated errors (refer to Figure 11 and Table 7 for the fit statistics) were fitted to examine whether the content domain model provides a better fit than the measurement models based on task-related specific constructs. The fit of both models was acceptable, CFA9 χ^2 (31) = 245.31, NFI = .93, CFI = .94, RMSEA = .150, and AIC = 293.71, and CFA9a χ^2 (32) = 313.19, NFI = .90, CFI = .91, RMSEA = .169, and AIC = 359.19. The two content domain models had worse fit than the earlier models with task-related specific constructs. Thus, even though the tasks clearly differed with respect to the content domains, content domain was not the best way to represent the data. The task-specific constructs better explained the pattern of data.

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[10] Additional models were fitted. A model with four correlated errors was dropped because of the difficulty in interpretation of the error correlations. The fit of another model with WMcsnb and one gF factor was worse when comparing with earlier models.
[11] The three n-back tasks were explicitly developed to have similar content to the three complex span tasks. In addition, the three gF tasks (number series, letter sets, and Ravens) were chosen to represent variety of content domains, and the Shipley was chosen to represent the mixture of content domains.

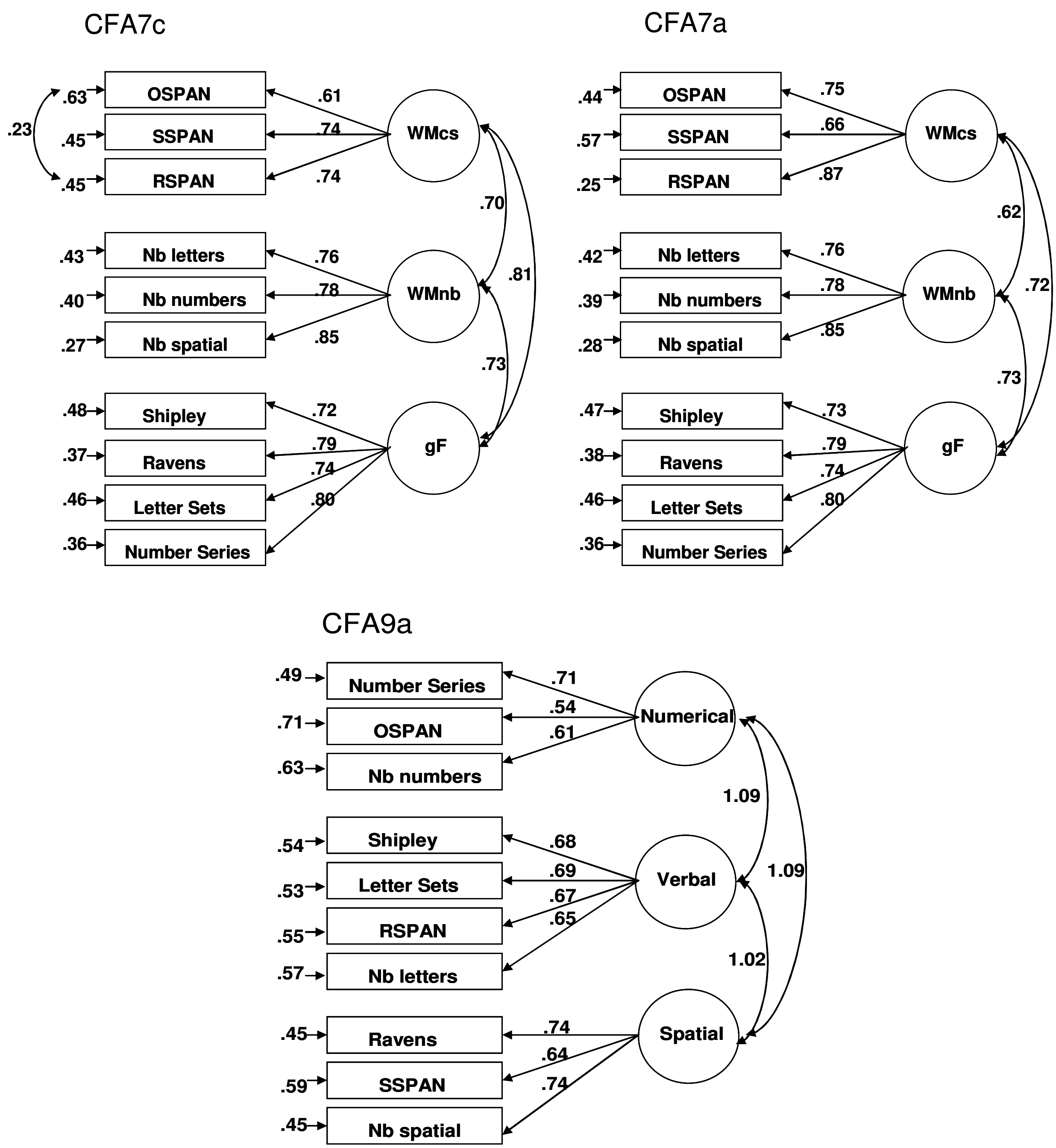


Figure 10. Models for Working Memory and Fluid Intelligence Variables (N=309). Panel A and B contrasts two three-factor CFAs with and without correlated error between the OSPAN and RSPAN tasks. Lower panel: three-factor domain CFA model with Numerical, Verbal and Spatial latent factors, with and without a correlated error. OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; Nb – n-back; WMnb = working memory n-back; WMcs = working memory complex span; gF = fluid intelligence.

As suggested by previous studies (e.g. Jaeggi et al., 2010a,b; Kane et al., 2004; 2007), the complex span tasks as well as the n-back tasks aim at tapping processes related to cognitive control. If that is the case, then a common construct created from the six WM tasks should reflect the amount of variance shared between the two constructs that might possibly represent cognitive control or executive attention. Thus, the question examined next concerned the contribution of a WM Common factor to the relationship between WM and gF. In addition to the model comprising two WM (no correlated errors) and one gF latent factor investigated earlier, a Common latent factor (WMcsnb) was formed from the six WM tasks (see also Kane et al., 2004). Again, WMcs and WMnb could freely covary as previously, but the paths between the Common factor and the two WM latent factors were fixed (CFA10). The fit of the CFA10 measurement model was very good, χ^2 (25) = 54.70, NFI = .98, CFI = .99, RMSEA = .062, and AIC = 114.70 (refer to Table 8 and Figure 11). The paths between the gF and both WM latent factors were moderate (.32 for WMcs and .28 for WMnb), where WMcs and WMnb correlated at .38, from Common to gF at .78. The next measurement model, CFA11, was identical to the CFA10 with one exception that the path between the WMcs and WMnb latent factors was fixed so that the only existing paths were to gF. In contrast to the CFA 10, in the CFA11 model the only meaningful correlation between the gF and WM constructs was from the Common factor (.92). The Common factor created from the six WM tasks predicted 61% of the variance in gF in this model. The loading of the Common factor indicates that when both WM latent factors correlate (CFA10), the WMcs predicts more unique variance in gF (10%) than the WMnb factor (7%). However, if we do not allow the WM factors to correlate, as in CFA11, the Common factor predicts (86%) of the variance in gF.

Table 8. Confirmatory Factor Models with Working Memory (WM), Common Working Memory (Common), and Fluid Intelligence (gF) Latent Factors (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A. Two WM (free to covary), one gF, one Common, no correlated errors*											
CFA10	**25**	**54.70**	**2.18**	**.98**	**.98**	**.99**	**.97**	**.92**	**.062**	**.027**	**114.70**
B. Two WM (path fixed), one gF, one Common, no correlated errors											
CFA11	26	60.11	2.31	.98	.98	.99	.96	.92	.065	.028	118.11

* Models in bold were retained for further analyses.

The loadings of singular tasks on the Common factor could also indicate the amount of shared common variance versus variance specific to particular construct (WMnb or WMcs). The loadings suggest that when the two WM latent factors are correlated (as in CFA10), the OSPAN and n-back numbers – both tasks representing the numerical domain – are the two tasks that have the lowest contribution to the Common factor (.30 and .37, respectively) and the highest to their respective WM factors, whereas the remaining tasks, spatial and verbal, had the highest contribution to the Common factor. When the two WM factors did not correlate (as in CFA11), the contribution to the Common factor was comparable across the six WM tasks. The contribution of the OSPAN and SSPAN tasks to the WMcs factor diminished in comparison with the previous model (CFA10). The residual variances from WMcs and WMnb contributed to the relation with gF when both WM latent variables correlated, whereas when this correlation was removed, no relationship remained between the WMcs and WMnb and gF besides the contribution through the Common factor. This pattern suggest that depending on whether the WM latent factors correlate or not, the contribution of observed variables to the Common factor changes, in addition to the magnitude of the relation of the three latent variables to gF.

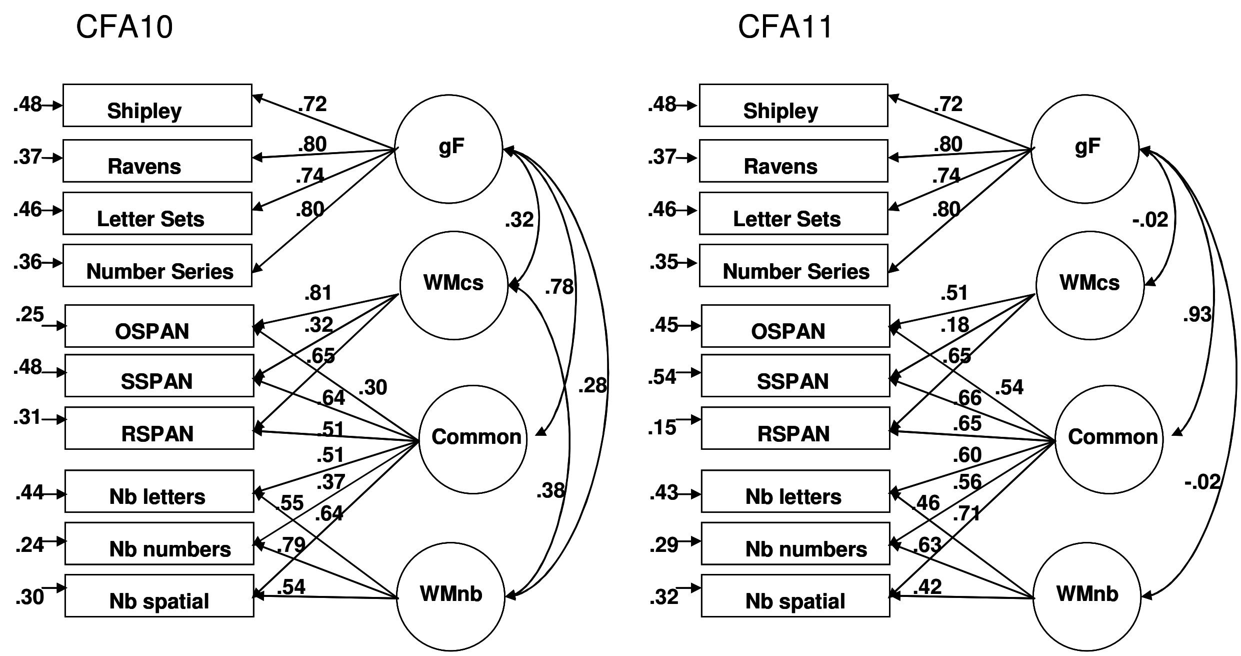


Figure 11. Models for Working Memory, Common, and Fluid Intelligence Variables (N=309). Panel A: two WM factors, one gF factor and a Common factor comprised all six WM tasks. Panel B: the path between the two WM factors is fixed. OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; Nb = n-back; WMnb = working memory n-back latent variable; WMcs = working memory complex span latent variable; gF = fluid intelligence latent factor.

Overall, the results of confirmatory factor analyses so far indicate that the observed variables contributed highly to the representation of their latent constructs. The cognitive tasks were best represented by the task-specific and not by the domain-specific constructs. The WMcs and WMnb were best described as separate but related latent constructs. They both highly correlated with gF, yet the WMcs seemed to have a slightly higher relationship with gF than WMnb, especially after adding the error correlation between the OSPAN and RSPAN. In addition, the similarity of the contribution of the two types of the WM tasks to gF diminished significantly by constructing the Common factor from the six WM tasks, which captured the entire contribution to gF when the path between the two WM latent factors was fixed to zero.

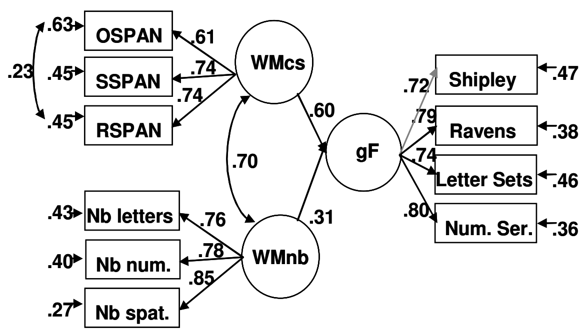
Structural Equation Models of Working Memory and Fluid Intelligence

The relationship between the two WM constructs and gF was examined next in a series of structural equation models. The best fitting measurement model comprising two WM and one gF factor without correlated errors (CFA7ca) and an alternative model with the OSPAN-RSPAN task errors correlated (CFA7c) were used for further analyses in the series of structural equation models with gF as the criterion construct and the WMcs and WMnb factors as the predictors (see Figure 12). The results indicated that the differential relationship between the WMcs and WMnb with gF changes with adding the correlation between the OSPAN and RSPAN variables.

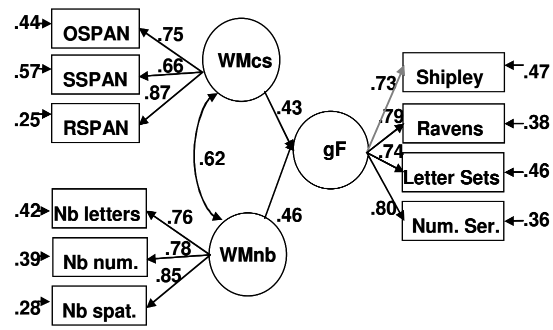
In the first model (SEM1a), all paths were free to covary. The fit of the model was very good, χ^2 (32) = 95.96, NFI = .97, CFI = .98, RMSEA = .081, and AIC = 141.96. As can be seen from the figure, both WM latent factors predicted roughly the same amount of variance in gF. The second model (SEM1) was identical to SEM1a with one exception of added correlated error between the OSPAN and RSPAN within the WMcs factor. The path covariance between the WMcs and gF changed to .60, whereas between the WMnb and gF changed to .31. The fit of this model (SEM1) was better than the first one, χ^2 (31) = 71.51, NFI = .98, CFI = .99, RMSEA = .065, and AIC = 119.51 (refer to Table 9). Note that adding the residual correlation between the

two complex span tasks changed the magnitude of the relationship of the two WM latent factors with gF. With error correlation, the WMcs path was twice as high as the path from WMnb to gF. In addition, adding the error correlation almost doubled the magnitude of the residual in both OSPAN and RSPAN tasks from .44 and .25 without the correlated

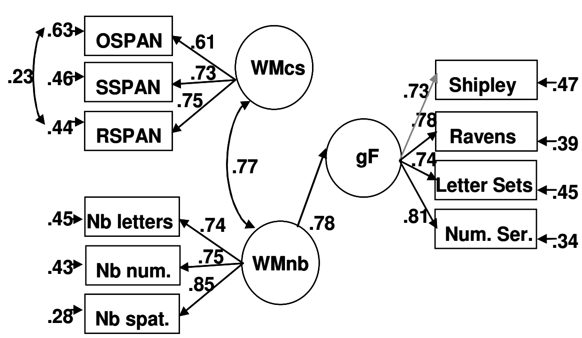
SEM1



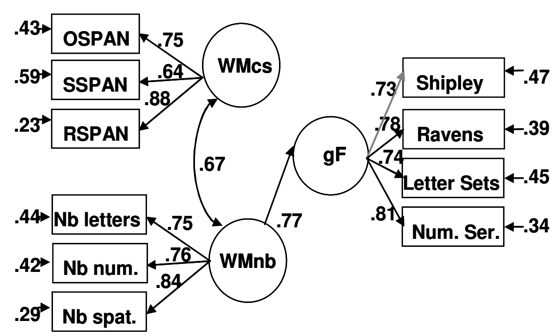
SEM1a



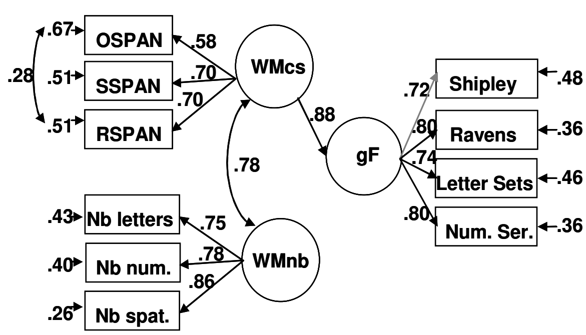
SEM2



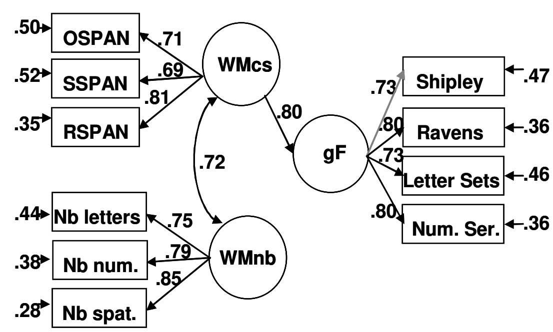
SEM2a



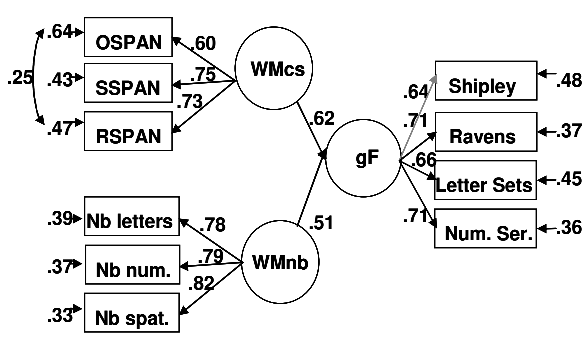
SEM3



SEM3a



SEM4



SEM4a

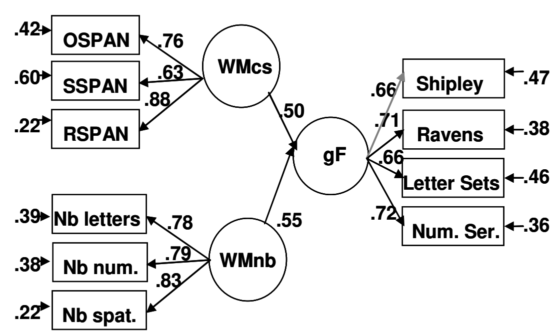


Figure 12. Structural Equation Models Involving Working Memory and Fluid Intelligence (N=309). Panel A and B contrasts the SEM models with and without one correlated error between the OSPAN and RSPAN complex span tasks. The remaining panels are variations of the first two models. OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; Nb = n-back; WMnb = working memory n-back latent variable; WMcs = working memory complex span latent variable; gF = fluid intelligence latent factor.

error to .63 and .45 with correlated error, respectively, as Figure 13 shows. The results clearly indicate that when no errors are correlated, the WMcs and WMnb variables account for roughly the same amount of variance in gF. However, when no errors were allowed to correlate as in SEM1a, the relations were roughly of the same magnitude.

Variants of the SEM1 and SEM1a models were fitted next, and their fit was compared to the two baseline models (SEM1 and SEM1a). In the structural models SEM2 and SEM2a, the path between WMcs and gF was fixed to zero. In the models SEM3 and SEM3a, the path between WMnb and gF was fixed to zero. In the last pair of SEM models in this series, SEM4 and SEM4a, had the path between the two WM latent variables fixed to zero symbolizing the absence of a direct effect. The four set of models shown in Figure 13 (SEM2 to 4a) was compared to the baseline models. In general, the four models (SEM2, SEM2a, SEM3, and SEM3a) indicate a slightly greater contribution from the WMcs to gF than from the WMnb factor. This tendency was also seen in another model with the correlated error (SEM4), where the path of correlation between the WM latent factors was fixed. One possible explanation would be that when adding the correlated error, the variance specific to the two tasks is relegated to the error correlation term, and this causes inflation of the relationship between the two WM latent variables and causing the change in the magnitude of the relationship between them and gF by inflating WMcs-gF and suppressing WMnb-gF relationship. It is important to note that overall, the task-specific error terms and error correlations were quite low across the tasks, namely, a great portion of variance was allotted to the latent constructs.

Table 9. Structural Equation Models Involving Working Memory (WM) and Fluid Intelligence (gF) Latent Factors (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A. All three paths free to covary. One correlated error. *											
SEM1	**31**	**71.51**	**2.30**	**.98**	**.98**	**.99**	**.96**	**.92**	**.065**	**.032**	**119.51**
B. All three paths free to covary. No correlated errors.											
SEM1a	**32**	**95.96**	**2.99**	**.97**	**.97**	**.98**	**.94**	**.90**	**.081**	**.047**	**141.96**
C. Fixed path between WMcs and gF. One correlated error.											
SEM2	32	114.33	3.57	.96	.96	.97	.93	.88	.091	.064	160.33
D. Fixed path between WMcs and gF. No correlated errors.											
SEM2a	33	125.00	3.78	.96	.96	.97	.92	.87	.095	.078	169.00
E. Fixed path between WMnb and gF. One correlated error.											
SEM3	32	80.57	2.51	.97	.98	.98	.95	.91	.070	.037	126.57
F. Fixed path between WMnb and gF. No correlated errors											
SEM3a	33	136.14	4.12	.96	.95	.97	.92	.86	.0101	.063	180.14
G. Fixed path between WMcs and WMnb. One correlated error.											
SEM4	32	154.96	4.84	.94	.93	.95	.91	.84	.112	.200	200.96
H. Fixed path between WMcs and gF. No correlated errors.											
SEM4a	33	170.45	5.16	.94	.93	.95	.90	.83	.116	.200	214.45

* Models in bold were retained for further analyses.

Four pairs of the SEM models were compared. The fit of the baseline model was still the best (refer to Table 9), and these two models (SEM1 and SEM1a) were retained for further analyses. These two models comprised two separate yet correlated WM latent factors with gF as a criterion measure. In the model without a correlated error (SEM1a), the WMcs construct accounted for twice as much variance in gF than the WMnb construct. The correlation between the WM constructs was high and equal .70. In contrast, when the OSPAN and RSPAN error within the WMcs construct was added, which was the case in SEM1 model, the contribution of both WM latent factors to gF was roughly the same. This pattern was also observed in model SEM4a, with the correlation between the two WM factors fixed to zero. Overall, the results of the CFA and SEM analyzes are in line with previous studies showing that WM is an important aspect of gF (e.g. Engle et.al, 1999; Kane et al., 2004; Kyllonen & Christal, 1990), but in contrast with other studies that concluded a weak relationship involving complex span and n-back tasks (Kane et al., 2007; Jaeggi et al., 2010a).

After establishing the amount of shared and unique variance accounted for in gF by the two WM latent factors, regression analyses were conducted to further explore the amount of incremental variance that each WM factor accounted for by the criterion gF measure. Z-score composites of the gF (created from the four gF tasks), WMcs (created from the three complex span tasks), and WMnb (created from the three n-back tasks) were entered into hierarchical regression analysis to examine the incremental variance that the WM tasks add to predict gF. The correlations between z-composites are displayed in Table 10.

Table 10. Correlations between the z-composites from WMcs, WMnb, and gF (N=309).

	gF_c	*WMcs_c*
WMcs_c	.618**	
WMnb_c	.609**	.524**

All correlations significant at p<0.01

The gF composite was the dependent variable. First, the WMcs and WMnb composites were entered together to identify the total amount of gF variance accounted for by the two predictors. The two WM composites together explained 49.5% (total R^2 =

.495) of the variance in higher-order cognition. The next step involved entering WMcs as the predictor in Step 1 and WMnb in Step 2. The WMnb accounted for significant gF variance (increase in R^2 = .112) over and above the WMcs, F(1, 306) = 149.754, *p*< .01. When the WMnb composite was entered as a predictor in Step 1 followed by WMcs, WMcs accounted for significant variance in gF as well, (increase in R^2 = .124) over and above the WMnb, F(1, 306) = 149.355, *p*< .01. Both WMcs and WMnb accounted for 25.8% (R^2 = .258) of shared variance in gF which is about half of the total variance in higher-order cognition explained by the two WM composites. These results are in accordance with the SEM models suggesting high relations between the WMcs and WMnb and their similar contribution in predicting gF.

Taken together, in contrast to previous work (Jaeggi et al., 2010; Kane et al., 2007; Oberauer, 2005; but see Shelton, Elliott, Hill, Calamia, & Gouvier, 2009; Shelton, Metzger, & Elliott, 2007), the present study indicates that the complex spans and 3-backs, even though best described as two separate constructs, reflect similar cognitive control abilities and magnitude of the relation to higher-order cognition. It is possible that the unique variance from each of the WM composites contribute to different mechanisms or processes (e.g. recall versus recollection and familiarity) reflected by the two types of tasks (sequential complex span and a continuous n-back, respectively), whereas the shared variance reflect the common cognitive control processes that are important in higher-order cognition reflected by both types of tasks. This, in turn, increases the importance of comparing or at least being aware of the different consequences of various kinds of n-back tasks on cognitive control in the studies examining the link between cognition and personality (see also Table 32, Appendix A).

Discussion of the Cognition only Models

Taken together, the CFA and SEM models of WM and gF clearly indicate that both WMcs and WMnb are strongly related to gF, although they also share from 38% to 50% of variance, depending on the model. Interestingly, the biggest differences between the two WM latent factors were mostly dictated by the influence of the task-specific error variance. In the SEM models in which both WM latent factors were allowed to correlate, the two models with correlated error (SEM1) and without correlated error (SEM1a) between the OSPAN and RSPAN tasks showed a differential relationship between WMcs with gF. This relationship changed from .60 without the correlated error to .43 with the correlated error, whereas the WMnb to gF changed from .31 without the correlated error to .46 with the correlated error. When WM latent factors were not allowed to correlate, in the two models with- (SEM4) and without the correlated error (SEM4a), the relationship between WMcs and gF changed from .62 to .50, whereas smaller change was observed for WMnb (from .51 to .55). Note also that the best fitting SEM model was the one where the two WM latent variables correlated and both independently predicted gF (model SEM1 and SEM 1a). It is important to note that only one error correlation was allowed (per earlier discussion, see footnote 9), within the WMcs latent factor. Other correlated errors were not allowed. Although the change in the relation between the latent variables caused by the correlated error is unlikely a spurious effect, this might also mean that something specific to the residual correlation, common to both OSPAN and RSPAN tasks that reflects the change in the magnitude of the relationship between WM and gF, is important and shapes the magnitude of the overall relationship. In sum, the models indicated that WMcs predicted gF at a similar or greater level than the WMnb. This indicates that both kinds of WM tasks assess related constructs, albeit not the same, and as such, should not be thought as being interchangeable measures of WMC.

Personality only models

Confirmatory Factor Analyses of the baseline models

The initial set of personality measurement models investigated the hypothesis regarding categorization of personality traits into two- and three higher-order factors. The question was whether a two-factor model with simple structure (each variable loads only on one factor) fits the data; and whether a three-factor model accounts better for the data than a two-factor model. Personality CFA models were based on the theoretical and empirical studies discussed in Chapter 1, yet two- and three- higher-order personality structures did not describe the present dataset adequately. A four-factor structure seemed to better account for the data and described the general personality patterns well. This conclusion was preceded by a series of CFAs examining two hypothesized models, two- and three-factor structures, followed by model modifications, exploratory factor analysis, and further modifications to achieve the best fit for a model that could account for the data well.

In the first measurement model, CFAP1, two latent factors, Action and Restraint, were represented by fourteen predictor variables. Nine personality traits (BASD, BASF, BASR, Promotion, AOP, AOF, AOD, Extraversion, and Openness) formed the Action latent variable, and five personality traits (BIS, Prevention, Neuroticism, Agreeableness, and Conscientiousness) formed the Restraint latent variable. In the alternative model, three latent factors, Action, Constraint, and Restraint, were formed to account for an alternative structure. In the second model (CFAP2), seven personality traits (BASD, BASF, Promotion, AOF, AOD, Extraversion, and Openness) formed the Action latent variable. Four traits (Conscientiousness, AOP, Agreeableness, and BASR) formed the Restraint factor, and three traits (Prevention, Neuroticism, and BIS) formed the Constraint factor (refer to Figure 13). All factors were allowed to covary. The models were conservative, meaning that each variable loaded on only one latent factor. Figure 13 represents the two CFA models. The overall fit of the model CFAP1 was very poor, χ^2 (76) = 956.52, NFI = .51, CFI = .53, RMSEA = .194, and AIC = 1014.52. Moreover, the interpretation was complicated by the fact that one of the loadings was >1. The fit of the second model (CFAP2) was also poor, χ^2 (74) = 995.02, NFI = .51, CFI = .53, RMSEA = .201, and AIC = 1057.02. Again, one of the loadings was > 1. A possible reason for a loading > 1 (1.3) in both models could result from having together BIS, Neuroticism and Prevention as indicator variables for the same latent factor. This fact became apparent while fitting alternative structures. In both models, most loadings of personality variables onto their respective latent factors ranged from -.12 to .73. Table 11 displays the complete fit statistics for the two models.

The results that yielded very poor fit in both hypothesized models clearly indicate that the two hypothesized CFA models with two- and three-higher order personality factors do not describe the data well and thus, have to be modified. Following modifications, other theoretically plausible combinations of observed variables within three and four latent personality factors did not produce adequately better fit. As none of these models achieved desirable fit to the data, it was necessary to turn to exploratory factor analysis in an attempt to find a better factor solution.

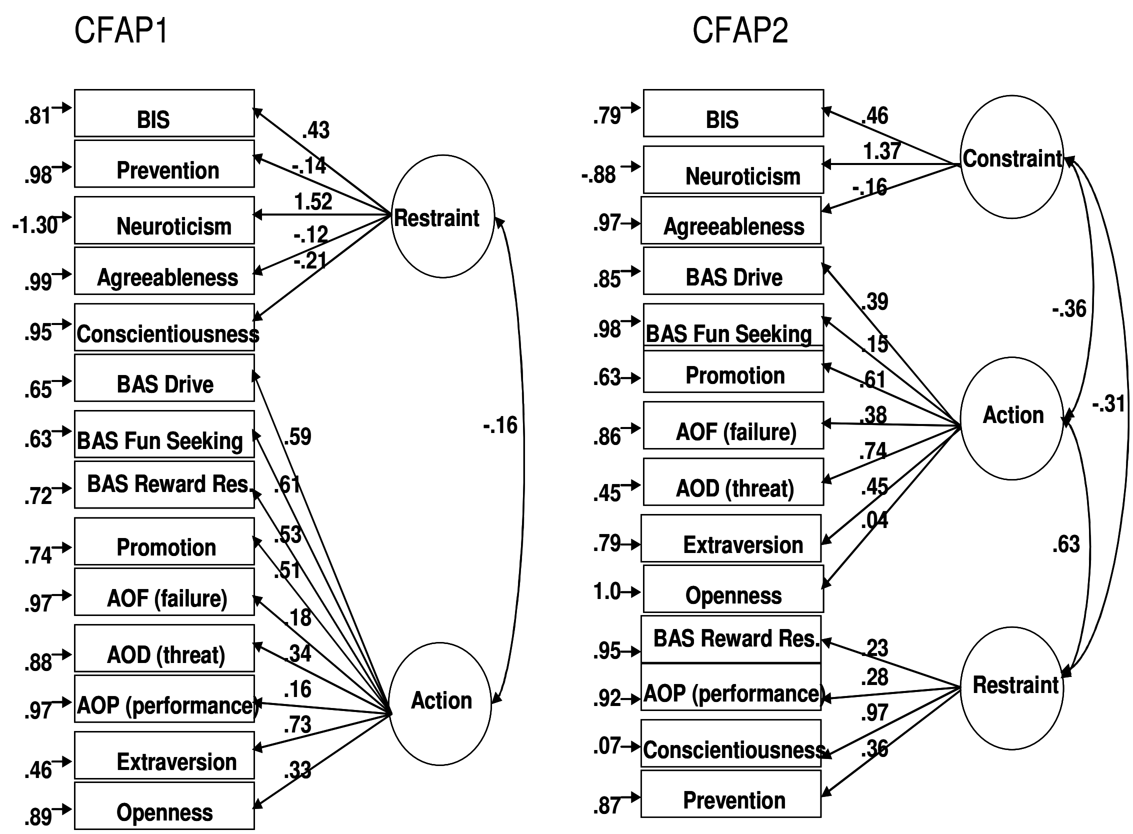


Figure 13. Confirmatory Factor Models of the Hypothesized Personality Two- and Three Higher-Order Factors (N=309). Panel A and B contrast two models with two- and three-higher-order personality factors. BIS = behavioral inhibition scale, BAS = behavioral activation scale; AO = action orientation.

Table 11. Confirmatory Factor Models Involving Personality Variables (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A. Two hypothesized higher-order personality factors											
CFAP1	76	956.52	12.58	.51	.43	.53	.69	.58	.194	.17	1014.52
B. Three hypothesized higher-order personality factors											
CFAP2	74	995.02	13.44	.51	.42	.53	.68	.55	.201	.16	1057.02

Exploratory Factor Analysis of fourteen personality traits

Exploratory factor analysis with principal axis factor extraction and Promax rotation (to allow for correlated factors) was performed (Loehlin, 2004). The results of this analysis revealed four higher-order personality factors with eigenvalues equal to 3.239, 2.523, 1.984, and 1.294. The four factors had primarily clear structure and loadings, but a number of traits expressed high correlations with two latent factors, suggesting the possibility of crossloadings. This, in turn, suggested that a simple structure might not be an adequate solution to achieve an acceptable model fit. Table 12 presents the results of the EFA with primary loadings in bold and listed also the secondary loadings, namely, the second highest correlations with a second factor, included in the table only when the correlation exceeded .30.

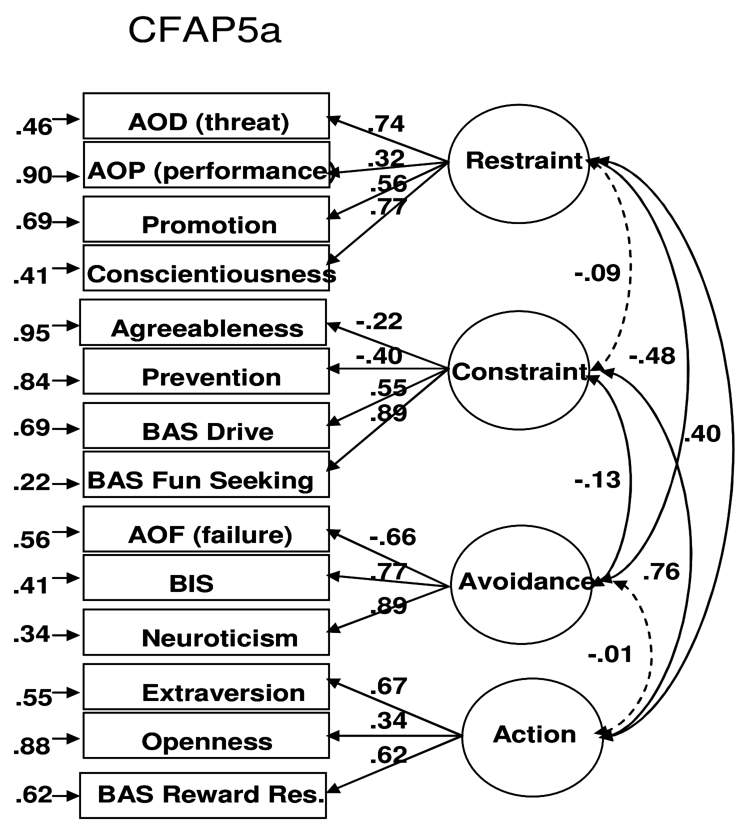


Figure 14. A four-factor Confirmatory Factor Model of the Personality Higher-Order structure fitted after the Exploratory Factor Analysis (N=309). BIS = behavioral inhibition scale, BAS = behavioral activation scale, Res. = Responsiveness; AO = action orientation.

Table 12. Exploratory Factor Analysis of Fourteen Personality Traits. Only the primary and secondary loadings (**highest** and second highest if also high) are displayed.

Variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*
BIS		**.841**		
BASD			.513	**-.731**
BASF			**.753**	-.529
BASR	.385		**.500**	
Promotion	**.559**		.355	
Prevention			-.299	**.530**
AOF		**-.675**		
AOD	**.642**	-.440		
AOP	***.335***			
Neuroticism	-.462	**.769**		
Extraversion	.416		**.680**	
Openness			**.506**	
Agreeableness				**.608**
Conscientious.	**.854**			

BIS = behavioral inhibition scale, BAS = behavioral activation scale, where BASD = Drive subscale, BASF = Fun
Seeking, BASR = Reward Responsiveness; AO = action orientation, where AOF = failure related, AOD = decision, AOP = performance; Conscientious. = Conscientiousness

Table 13. Models following the Exploratory Factor Analysis on Personality Variables (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A. Four higher-order personality factors for the structure as proposed in the EFA											
EFAP	71	656.96	9.25	.65	.58	.67	.77	.65	.164	.14	724.96
B. Four higher order personality factors following the EFA											
CFA5a	71	569.17	8.01	.69	.64	.72	.79	.69	.151	.12	637.17
C. Four higher-order personality factors (Restraint, Avoidance, Approach and Action), 12 observed variables, 9 crossloadings											
CFAP7B	39	125.73	3.22	.92	.90	.94	.94	.87	.085	.047	203.73
D. Four higher-order personality factors (Restraint, Avoidance, Approach and Action), 12 observed variables, 7 crossloadings *											
CFAP7Bd	**41**	**144.34**	**3.52**	**.90**	**.88**	**.93**	**.93**	**.86**	**.090**	**.053**	**218.34**

* Model in bold was retained for further analyses.

The fit of the model (EFAP) was better, but still not acceptable, χ^2 (71) = 656.96, NFI = .65, CFI = .67, RMSEA = .164, and AIC = 724.96, and was modified based on the specific suggestions provided by the EFA. The modifications provided by LISREL improved fit slightly, but the overall fit was still not acceptable, CFA5a, χ^2 (71) = 569.17, NFI = .69, CFI = .72, RMSEA = .151, and AIC = 637.17. Table 13 shows the complete fit statistics for the two models (EFAP and CFA5a). Figure 14 illustrates the CFA5a model. Similarly as for cognitive models, error correlations were not taken into account in the modification process.

Crossloadings

Modifications of the CFA and EFA models improved the overall fit and RMSEA but not enough to accept the model according to statistical guidelines. It become clear from the analyses performed so far that a simple personality structure seems not to be the best solution. One potential resolution giving the results of the EFA, was to implement crossloadings. That is, to allow personality trait to load into more than one latent variable. Proposing a model with crossloadings stems from the premise that personality traits may be better represented as a combination of different aspects likely described by more than one latent variable. If one accepts that a trait, which scores are based on a self-report questionnaire, captures aspects that are present in more than one latent variable, then the crossloadings seem to be a reasonable step towards improving a model fit. Although no satisfactory fit was yet achieved, the resulted personality models with crossloadings lead to the conclusion that crossloadings might be indeed a reasonable step, yet unfortunately not enough to achieve an acceptable fit. The next step involved elimination of the traits with consistently the smallest loadings across the models. As a result, the next set of models involved 12 traits and allowed them to crossload.

Personality only models with two traits dropped: Agreeableness and AOP

The next step towards improving model fit involved dropping two personality traits that had the weakest loadings on their primary latent factors. Agreeableness and AOP (performance related action orientation scale) consistently had the lowest yet significant loadings into their primary factors independently of model configuration. For example, the loading of Agreeableness in the CFAP5a model on the Constraint factor was -.22, whereas the loading of the AOP on the Restraint factor was .32. Overall, both personality traits had loadings lower than .35. They also had very high residuals (.95 and .90, respectively) and it seemed that they did not contribute much to the overall personality structure. In addition, the AOP had very low communality in the EFA analysis (.169). As a result, Agreeableness and AOP were dropped from further models.

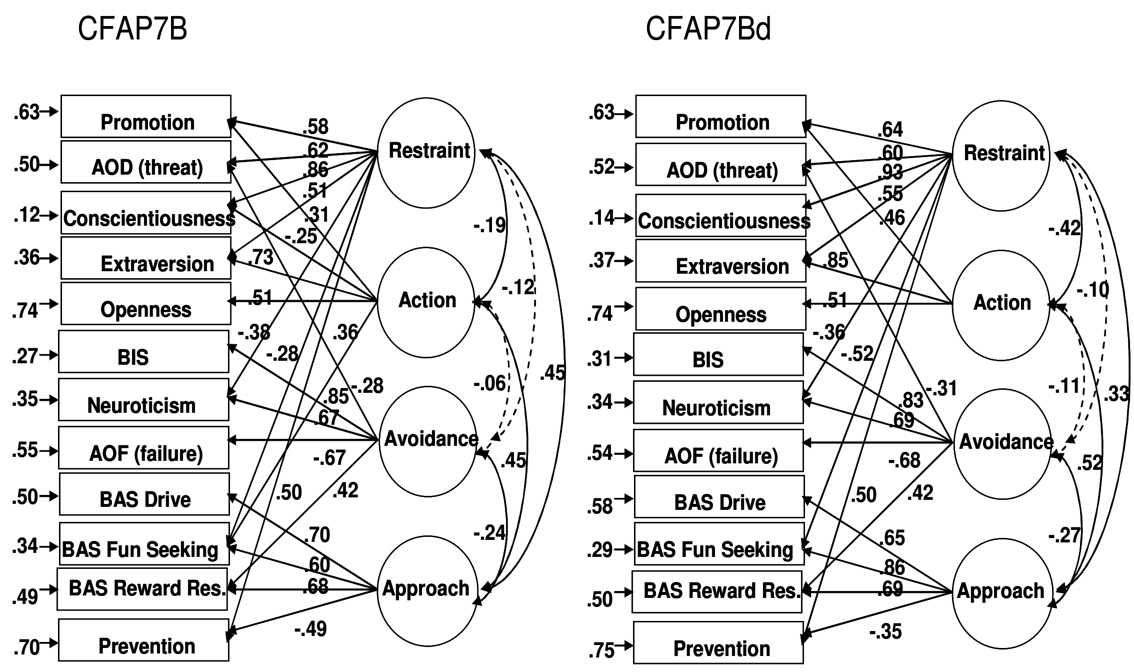


Figure 15. Final Confirmatory Factor Models of Personality (N=309). Panel A and B contrasts two final CFA models for personality structure for this study differing in the number of crossloadings. Two crossloadings were removed in the CFAP7B, Panel A, which resulted in the model CFAP7Bd, Panel B. BIS = behavioral inhibition scale, BAS = behavioral activation scale; AO = action orientation.

In the following CFA models, twelve personality traits formed four latent factors. Subsequent models incorporated crossloadings between two or three latent factors as suggested by series of modification indices in LISREL. No residual correlations were allowed. The choice of crossloadings over correlated errors was dictated by easier theoretical explanation of crossloadings than correlated errors[12]. Applying a series of steps and modifications improved model fit and subsequently resulted in proposing a modified combination of personality traits forming the four-factor structure (model CFAP7B in Figure 15, left panel; Table 13). Next, with an aim to achieve more parsimonious model, all the crossloadings of each trait with three latent factors were examined. Two of the crossloadings were eliminated while only minimally worsening the overall model fit. The resulting model (CFAP7Bd) is introduced in Figure 15 on the right panel and Table 13 for fit statistics.

Numerous modifications from the initial two models in both the membership of the indicator variables within particular latent factor, addition of crossloadings and elimination of two indicator variables prompted the need to adjust the labels for two of the new latent personality factors to capture better their characteristic. This resulted in four latent personality factors named Restraint, Avoidance, Approach, and Action. This change accommodated the character of indicator variables that had constituted the respective constructs. It is important to note that across the personality models examined so far, the indicator variables had significant loadings onto their respective latent factors

[12] Note that, especially in personality, different traits measure various aspects of personality, which might translate into a need for crossloadings to fully account for the trait characteristic. If that is the case, this should result in a better model fit. Another explanation for improvement of fit would be that loosing degrees of freedom is what improves the model.

and a great majority of them had very high to reasonable magnitude of loadings and error terms.

The new model (CFAP7B) incorporated four higher-order personality factors composed from twelve indicator variables as shown in the left panel in Figure 15. The final model (CFAP7Bd) is shown in the right panel of Figure 15. At this point, LISREL modification indices did not suggest (besides adding correlated errors) any further actions to improve the model fit. The loadings of indicator variables to their respective latent factors were significant. The first factor, Restraint, was formed from Conscientiousness, Prevention, Promotion, AOD and three crossloadings: a positive crossloading from Extraversion and two negative crossloadings from Neuroticism and BASF. The resulted Restraint factor characterizes self-control, self-discipline, achievement, emotional stability, and sensitivity to threat. The Avoidance factor was formed from the BIS scale, Neuroticism, a negative loading from the AOF scale and two crossloadings: from BASR and a negative crossloading from the AOD scale. Briefly, the Avoidance factor characterizes anxiety, hesitation, and reward sensitivity. Two other factors were similar in their overall characteristics as most of the personality traits that formed them were included in the same factor (Action) in the initial, hypothesized models. In the final model, though, the third factor, Approach, comprised BASD, BASF, BASR, and a negative crossloading from the Prevention scale. The fourth factor, Action, comprised Extraversion, Openness, and a crossloading from Promotion scale. The Approach factor can be characterized primarily by preference to change, whereas the Action factor primarily can be characterized by flexibility, openness, dynamics, and impulsivity. Table 14 indicates that the fit of the new CFA model (CFAP7B) improved significantly, χ^2 (39)

= 125.73, NFI = .92, CFI = .94, RMSEA = .085, and AIC = 203.73, and now the model is acceptable.

The variables with the lowest loadings on their respective secondary or tertiary latent factors were taken out and the resulting models fitted. Only one crossloading was dropped at a time. The change that only slightly worsened model fit and RMSEA to .090 was when the loadings between Conscientiousness and BAS-Fun Seeking to the Action latent factor were dropped[13]. Since the two models were almost identical in their fit, the model CFAP7Bd was retained for further analyses because of its better parsimony, namely, lower number of crossloadings at almost no expense in the model fit (Byrne, 1995; Jöreskog, 1993; Kline, 1998; Tabachnick & Fidell, 1996). The final number of crossloadings was seven with two latent factors per trait. Table 14 lists the personality traits with and without the crossloadings. Out of seven total crossloadings, Restraint had the most (six), sharing two with Avoidance, two with Approach, and two with Action. The remaining crossloading was between Avoidance and Approach. The BASF scale is one example of a trait having a crossloading with two latent personality factors, positive with Approach and negative with Restraint. An interpretation might be that preferring change and being approachable accounts for the loading on the Approach factor, whereas being low on self-discipline and achievement leads to the loading on the Restraint factor.

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[13] When comparing the model CFAP7Bd to the best fitting model CFAP7B, the loading of Conscientiousness to its main latent factor changed from .86 to .92. Although all the paths remained significant, the change affected the two loadings on the Action latent factor from two other traits that were also a part of the Restraint factor: the loading of Promotion to the Action latent factor (from .31 to .46), and Extraversion to the Action latent factor (from .73 to .83). More importantly, this one change affected the path between the Restraint and Action latent factors, which became significant. The model CFAP7Bd had an acceptable fit, $\chi 2$ (41) = 144.34, NFI = .90, CFI = .93, RMSEA = .090, and AIC = 218.34.

Table 14. Personality Variables With and Without Crossloadings in model CFAP7Bd (N=309).

Traits with Crossloading	*Traits with No crossloadings*
Promotion (Restraint, Action)	Conscientiousness (Restraint)
Extraversion (Restraint, Action)	BIS (Avoidance)
AOD (Restraint, Avoidance)	AOF (Avoidance)
Neuroticism (Restraint, Avoidance)	BASD (Approach)
Prevention (Restraint, Approach)	Openness (Action)
BASR (Avoidance, Approach)	
BASF (Restraint, Approach)	

Table 15. Factorial Membership of the Personality Questionnaires from the Final Model.

Factor name	NEO-PI-R	BISBAS	Action orientation	Promotion prevention
Avoidance	N (.69)	BIS (.83)	AOD (-.31)	
		BASR (.42)	AOF (-.68)	
Restraint	C (.93)	BASF (-.52)	AOD (.60)	Prom (.64)
	N (-.36)			Prev (.50)
	E (.55)			
Approach		BASF (.86)		Prev (-.35)
		BASR (.69)		
		BASD (.65)		
Action	E (.85)			Prom (.42)
	O (.51)			

Table 15 lists the loadings of the traits according to their membership to particular questionnaires into their respective constructs. The NEO-PI-R represented three of the four latent constructs. The Neuroticism represented primarily the Avoidance construct and Restraint as a secondary negative loading. Restraint comprised also Conscientiousness and a secondary loading from Extraversion. The Action construct represented Extraversion and Openness. The BIS/BAS shared three latent constructs with mainly the three BAS scales occupying the Approach construct. The BIS and a secondary loading from BASR completed the Avoidance construct. The BASF subscale had also a secondary negative loading onto the Restraint construct. The Action orientation scale represented two latent constructs: Avoidance (AOF and a secondary loading from AOD, both negative) and Restraint (AOD). Finally, Promotion/prevention represented three latent factors: as primary traits on the Restraint construct, and secondary loadings on the Approach construct (negative from Prevention) and Action (Promotion).

Table 16 shows correlations among the latent factors in the final CFA model (CFAP7Bd). The Approach factor had a negative correlation (-.27) with the Avoidance factor, and a positive correlation with the Restraint factor at .33. The Action factor had a negative correlation with the Restraint factor at -.42 and a highly positive correlation with the Approach factor at .52, which was expected as the Action and Approach factors were highly related. Note that Action and Avoidance as well as Action and Approach did not share any crossloadings. That means that even though Action and Approach have quite significant correlation and both factors consist of the traits initially included in one factor (Action), splitting them into two related but distinct factors was plausible. Action and Avoidance, on the other hand, do not correlate, thus, they are completely separate factors. This seems to be why they do not share loadings.

Table 16. Correlations Between the Latent Personality Factors, model CFAP7Bd (N=309).

	Avoidance	Restraint	Approach
Restraint	-.10		
Approach	-.27*	.33*	
Action	-.11	-.42*	.52*

As seen in the table, four out of six correlations between the latent variables were significant. An additional model was fitted that fixed to zero the two nonsignificant paths from Restraint to Avoidance and from Avoidance to Action, to examine whether removing these two correlations would improve parsimony of the model. The resulting model did not differ from the model CFAP7Bd, and was not considered further (see also Friedman & Schustack, 2006). Thus, the model CFAP7Bd was retained for further analyses.

Interpretation of the factorial structure of personality

The new personality structure and its interpretation was proposed to account for the structure held by the final CFA model. Table 17 depicts trait characteristics for the twelve personality traits included in the final model as a starting point in defining the higher-order personality factors as shown in Table 18. The table summarizes factorial interpretation of the model, describes the four personality constructs and their descriptors.

As Table 18 indicates, the Restraint construct characterizes self-discipline with the leading trait Conscientiousness (loading .93). Other important characteristics include internal discipline, initiative, determination, and emotional stability, but also avoiding new rewards and preference for safety and cautiousness. The Restraint factor correlated negatively with the Action and positively with the Approach factor signifying its relation with some characteristics of Approach, including assertive and optimistic patterns. A negative correlation with Action could mean contrasting stability with flexibility, safety with variety and novelty. Continuing the analysis of Table 18, the Avoidance construct characterizes primarily hesitation, with the BIS scale as the leading trait (loading .83). The main characteristic of the Avoidance construct is anxiety, rumination, indecisiveness, and hesitation in making decisions. Although the three paths to other personality constructs from Avoidance were negative, only its negative correlation with Approach was significant. This likely means a contrast between active goal pursuit with hesitation in decision-making process, and optimism with ruminations.

Table 17. Trait descriptions Within the Twelve Personality Variables Used in the Final Model CFAP7Bd. NEO-PI-R facets and their characteristics, see Table 31 Appendix A.

Neuroticism	**Extraversion**	**Conscientiousness**	**Openness**
Anxiety, Angry hostility, Depression Self-consciousness, Impulsiveness, Vulnerability	Warmth, Gregariousness, Assertiveness, Activity, Excitement-seeking, Positive emotions	Competence, Order, Dutifulness, Achievement, Self-discipline, Deliberation	Fantasy, Aesthetics, Feelings, Actions, Ideas, Values
(-): emotional stability, optimism, confident, irritable, self-confident (+): worrying, impatient, inhibited	(-): aloof, shy, withdrawn (+):spontaneous, warm, enthusiastic, confident, clever, optimistic	(-): careless, impatient, moody, distractible, absent-minded, lazy (+): efficient, self-confident, thorough, ambitious, determined, persistent, organized	(-): mild, cautious, conservative (+): imaginative, humorous, idealistic, original, inventive, spontaneous, curious, insightful, versatile
BIS avoidance of novelty, fear, anxiety, nervousness, aversive motivation, restraint towards a goal, inhibition of behaviors with potentially negative outcomes, frustration	**BAS** reward, happiness, impulsiveness, feel positive, goal striving		
	BAS-Reward Responsiveness (BASR) "positive responses to the occurrence or anticipation of a reward"	**BAS-Fun Seeking** (BASF) "desire for new rewards and a willingness to approach a potentially rewarding event on a spur of the moment"	**BAS-Drive** (BASD) "persistent pursuit of desired goals"
Prevention safety, responsibilities, cognitive dissonance, security-related focus; triggered by security needs, ought, loss situations; sensitivity to pain strategy avoidance; commitment, certainty, vigilance; perseverance, concrete perspectives; experience of being rejected; negative stereotypic expectations; extremes: calmness vs. anxiety	**Promotion** accomplishments, aspirations, eagerness, well-being, nurturance-related focus; triggered by nurturance needs, ideals, gain related situations; yields sensitivity to positive outcomes, strategy approach; persistence; flexibility, open-mindedness, timely progress, impulsivity; experience of being ignored; positive stereotypic expectations; growth, abstract and ideal perspectives; flexibility, open-mindedness, fast progress; extremes: happiness vs. sadness	**AOD** (demand) decisiveness, change, initiative, active versus "indecisive and inertial"; able to quickly act upon decisions; extremes: initiative vs. hesitation	**AOF** (threat) becoming challenged versus staying threatened in threatening situations; able to return to action quickly after failing an activity; extremes: disengagement vs. preoccupation

Sources: Carver & White (1994), Costa & McCrae (1992), Jostmann & Koole (2006), E.T. Higgins (1997), Molden, Lee, & E.T. Higgins (2008).

Table 18. Factorial Interpretation of the Final Confirmatory Factor Model (CFAP7Bd) Involving Twelve Personality Variables (N=309). [14]

Single describing adjective	Factor characteristic	Factor name	Descriptors
Self-discipline (Conscientiousness) (+) *C*, PRO, AOD, (E), PRE (-) (BASF) (N)	accomplishment, achievement, planning, advancement, aspirations, preference for stability, reliable, reserved, responsible, safety, security, control of impulses, self-control/self-discipline, blocking, calmness, determination, resistance to temptation, emotional stability, initiative, internal discipline, organizing, optimistic, outgoing, assertive, handle difficult situations well, able to act upon decisions quickly	**Restraint**	C (.93) PRO (.64) AOD (.60) PRE (.50) E (.55) BASF (-.52) N (-.36)
Hesitation (BIS) (+) *BIS*, N, (BASR) (-) AOF, (AOD)	cautiousness, anxiety, rumination, restraint, avoidance, preoccupation, negative affect, indecisiveness, hesitation in decision-making, external world, reward sensitivity, dependence, lack of adaptation, sensitivity towards previous or expected events	**Avoidance**	BIS (.83) N (.69) AOF (-.68) BASR (.42) AOD (-.31)
Change (BASF) (+) *BASF,* BASR, BASD (-) (PRE)	active goal pursuit, preference for change, anticipation of reward, desire for new rewards, approach orientation, flexibility, focus on positive responses to anticipation of reward, approach rewarding events, arousal, energy	**Approach**	BASF (.86) BASR (.69) BASD (.65) PRE (-.35)
Open-mindedness (Extraversion) (+) *E,* O (-) PRO	dynamics, happiness, optimism, joy, well-being, impulsivity, novelty, stimulation, creativity, flexibility, focus on anticipation of pleasure, preference for variety, intellectual curiosity, openness to change, open-mindedness, openness to different values, experiencing variety of activities, researching novel ideas, energetic	**Action**	E (.85) O (.51) PRO (.42)

Sources: Costa & McCrae, 1992; Carver & White, 1994; Gray, 1982; Kuhl & Beckmann, 1994; Kuhl, 2000; E.T. Higgins, 1997; Digman, 1997). BIS = behavioral inhibition scale, BAS = behavioral activation scale, where BASD = Drive subscale, BASF = Fun Seeking, BASR = Reward Responsiveness; PRO = promotion focus; PRE = prevention focus; AO = action orientation, where AOF = failure related, AOD = decision, AOP = performance; N = Neuroticism, E = Extraversion, O = Openness; A = Agreeableness; C = Conscientiousness. Red ink = the trait with the greatest loading on its respective latent factor; blue ink = a crossloading with the respective factor (a secondary loading).

[14] A model with correlated errors has also been investigated, but was abandoned as difficult to interpret the model in general and the correlated errors. Choosing crossloadings as a means of improvement was justified and much easier to interpret.

The Approach construct comprises all three subscales from the BAS scale (Carver & White, 1994) and thus its primary characteristic is change, with the BASF subscale as a leading trait (loading .86). Approach characterizes preference for change, flexibility, and reward sensitivity. The three paths from Approach were significant and included positive correlation with the Restraint and Action constructs, and a negative correlation with Avoidance. Finally, the Action construct is characterized by open-mindedness, with a leading trait Extraversion (loading .85). Its main characteristic defines dynamics, optimism, pleasure, curiosity, and openness to change. With a significant correlation with the Approach and negative correlation with Restraint, the Action construct confirms its characteristic as open-minded with a positive attitude and flexibility in behaviors. Overall, the final CFA model of higher-order personality structure depicted different personality characteristics within the four factors that offer differential relationship and dynamic.

Discussion of Personality only Models

The two hypothesized initial models poorly represented the data as shown in Figure 14 and confirmed by their inadequate fit. The measurement model of personality structure greatly improved its fit in a series of steps that aimed at finding a good fitting model. The steps involved (a) changing the number of latent constructs from two or three to four, (b) eliminating personality traits with the lowest loadings to the latent factors, (c) adding crossloadings between some of the personality traits and their latent constructs, (d) tuning the number of crossloadings to achieve a relative model parsimony. These four basic steps allowed improvement from a very poor model fit (CFA = .52) to an acceptable fit (CFA = .93) and resulted in proposing a personality structure represented by four major personality questionnaires with diverse backgrounds, structures and implementations. From the best fitting model achieved, two crossloadings have been eliminated, leaving seven crossloadings with two latent factors per crossloading. The resulting model was retained for further analyses. The purpose of adding crossloadings in the first place was to model and describe possible instances where traits share their characteristics with more than one latent factor. The outcome being significantly improved fit of the model with crossloadings even though with the smaller number of traits, justifies the steps taken to develop a new personality structure depicted also in the results of the EFA. The steps taken from the initial models to the final model prompted a change of labels for the latent personality factors that better reflected the characteristic of the Restraint, Avoidance, Action, and Approach.[15] Although it was possible to find a good fitting model through modifications, it is important to note, that alternative models exist and may be equally plausible and interpretable. However, the hypothesized initial models did not produce a good fitting model structure when 14 personality traits were put in the model as initially hypothesized. The final personality structure represented by the model (CFAP7Bd) was used next in identifying the relationship between personality and cognition in a series of CFA and SEM models involving joint personality and cognitive variables.

[15] Simpler personality models and replications of simple models existing in the literature (e.g. Digman, 1997; Elliot & thrash, 2002; Smits & Boeck, 2006) have also been investigated. In some instances, the replications were not possible. For example, because of relatively low overall correlations among the NEO-PI-R traits, a simple CFA model with two higher-order structure (Digman, 1997; Alpha and Beta) of the NEO-PI-R could not be performed. A one-factor model did converge resulting in a general personality factor (GPF; see Musek, 2007; Erdle, Irwing, Rushton, & Park, 2010; Erdle et al., 2010; but see Revelle & Wilt, 2009).

Joint personality and cognition measurement model

After establishing the best fitting measurement models separately for the cognitive variables and personality traits, the joint CFA model was formed. The joint measurement model (model CP7BB7d; refer to Table 19) comprised three cognition latent factors (WMcs, WMnb, and gF) and four personality latent factors (Restraint, Avoidance, Approach, and Action) with seven crossloadings within the personality domain and no correlated errors. The latent factors were free to covary. The fit of this model (CP7BB7d) was good, χ^2 (181) = 397.10, NFI = .92, CFI = .96, RMSEA = .062, and AIC = 541.10. This model (CP7BB7d) depicted in Figure 16 was retained for further analyses in the structural equation models[16].

Table 19. Confirmatory Factor Models of Working Memory, Fluid Intelligence, and Personality Variables with 9 crossloadings (A) and 7 crossloadings (B), no correlated errors (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
A.CP7B	179	356.94	1.994	.93	.95	.96	.90	.87	.057	.050	504.94
B.CP7BB7d	181	397.10	2.19	.92	.94	.96	.90	.85	.062	.058	541.10

Table 20 lists the path correlations between latent variables. Three personality constructs had significant path correlations with gF construct. The Avoidance factor had a small positive relationship at .15, Restraint had a similar but negative correlation at -

[16] An alternative version of the cognition-personality model with one correlated error between the OSPAN and RSPAN had slightly better fit, χ^2 (180) = 373.57, NFI = .93, CFI = .96, RMSEA = .059, and AIC = 519.34. This modification did not change the overall relationship between the constructs. Adding error correlation did change the magnitude of correlations within the cognitive measures in the same fashion as in cognitive only models, but did not change the numbers between the cognitive and personality measures.

.14, and the Approach having much higher negative correlation at -.40. The two WM constructs had significant path correlations with three of the personality constructs with roughly similar magnitude of the relationship when comparing the two WM constructs. The Restraint factor had small negative relationship with WMcs and WMnb factors (at -.16 and -.15, respectively), which was of the same magnitude as the relationship with gF. The Approach factor had moderate negative relationship with both WM (at -.21 and -.32), which was a somewhat lower in magnitude than the relationship of Approach with gF at -.40. Finally, Action was related positively to both WM constructs (at .17 and .15, respectively). The path correlations between the two WM latent factors and gF were almost identical (at .72 and .73, respectively), with a .62 correlation between the two WM factors. The paths between Avoidance and two WM constructs as well as between Action and gF did not reach significance.

Table 20. Correlations Between the Working Memory, Fluid Ingelligence, and Personality Latent Factors, model CP7BB7d (N=309).

	Avoid	Restr	Approach		gF	WMcs	WMnb
Avoidance				Avoidance	**.15**	-.02	.05
Restraint	-.09			Restraint	**-.14**	**-.16**	**-.15**
Approach	**-.27***	**.31***		Approach	**-.40**	**-.21**	**-.32**
Action	-.13	**-.42***	**.54**	Action	.07	**.17**	**.15**
					gF	WMcs	WMnb
				WMcs	**.72**		
				WMnb	**.73**	**.62**	

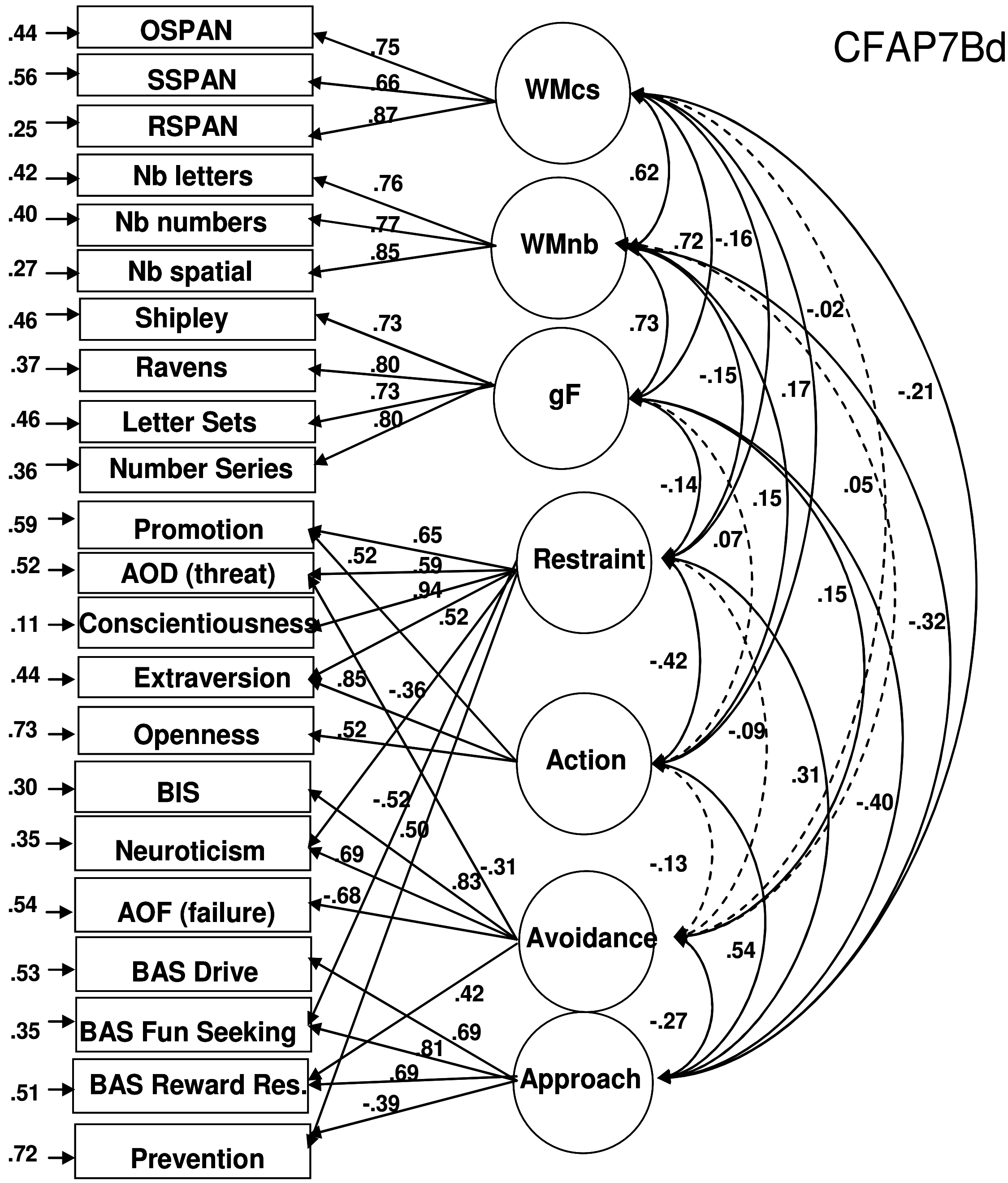


Figure 16. Final Confirmatory Factor Model of cognitive and personality relationships (N=309). Table 21 displays the significance of the paths. BIS = behavioral inhibition scale, BAS = behavioral activation scale, AO = action orientation; The broken line indicates no significant path. OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; Nb = n-back; WMnb = working memory n-back latent variable; WMcs = working memory complex span latent variable; gF = fluid intelligence latent variable.

Personality and Cognition Structural Models

The presence of crossloadings in the personality part of the model made it difficult to examine regressions between the composite scores for each latent personality factor, their contribution to prediction of gF and the composition of variance in cognition – personality relationship. Thus, combinations of SEM models were tested to examine the contribution of different factors to gF. Tables 21–25 list sets of the SEM models that examined different dependencies between the two WM, gF, and four personality latent factors. Specifically, paths were examined with (1) personality and WM factors independently influencing gF; where (2) personality higher order factors influence gF through WM, (3) personality higher-order factors influence gF independently of WM, and (4) personality higher-order factors influence both gF and WM. In addition, simpler models were fitted, that comprised (5) only gF and personality factors, and (6) only WM and personality factors. Figure 19 presents the four model sets. These models are presented in a more schematic way by leaving out the observed variables and showing crucial parts of the models, which include the path loadings between the latent variables in various configurations, as the loadings of the observed variables into their latent factors are identical to those depicted in Figure 16 from previous analyses. Within each group of models, first all personality higher-order factors are fitted in addition to the cognitive factors, followed by fitting singular personality factors in addition to the cognitive factors. Since the models are nested (all factors take part in the model, yet some of the paths may be fixed), the sets of models were compared by the AIC.

(1) Personality and WM factors independently influence gF

The first set of SEM models examined the independent influence of personality and WM factors on gF. This relation was modeled by having paths from personality factors to gF, and independent paths from WMs to gF (Figure 17). When singular personality factors had paths to gF, the WMcs and WMnb latent factors had a similar relation to gF (ranging from .42 to .48 and from .42 to .44, respectively). The Restraint did not influence gF with its zero path correlation. However, the remaining personality factors had significant paths to gF, with Avoidance having a significant positive loading (.14), and Action and Approach significant negative loadings (-.13 and -.16, respectively). Table 21 lists the fit indices for this first set of models[17]. The first row in Figure 18 depicts the graphical representation of the models from set1.

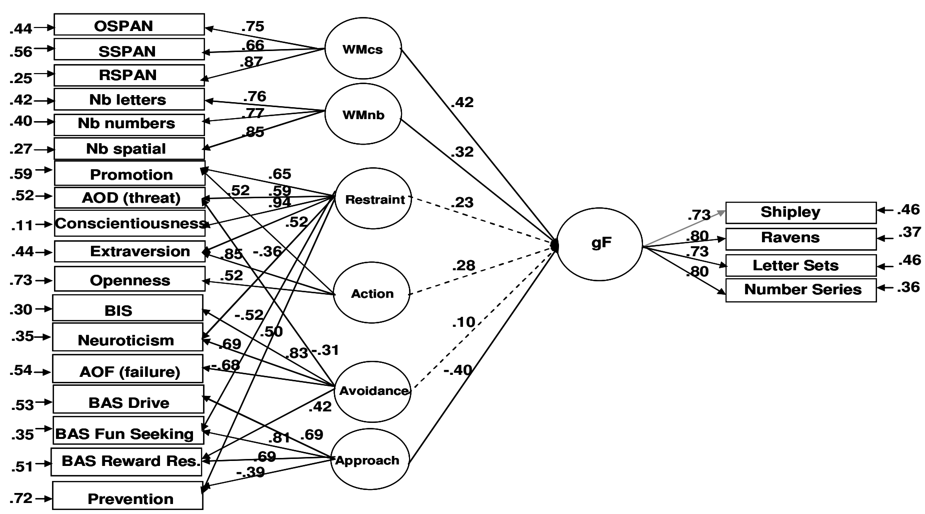


Figure 17. Structural Equation Model depicting the relation of personality and WM to gF.

[17] A model with correlated error between the OSPAN and RSPAN was also fitted to examine whether this changes the relationship between other factors than WMs with gF as seen previously. Indeed, in addition to changing the relationships, the error correlation changed the relation of personality factors to gF. Specifically, in addition to the fact that a path from WMnb to gF lost significance, the only personality factor with significant path to gF was Avoidance (instead of Approach, which was significant in the model with no correlated error).

Table 21. Structural Models of Working Memory, Fluid Intelligence, and Personality, set1 (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
4 personality, 2 WM factors have paths to gF.											
PWMsGf	181	397.10	2.19	.92	.94	.96	.90	.85	.062	.058	541.10
1a: Restraint, 2 WM factors have paths to gF.											
RWMsGf	184	412.94	2.24	.92	.94	.95	.89	.85	.064	.064	550.94
1b: Avoidance, 2 WM factors have paths to gF.											
AvWMsGf	184	407.19	2.21	.92	.94	.96	.89	.85	.063	.061	545.19
1c: Approach, 2 WM factors have paths to gF.											
ApWMsGf	184	404.74	2.21	.92	.94	.96	.89	.85	.062	.060	542.74
1d: Action, 2 WM factors have paths to gF.											
AcWMsGf	184	407.74	2.21	.92	.94	.95	.89	.85	.063	.061	545.74

(2) Personality influences gF through WM

The second set of the SEM analyses examined the influence of personality on gF through WM. This relation was modeled by having paths from personality to WMs and from WMs to gF. There were no direct paths from personality to gF. The relations differed from those indicated in the first set. Specifically, when examining the influence of singular personality factors, both paths from Restraint to WMcs and WMnb were significant (.15 and .16, respectively). In addition, a negative relation from Approach to both WMs (-.30 and -.40, respectively) was observed. Table 22 lists the fit indices for this second set of models. Action and Avoidance did not influence any of the WM factors (.10 and .07 for Action, and .02 and .08 for Avoidance, respectively). Did it influence the relation of WMs with gF? It did not change the relations, which remained at a similar level. The second row in Figure 18 presents the graphical representation of the models from sets2.

Table 22. Structural Models of Working Memory, Fluid Intelligence, and Personality, set2 (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
2a: Restraint to 2 WM factors to gF.											
	190	529.99	2.78	.90	.92	.93	.86	.82	.076	.120	655.99
2b: Avoidance to 2 WM factors to gF.											
	190	540.20	2.84	.90	.91	.93	.86	.82	.077	.130	666.20
2c: Approach to 2 WM factors to gF.											
	190	492.99	2.59	.90	.92	.94	.87	.83	.072	.100	618.99
2d: Action to 2 WM factors to gF.											
	190	536.79	2.82	.90	.91	.93	.86	.82	.077	.130	662.79

(3) Personality influences gF independently of WM

The third set of SEM models examined whether personality influences gF independently of WM. This relation was modeled by having paths from personality to gF, and independent paths from WMcs and WMnb to gF. In this configuration, paths from Avoidance (.16) and Approach (.24) to gF achieved significance. Both Restraint (-.04) and Action (-.11) paths to gF were nonsignificant. Table 23 lists fit indices for the third model set. Overall, personality did not change the magnitude of relations of WM with gF.

Table 23. Structural Models of Working Memory, Fluid Intelligence, and Personality, set3 (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
3a: Restraint to gF, 2 WM factors to gF.											
	191	538.89	2.82	.90	.91	.93	.86	.82	.077	.130	662.89
3b: Avoidance to gF, 2 WM factors to gF.											
	191	534.23	2.79	.90	.92	.93	.86	.82	.076	.130	658.23
3c: Approach to gF, 2 WM factors to gF.											
	191	522.15	2.73	.90	.92	.93	.87	.82	.075	.130	646.15
3d: Action to gF, 2 WM factors to gF.											
	191	536.62	2.80	.90	.92	.93	.86	.82	.077	.130	660.62

(4) Personality influences both gF and WM

The fourth set of SEM models examined the influence of personality with gF and WMs, with simultaneous relation of WMs and gF. This relation was modeled by having paths from personality to all three cognitive latent variables (gF, WMcs, and WMnb) in addition to the presence of paths from WMs to gF. This configuration revealed that the Restraint factor again had nonexistent path to gF (-.01), yet significant paths to WMs (-.15 and -.15). In contrast, the Avoidance and Action factors had significant path with gF (.15 and -.11, respectively) but nonsignificant paths with WMcs and WMnb (-.00 and -.06 versus .11 and .08, respectively). The Approach factor had the highest relations with the three cognitive factors as indicated by significant paths to gF (-.20) and both WMs (-.27 and -.37). Table 24 lists the fit indices for this set of models. The fourth row in Figure 19 graphically represents the models from sets4.

Overall, the results from the fours sets suggest specific but varying relations paths between four personality and three cognitive constructs virtually mimicked the magnitudes of the paths and relations between the Avoidance and cognitive factors from the CFA models. The Restraint factor had consistently no relationship with gF, and was the least stable construct in terms of the sign and magnitude of the relationship with the two WM constructs. Approach had consistent moderate negative associations with the three cognitive latent variables. Finally, Action had a comparable negative relationship to Approach with gF in set1 but the rest of the relations between Action and cognitive variables was opposite than those of Approach with cognitive variables. Action was not related to any of the cognitive constructs in sets 2-4.

In most configurations, personality variables did not change the relations within the gF and WMcs and WMnb. The only changes might have been caused by the Approach construct (see set4, Figure 18). Besides this, the results of the four sets of SEM models suggest that the relationship between certain higher-order personality factors and gF or/and WMs exists. However, for the most part these relations do not influence the relationship within the cognitive factors. This does not preclude the influence of personality on task performance, as might be seen from the zero-order correlations between cognitive and personality variables, significant paths from personality to cognition latent factors as well as from the results of additional analyses below. Moreover, these results suggest that personality influences cognition. Yet, the results demonstrate that the influence of personality on cognitive task performance is largely independent of the subsequent influence of WM on gF.

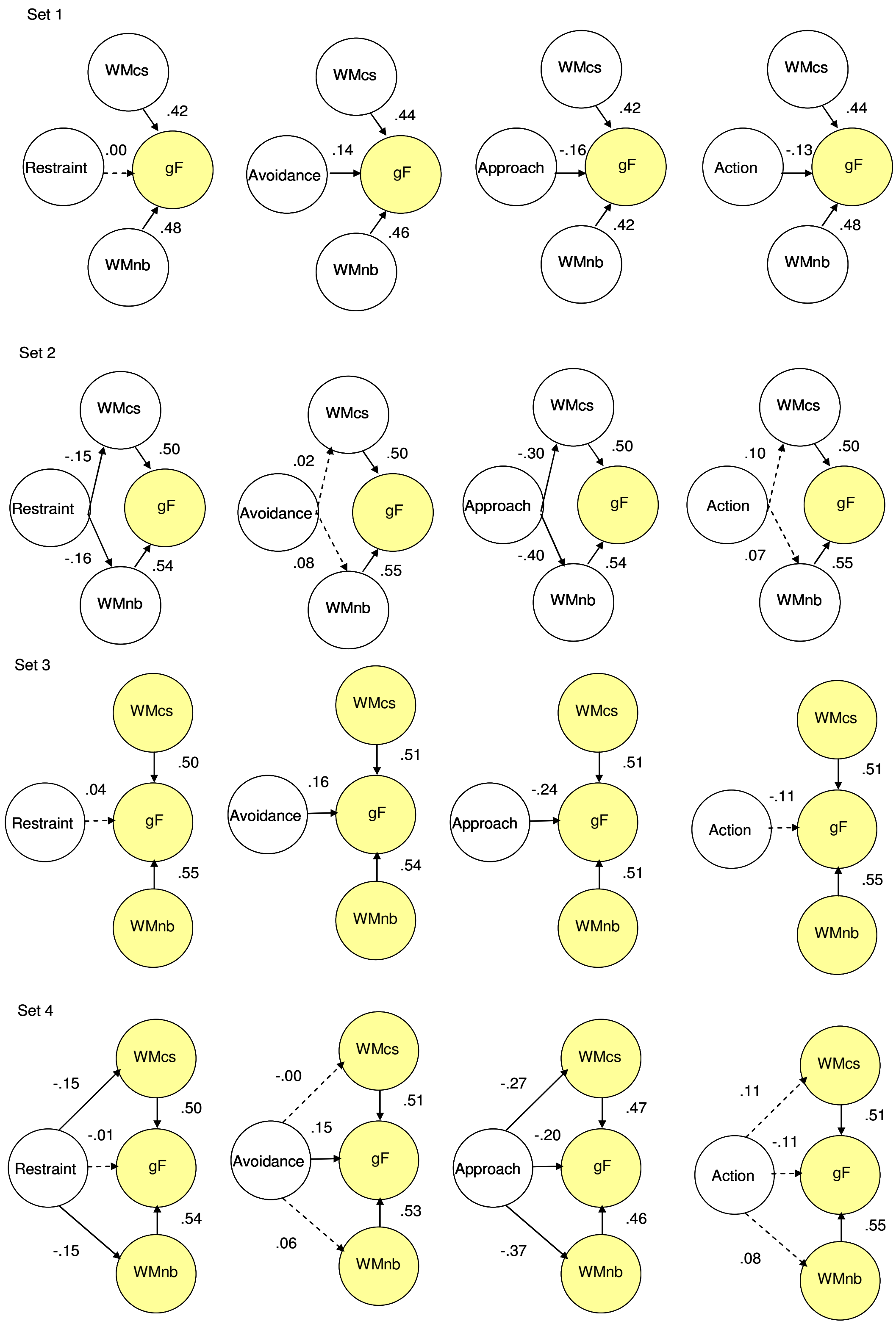


Figure 18. Schematic representation of the four sets of SEM models with cognitive and personality latent factors (N=309). Dashed lines indicate nonsignificant relationship. From left to right, columns: a, b, c, d.

Table 24. Structural Models of Working Memory, Fluid Intelligence, and Personality, set4 (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
4a: Restraint to gF, Restraint to 2 WM, 2 WM factors to gF.											
	189	529.91	2.80	.90	.92	.93	.86	.82	.077	.120	657.91
4b: Avoidance to gF, Avoidance to 2 WM, 2 WM factors to gF.											
	189	534.84	2.82	.90	.92	.93	.86	.82	.076	.130	662.84
4c: Approach to gF, Approach to 2 WM, 2 WM factors to gF.											
	189	478.32	2.53	.91	.93	.94	.88	.83	.070	.100	606.32
4d: Action to gF, Action to 2 WM, 2 WM factors to gF.											
	189	533.51	2.82	.90	.91	.93	.86	.82	.077	.130	661.51

(5) and (6) Personality influences only WM or gF

The remaining sets examined the relations of personality to one of the cognitive variables, either gF or WM. The SEM model depicting four personality factors related to gF was fitted first. The results indicated that three personality latent variables, Approach, Action and Restraint, had significant paths to gF, as seen in Figure 19 (left panel). Table 25 lists the fit indices for this set of models[18]. The Avoidance factor consistently had the weakest relationship to any of the cognitive latent factors suggesting interestingly that Avoidance characterized by hesitation and including anxiety rumination do not influence cognitive performance.

[18] See Figure 28, Appendix A for the full model.

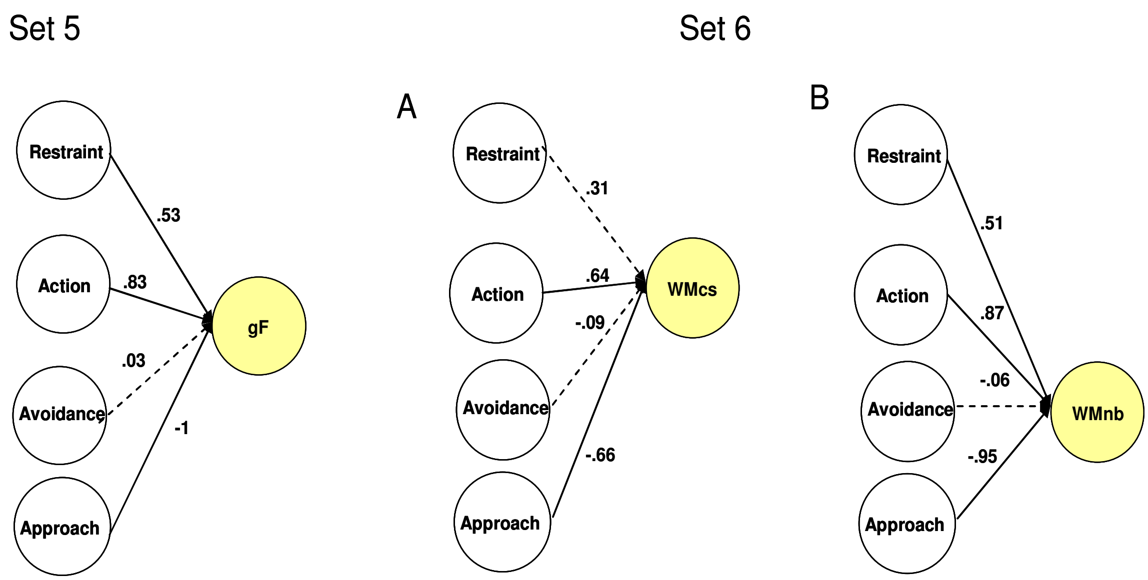


Figure 19. Schematic representation of SEM for Sets 5 and 6. Note: personality latent factors correlate with each other in these models.

The next set of models examined the individual relation of personality factors to either WMcs (model 6a) or to WMnb (model 6b in Figure 19). For WMnb the path from Avoidance to WM was not significant, whereas the remaining three personality factors had significant paths in the same way as the gF model in the left panel. Approach had the strongest relationship, followed by Action, then Restraint, consistent with the previous models. In WMcs model, the path from Restraint did not reach significance.

Table 25. Structural Models of Working Memory, Fluid Intelligence, and Personality, sets 5 and 6 (N=309).

Model	*df*	χ^2	χ^2/df	NFI	NNFI	CFI	GFI	AGFI	RMSEA	SRMR	AIC
Set 5. 4 personality to gF											
PgFSEM	87	248.96	2.86	.90	.91	.93	.91	.86	.078	.059	346.96
Set 5. 4 personality to gF, no correlations between the latent variables											
PgFSEM	87	248.96	2.86	.90	.91	.93	.91	.86	.078	.059	346.96
Set 6a: 4 personality to WMcs											
P-WMcs	118	367.14	3.11	.87	.88	.90	.88	.83	.083	.110	473.14
Set 6b: 4 personality to WMnb											
P-WMnb	118	350.16	2.96	.87	.88	.91	.89	.84	.070	.110	456.16

Discussion of the Joint Personality – Cognition Models

The SEM models tested in this section clearly indicate the differential relationship between the cognitive and personality latent factors with Approach having the strongest negative relationship with gF, WMcs, and WMnb followed by smaller effects between Restraint and the three cognitive constructs. Furthermore, Avoidance had positive relationship with gF, and no relationship with any of the WM factors (sets 1-4), whereas Action had positive relationship with both WM constructs, but none with gF. Besides Approach that had moderate correlations with cognitive constructs, the relations between other personality constructs and gF, WMcs, and WMnb were twice as small in magnitude as Approach. The results discussed thus far indicate that personality and higher-order cognition have a diverse but consistent relationship across models, even though the magnitude, besides Approach, is small in range[19].

[19] This relationship changes slightly after adding the error correlation between the OSPAN and RSPAN tasks to the model.

N-back Trial Type Discussion

Kane et al. (2007) found that lures had the greatest influence on the number of false alarms and incorrect responses to targets, indicating that this type of trial requires high level of cognitive control. As different features or behaviors may be important on a trial-by-trial basis and because of the importance of different trial types on cognitive task performance, additional analyses examined the correlations between personality and three types of n-back trials (targets, nontargets, and lures). Table 26 displays zero-order correlations between the n-back overall d', three trial types, and personality traits. The d' measure of sensitivity from the three n-back tasks consistently correlated with four personality traits: positively with Prevention and Agreeableness, and negatively with BASD and Conscientiousness. This implies that these four traits may be important in n-back performance. The spatial 3-back task correlated with three more personality scales: negatively with BASF, BASR and the AOP scale. This would suggest that being cautious might benefit performance on lure trials.

Across the three trial types, lures had the most consistent correlations with personality traits: negative with BASD, AOD, and Conscientiousness, and positive with Prevention. As seen from the table, lures had somewhat similar patterns of correlations with personality variables as the overall d'. As a reminder, lure trials required answer "no" for items with correct stimulus but in the wrong slot, e.g. 2-items back instead of 3-items back. Nontarget trials that required answer "no" to an item that was different from the target had quite consistent correlations with Prevention, and negative with BASD. Finally, target trials that require answer "yes" for the correct recognition that the item on the screen is the same as three items back, had the least number of correlations, mainly negative correlations with BASD.

Table 26. Correlations between personality traits, the n-back task performance (d'), and n-back trial types (N=309).

Trait	*d' let*	*d' nu*	*d' sp*	*Ntg let*	*Tg let*	*L let*	*Ntg nu*	*Tg nu*	*L nu*	*Ntg sp*	*Tg sp*	*L sp*
BIS												*.12*
BASD	**-.23**	**-.18**	**-.31**	**-.21**	**-.16**	**-.15**	**-.21**	*-.13*	*-.13*	**-.25**	**-.27**	**-.17**
BASF			**-.15**	-.11						*-.11*	*-.14*	
BASR			**-.19**				*-.13*			**-.20**	*-.13*	
PRE	*.12*	*.13*	**.18**	**.16**		*.11*	**.17**		**.19**	**.17**	*.12*	*.13*
AOD						**-.16**	*-.11*		*-.13*	**-.17**		**-.20**
AOF										*.12*		
AOP			*.11*									
N												*.12*
O											*.12*	
A	*.12*	*.12*	*.11*		*.13*			*.11*				
C	*-.13*	*-.12*	*-.11*			**-.15**	*-.13*		*-.13*	**-.19**		**-.18**

BIS = behavioral inhibition scale, BAS = behavioral activation scale, where BASD = Drive subscale, BASF = Fun Seeking, BASR = Reward Responsiveness; PRE = prevention focus; AO = action orientation, where AOF = failure related, AOD = decision, AOP = performance; N = Neuroticism, O = Openness; A = Agreeableness; C = Conscientiousness. Ntg = nontargets; Tg = largets; L = lures; let = letters; nu = numbers; sp = spatial. Significant correlations are marked in italics ($p < .05$) and in bold ($p < .01$). Extraversion had no relations with n-back trials.

Within the cognitive domain, the nontarget and lure trials (both requiring answer "no") had the highest correlations across the four gF tasks, consistently higher than with the complex span tasks (see Table 27). The spatial n-back had slightly higher correlations than the n-back letters and numbers with the target trials.

Although the magnitude of correlations was small to moderate, the results indicate that specific personality traits relate to the performance on subsequent trial types across the three n-back tasks. That is, greater lure accuracy means having higher scores on Prevention, Agreeableness, and lower scores on Conscientiousness and BASD. Could that combination of traits be in some way advantageous in cognitive task performance?

Similarly, correlations of different trial types within the cognitive domain differ among the three trial types. An important fact is also that the correlations are based on a different number of observations across the three trial types, because of a varied frequency of trail types. Lures are the least frequent and occur only 7 times across the 48 trials within a block. Note also, that correlations in Table for lures are quite strong for such a small number of observations.

Table 27. Correlations between fluid intelligence and complex span tasks, the n-back task performance (d'), and n-back trial types (N=309).

Variable	*Ntglet*	*Tglet*	*Llet*	*Ntgnu*	*Tgnu*	*Lnu*	*Ntgsp*	*Tgsp*	*Lsp*
Ship	.502		.372	.485		.383	.566	.312	.450
Raven	.508		.398	.404		.311	.471	.400	.391
LetSets	.484		.410	.407			.399	.373	.354
NumSer	.424		.325	.424		.361	.512	.433	.466
OSPAN					.330		.340	.328	
SSPAN	.393		.301	.306			.428	.400	.326
RSPAN	.413			.355	.320		.473	.380	

Tg = largets; L = lures; let = letters; nu = numbers; sp = spatial; Ship = Shipley; LetSets = Letter Sets; NumSer = Number Series; OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span. Only shown correlations >.300; all correlations significant at $p<.01$.

When taking into account focus of the four personality instruments on different aspects of personality, the following interpretation of the four traits could be offered. The negative correlation of the lure trials of the three n-back tasks with BASD would suggest that better performance on the lure trials could stem from motivational premises of being less firm in pursuit of desired goals. If one assumes that restraint could lead to slightly more time needed for processing the available information and comparing the two items, this explanation could be plausible. This could refer to the retrospective aspect of personality represented here by the positive correlation from the Prevention focus, defined by traits of safety and vigilance. This suggests that being cautious leads to better performance on the lure trials. Another important personality trait in this particular case was a negative relationship of the lure trials with AOD (demand-related), the action orientation subscale related to prospective planned behaviors. The negative relation with AOD suggests better performance on the lure trials for indecisive individuals whom it takes longer to decide about initiating behavior or those who hesitate to take an action. Finally, a general personality describing typical person behavior was represented by Conscientiousness, which had a negative relationship with the performance on the lure trials. That means that less order, less determination, and less persistency indicates in this particular situation higher rate of correct rejection of lures. Together, the four traits represent aspects of personality related to persistence, decisiveness, hesitation, determination, or security focus, as well as related behaviors, which could result in similar behaviors or consequences related to cognitive task performance, and might serve as a profile that characterizes particular schemata or pattern of behavior related to cognitive task performance on specific type of trials. Indeed, a correct rejection as a response to the lure trial requires hesitation and restraining from behavior, especially if this kind of trial is very infrequent.

The spatial n-back was the last in the series of the three n-back tasks. Interestingly, as personality traits showed consistent but at the same time differential relations across the n-back trial types, the spatial version had correlations with more personality traits than the two n-backs performed before the spatial task. This might suggest that when the time passes, additional personality traits become important in cognitive task performance. It should be noted that the last n-back task (spatial) performed in the series of n-back tasks might stem from various factors, such as the order effect, domain specificity of the task, or practice related to the knowledge of the procedure shared by the three n-back tasks. Additional factors that might be important here and might reflect or explain this pattern of correlations are tiredness, monotony, and time-on-task (e.g. long session versus short session in a different study). As discussed earlier, multiple types and variations of n-back tasks exist in the literature. The present results reflect only what can be said about the specific 3-back task characterized by high demands on cognitive control, with different types of stimuli. As stated by Kane et al., (2007, p.621), "n-back captures variance from different constructs depending on the parameters of its embedded memory test".

NEO-PI-R Facet Correlations with Cognitive Measures

Table 28 displays correlations between facets of the five traits from the NEO-PI-R questionnaire and cognitive tasks[20]. Although some of the correlations were at the $p<.01$ level, overall all were small in magnitude. The Letter Sets that requires making decision about which item does not belong to the remaining items in the series, had the highest number of correlations with the NEO-PI-R facets. Four of them were negative correlations with Neuroticism facets, Anxiety, Depression, Self-Consciousness, and Vulnerability, and two positive with Openness facets, Actions and Ideas (see DeYoung et al., 2005). The number series requiring series completion had three negative correlations with the Neuroticism facets, Anxiety, Depression and Self-Consciousness. Thus, the more a person gets frustrated, nervous, hopeless, worries and do not copes well with

---

[20] Within-facet correlations ranged from .190 to .612 for Neuroticism, from .236 to .554 for Extraversion, from .105 to .479 for Openness, from .148 to .447 for Agreeableness, and for Conscientiousness from .305 to .645.

stress, the worse the performance on the two gF tasks involving series completion (Number Series) or finding non-match within a series (Letter Sets). Conversely, the more a person likes novelty, experiencing variety of activities, and is intellectually curious and open-minded, the better the performance.

Performance on Shipley and Raven tasks shared correlations with the Values facet from Openness. In addition, the correlations between Raven and Gregariousness facet from Extraversion approached significance (p=.051). When comparing the patterns of correlations from Table 28 with the correlations between the higher-order personality and cognitive constructs, the sign of the correlations seems to be negative for gF (but within the latent correlations it is positive with Avoidance), and positive with Openness (again, negative with Action latent construct). The overall pattern of correlations would suggest also the potential influence of the time limit. In the Number Series, the participant has 4.5 minutes to complete 15 series, whereas in the Letter Sets, the participant has to recognize a non-match in 20 items within 5 minutes period. Interesting fact was consistent correlations between the Values facet and the two gF tasks, Shipley and Ravens. Note that both tasks were administered over two different sessions. The complex span tasks had minuscule number of correlations with the NEO-PI-R facets. The only significant were negative correlations between the SSPAN and Depression facet from Neuroticism and Order facet from Conscientiousness. Another correlation was between the RSPAN and the Trust facet from Agreeableness trait. These correlations would suggest the importance of confidence, organization, precision, and not being cautious to achieve better scores on the SSPAN and RSPAN tasks.

Table 28. Significant correlations between the facets of the NEO-PI-R, fluid intelligence, complex span tasks, and the n-back task performance (d') (N=309).

	Ship	Raven	Let Sets	Num Ser	OSPAN	SSPAN	RSPAN	Nb lett	Nb num	Nb spat
N1			-.144*							
N3			-.150**	-.159**		-.115*				
N4			-.183**	-.131*				-.168**		
N6			-.127*	-.119*						
E2		.111†								
O4			.129*							
O5			.131*							
O6	.139*	.135*						.127*	.153**	
A1							.114*			
C2						.132*				

N = Neuroticism; E = Extraversion; O = Openness; A = Agreeableness; C = Conscientiousness; Ship = Shipley; LetSets = Letter Sets; NumSer = Number Series; OSPAN = Operation span; SSPAN = Symmetry span; RSPAN = Reading span; nblett = n-back letters; nbnum = n-back numbers; nbspat = n-back spatial. NEO-PI-R facets: N1 = Anxiety; N3 = Depression, N4 = Self-Consciousness, N6 = Vulnerability, E2 = Gregariousness, O4 = Actions, O5 = Ideas, O6 = Values, A1 = Trust, C2 = Order. Only shown significant correlations, ** (*p*<.01), * (*p*<.05), † (*p*=.051).

The correlations within the three n-back tasks were also infrequent. The n-back letters correlated negatively with the Self-Consciousness facet from Neuroticism. In addition, the n-back letters and numbers (similarly to the Shipley and Ravens) correlated with the Values facet of the Openness trait. The relevant adjective from the Values facet that could relate the correlations with the three cognitive tasks is "unconventional" (Costa & McCrae, 1992) as the Shipley, Ravens, and then the first two n-back tasks require novel and non-cautious solutions to solve a problem. Two cognitive tasks, OSPAN and n-back spatial did not correlate with any of the NEO-PI-R facets.

Variations across the groups differing in WMC

One of the goals of examining the variations across the groups differing in WMC was to investigate whether individuals differing in their WMC have disparate relationships within the cognitive and then personality domains. This was followed by investigation of whether both groups differ in the personality structure and cognition relationship. One way to accomplish this goal was to use the CFA and SEM models developed earlier in order to fit the same structures, but split the sample into higher and lower WMC span groups accordingly to the three complex span *z*-composites. The question was whether, between individuals with lower WMC in comparison to the higher WMC group, there is a differential relationship between personality and cognition at a latent level as well as within the two domains.

Three pairs of models (see Figures 20, 21, and 22) compared the model structure and fit for the two groups (higher and lower WMC). The models that were fitted were the same as the final models introduced in previous sections. The first pair compared the cognitive CFA model across the two groups (see Figure 20). There was a substantial difference in the loadings of the three complex span tasks between the two groups. The model for the higher half of the sample clearly had problems with interpretation as the paths from WMcs were >1. This was probably caused by more restricted range of scores achieved by the higher than the lower group. A small difference was also seen in the loading of the n-back numbers, which is lower for the higher WMC group.[21]

[21] For higher/lower CFA cognitive models, LISREL did not propose any modifications to the higher group's model, but proposed three modifications to the lower group model, including correlating error between the OSPAN and RSPAN, then moving the SSPAN to the gF latent factor, and the WMnb factor. Second and third modification did not improve the model, but adding the error correlation did. This is interesting from the perspective of modifications where LISREL proposed to correlate OSPAN-RSPAN error for the lower but not for the higher group.

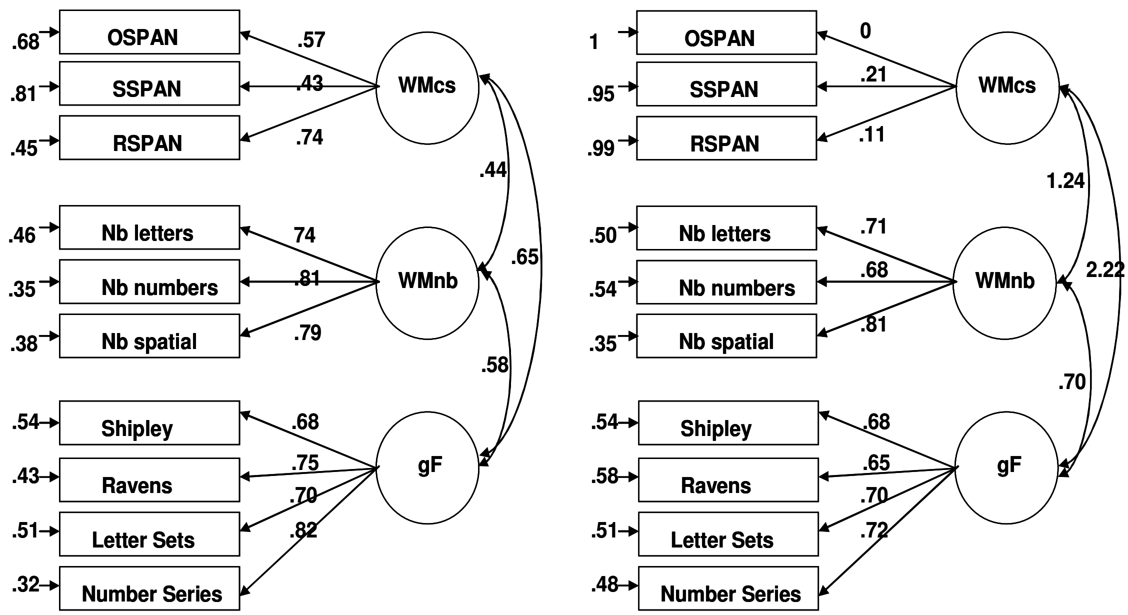


Figure 20. Comparison of two CFA cognitive models between lower half (left panel) and higher half (right panel) of the sample.

The next pair of models (Figure 21) depicted the best fitting version of the cognitive SEM model. The two groups seem to differ in the contribution of the WMnb and WMcs constructs to gF. The lower WMC group had a higher relationship between WMcs and gF than with the WMnb construct. The opposite happened for the higher WMC group. Note Shipley’s much smaller loadings in both models in comparison to the previous models. The last pair of models (Figure 22) compared the best fitting personality model for the higher and lower WMC groups. The two models were quite similar. What differentiated them was the magnitude and significance of path correlations between Restraint and Action, and between Action and Avoidance. Thus, only within the relationship between these two pairs of constructs we could search for possible differences between the groups in personality structures.

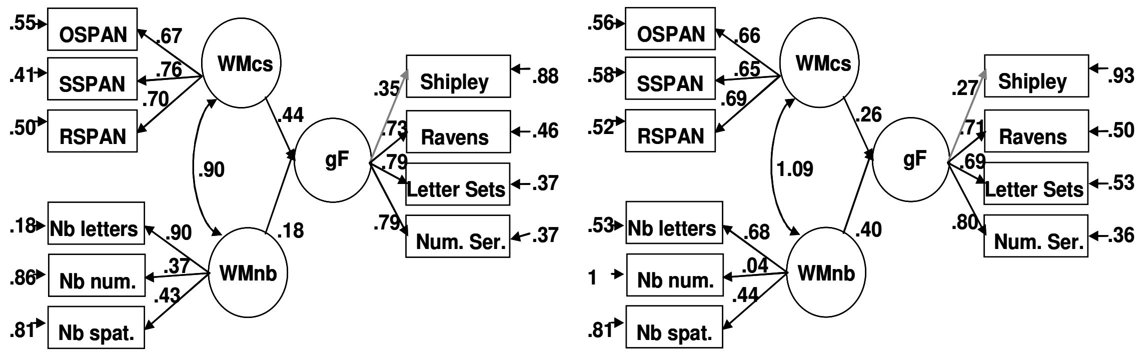


Figure 21. Comparison of two SEM cognitive models between lower (left panel) and higher half (right panel) of the sample.

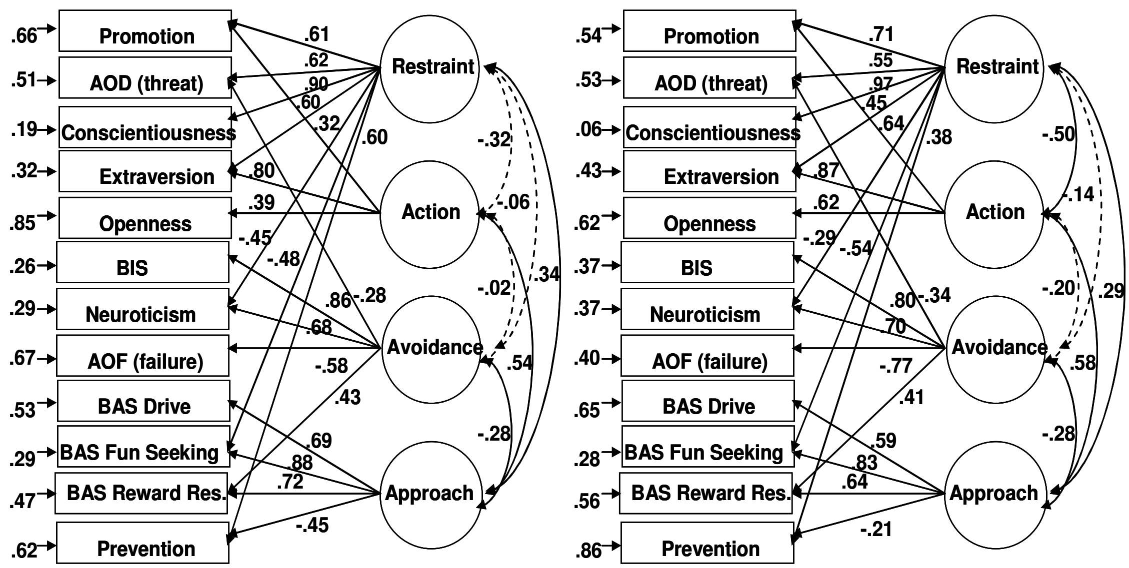


Figure 22. Comparison of two personality models split based of the 3z scores from three WMcs tasks for lower and higher half of the sample.

In short, specific differences were observed across the pairs of models. The interpretation could be difficult because of possible factors that could influence the results for the two groups. One possible factor could be the characteristic of the present sample, which could possibly cause very small loadings within the WMcs construct for the higher groups, or correlations > 1 between the constructs (for details considering the two sub-samples see Appendix B, Table 33, Figure 29, 30). [22]

The objective of the next analysis was to examine, discriminate and compare personality profiles of Higher and Lower WMC groups in order to determine whether the two groups differ substantially in their personality profiles and dominant traits. Twelve personality traits were used as predictors of cluster membership to group individuals into clusters. Parallel analyses were conducted for the higher and lower WMC groups that were based on the 3-z complex span tasks, yielding two sets of results. The resulting clusters were then compared between the two WMC groups to determine whether personality profiles within the clusters differ between the groups.

Appendix C comprises detailed results, relevant tables and figures concerning cluster and discriminant analyses. Overall, the cluster and discriminant analyses indicated that both Higher and Lower WMC groups are best described by four personality profiles and that these profiles despite certain similarities (e.g. between the patterns of personality organization between clusters 1 and clusters 2 for the two groups), when comparing respective clusters, the two groups differ in specific personality traits. The BIS, BASF, Openness, Conscientiousness, and Prevention differed across the pairs of compared profiles most often. Figure 23 depicts the four clusters for each group.

[22] For the higher/lower groups CFA personality model, LISREL proposed two modifications (besides error correlations) for the higher group model: AOD (loading .30; RMSEA lowered from .097 to .092) and Conscientiousness (loading = .34, RMSEA=.093; did not improve when added as a second modification) to Action. No modifications were proposed for the lower group.

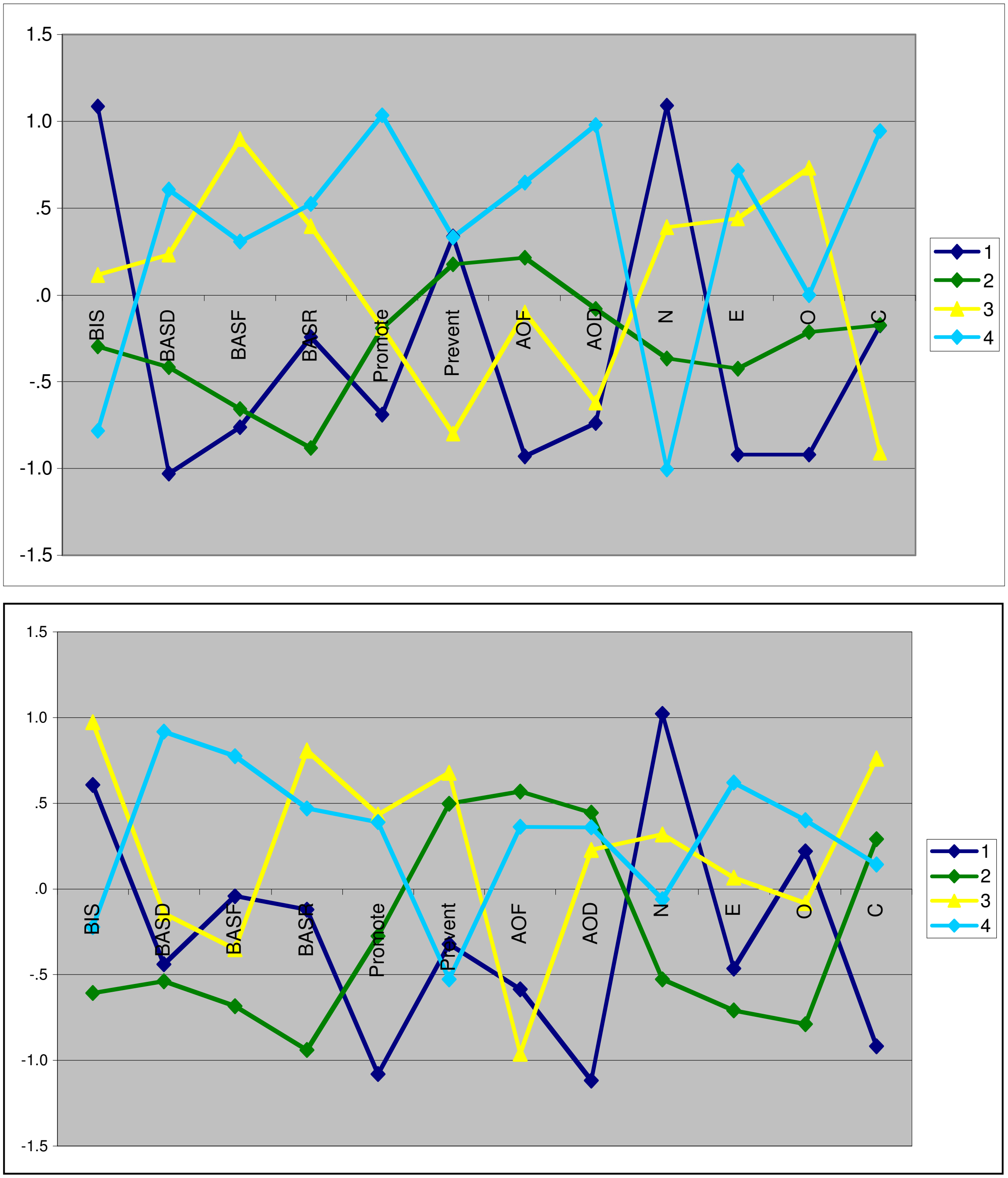


Figure 23. Lower WMC group forming 4 clusters with 12 personality traits. Number of cases in each cluster as follows: 33(1), 34(2), 37(3), 50(4) (upper panel). Higher WMC group forming 4 clusters with 12 personality traits. Number of cases in each cluster as follows: 17(1), 57(2), 42(3), 39(4) (lower panel). Final cluster centers are reflected in the Y axis, personality traits are reflected in the X axis.

Discussing the idea proposed in the CABA framework (MacCoon, Wallace, & Newman, 2004), attention-balanced individuals allocate resources equally to reward and punishment cues, therefore it might be speculated they might prefer or utilize personality traits and profiles that are more directed towards balanced traits, for example, Conscientiousness, Prevention, Openness, or AOD, as well as be flexible in overt behaviors, with traits like Openness, Extraversion AOF or AOD. In addition, as the reward or punishment cues would not be in their focus, it might be suspected that they would have low levels of BIS or BAS-related traits. If attention-imbalanced individuals prefer to use prepotent responses as a default strategy, this might be a characteristics related to rigid or hesitant traits, such as Prevention, BIS, or Neuroticism.

Although cluster analysis is very useful tool in terms of finding profiles or organization within groups, one potential drawback of this method is some extent of subjectivity concerning choosing the right number of clusters. The present analysis attempted to overcome this drawback by using multiple clustering methods that allowed for making informed decision, and conclude more confidently the number of clusters for each group that makes psychological, interpretational, and statistical sense.

CHAPTER 4

DISCUSSION

The present study addressed number of questions concerning (1) how closely the WMnb and WMcs constructs are related and how strongly they relate to gF, (2) how much the two WM constructs have in common and how this common variance relates to gF, (3) the nature of the relationship among the diverse personality variables pertaining to a higher-order personality structure hypothesized from the literature, (5) the relationship between the resulted higher-order personality and cognitive constructs, (6) whether any personality higher-order factor adds to the prediction of gF by WM (7) differential relationship between personality and cognition in individuals higher versus lower based on the composite scores from the complex span tasks. Supplementary analyses aimed at examining more focused aspects of the relationship between personality and cognition. The first supplementary analysis examined personality in relation to the n-back trial type, and was focused on cognitive task performance on a trial-by-trial basis. Another supplementary analysis investigated correlations between the NEO-PI-R (Big Five) facets and cognition. The next supplementary analysis examined the correlations between the n-back trial type and other cognitive tasks. The final supplementary analysis compared the results across two subsamples.

To answer the posed in the study questions, 317 young adults, GT student population and the community volunteers from greater Atlanta area, 18-30 years old, from which 309 were included in the analyses, performed various WM and gF tasks and completed four personality questionnaires. The questions were primarily investigated via latent variable approach, but also via regression analyses, cluster and discriminant function analyses, and correlations. Overall, the findings indicate that the two WM factors, one formed from the complex span tasks and the other from the n-back tasks, are substantially correlated and related to gF. The two WM factors are best described as two separate constructs, suggesting that the tasks used to build the constructs are specific enough to account for unique qualities and thus justify existence of separate constructs. The hypothesized two- and three-factor personality structure did not describe the data well. A four-factor model seemed to illustrate adequately the data. The resulting joint personality-cognition model comprised seven latent factors, from which three were cognitive and four were personality factors. The results indicate that personality and cognition are related, yet the link differs across higher-order personality factors. For example, Avoidance comprising BAS, Neuroticism, and a negative loading from the AOF (failure related action orientation) as the three leading traits did not relate to any of the two WM factors, but consistently and positively correlated with the gF construct. In contrast, the Approach factor comprising the three BAS scales as the leading traits had consistent negative relations, ranged from -.20 to -.40, with the three cognitive factors. Some of the results were surprising, such as the sign of the relationship between Approach and cognitive latent factors, which was opposite to expected. Another puzzling fact was that a performance related AOP scale did not relate extensively to any other personality traits.

The first part of the first hypothesis stated that the complex span tasks and n-back tasks will not show significant discriminant validity, thus, will represent a common construct. The results suggest that WMcs and WMnb are best described as two separate constructs, as the model with six tasks in one construct fitted significantly worse. Thus, the two factors are less likely to represent one common WM latent variable. The second part of the hypothesis stated that if, as might be suggested by high correlations between the n-back and complex span tasks, the two tasks represent the same construct, then the two WMC latent variables should not differ. If, on the other hand, the complex span tasks and n-back tasks capture different aspects of the WMC construct (e.g. Kane et al., 2007; see also Jaeggi, Buschkuehl et al., 2010), the two WMC latent variables would differ in the relationship to the gF latent construct. The CFA models clearly indicate that neither statement is true. As stated earlier, both WM latent factors are best described as highly correlated yet two separate constructs. This is partly in contrast with Kane et al. (2007) conclusions that complex span and n-back tasks capture different aspects of the WMC construct.

What could possibly cause the differences in conclusions? Kane et al. for their cognitive measure used 3-back letters task and OSPAN as the two cognitive control tasks to compare with, and the Raven task as the measure of gF. The OSPAN task consisted 2-5 word pairs within each trial, whereas in the present study, the range of trials consisted from 3 to 7. In addition, the Raven task was paper and pencil and included 18 odd trials whereas here, all cognitive tasks were computer administered. The present n-backs besides the similar structure and composition of the trial types, were also different in multiple aspects from the n-backs from Kane et al. For example, Kane et al.'s task was twice as long with double the number of trial and blocks, and participants had twice as many trials to practice the task beforehand. In addition, scoring method also differed (Conway et al., 2005). Kane et al. found weak correlations between the OSPAN and 3-

back letter task. In another study, Oberauer (2005) reported weak to moderate correlations between n-back and complex span tasks (see also Jaeggi et al., 2010a, b) whereas Gray et al. (2003) demonstrated strong relation between n-back and the Raven task. Since WM reflects control of interference, could the n-back sequences cause interference that may affect performance? In Oberauer (2005), WMC (four WM tasks, including two complex span tasks) predicted 23-36% of variance in lure accuracy (d'), whereas in another study (Gray, Chabris, & Braver, 2003) with 3-back and Ravens, Ravens predicted performance on lure and target trials (.36). In the present study, the n-back and complex span tasks correlated at a latent level (in a range between .62 and .77) and their zero order correlations oscillated between .279 and .488. Part of this correlation may stem from the similarity of the stimuli between the respective spatial, numerical and verbal pairs of tasks, although the fit of the model with latent variables reflecting content domain was worse than of the model with the three cognitive constructs separated. In part, the similarity may be at a construct level, although again, the CFA model with two separate WM constructs fitted better than the model with a unitary WM construct.

Both WMcs and WMnb were significant and strong predictors of gF in the present study. The consistently high relations between the n-back and complex span tasks indicate construct validity of the n-back in the present study: the three tasks correlated with other WM measures. These results are somewhat similar to Shelton et al. (2009; see also Shelton et al., 2007; Shamosh et al., 2008) who reported the correlations around .50 between the n-back and OSPAN tasks. The present results were in contrast to other studies that report weak correlations with complex span tasks in ranges from .10 to .24, albeit higher correlations with Raven (average about .42; range from .19 to .66; see also

Colom et al., 2008; Kane et al., 2007; Oberauer, 2005; Roberts & Gibson, 2002). The correlations obtained by Kane et al. (2007) between the 3-back and OSPAN were very weak, which lead the authors to conclude that the n-back and complex span tasks do not reflect a single construct. In addition, both types of the WM measures accounted for independent variance in gF. Importantly, the n-back predicted gF only at higher levels of load, which would reflect the importance of attention control reflected in more difficult versions of the n-back task (Jaeggi, Buschkuehl et al., 2010; Kane et al., 2007).

The Common factor created from the six WM tasks would also suggest existence of substantial shared processes related to cognitive control or executive attention between the complex span tasks and the n-back tasks. Yet, the divergent validity of the two kinds of tasks was shown in regression in the amount of the unique variance in gF predicted by the n-back and complex span z-composites, and because the two WM latent variables were better described by two constructs than a one joint construct.

An important aspect of the n-back task itself that should be briefly discussed is reliability. Studies reporting reliability estimates for the n-back tasks range from .02 to .91, and only 2- and 3-back versions of the n-back task achieve reliabilities higher than .80 (Jaeggi et al., 2010; also Shelton et al., 2009; Friedman et al., 2006; Friedman et al., 2008; Oberauer, 2005; Kane et al., 2007). The reliability of the n-back tasks in the present study ranged from .757 to .815, in accordance with the range of reliabilities reported for more demanding versions of the n-back.

Another aspect concerning the results is the fact that most of the cognitive models in this study include two versions of the WMcs latent structure, one with no correlated errors, and the second with one correlated error between the OSPAN and RSPAN tasks.

The reason for including both versions of the model is that (a) the fit of the model with correlated error was better than with no correlated error for each model tested, but (b) inclusion of correlated error in some instances changed the magnitude of the relationship between the WMcs and WMnb constructs as well and, in some instances, the magnitude of path correlations between a number of the personality latent constructs. For example, the Avoidance rather than Approach factor had significant path to gF. The arguments exist for and against of using one model structure over the other model structure. To get a full and fair picture of the differential relationships within cognitive and between cognitive and personality domains, both versions are reported here. In the model with correlated error, the differences between the amount of variance accounted for by the predictors for WMcs was uniquely accounting for 36% of variance in the criterion gF construct, whereas it was almost 10% for the WMnb. In contrast, both WM latent factors accounted uniquely for roughly the same amount of variance, 20%, in the criterion gF in the model with no correlated error. Kane et al. (2004; Figure 3, p. 202) also compared two sets of models (one- versus two-factor WM model) where in one set of models they allowed four errors to correlate whereas in the second set of models they fitted conservative versions, with no correlated errors. Kane et al. concluded that the models without correlated error provided worse fit than the models with correlated errors, which was consistently revealing in the present study as well. However, even though adding the correlated errors was theoretically justified, this change affected the pattern of results in their study. As a result, they initially took into account both sets of models but based their conclusions on a more conservative set of models.

As the present research involved investigation of multiple aspects of the cognition, personality, and cognition-personality relationship, and despite providing additional evidence across the three domains of interest, this work identified a number of remaining questions and lines of research to pursue in the future. Examples include a better understanding of (1) the inconsistent sign of correlations between the BAS scales and cognitive variables, (2) the positive relation of Agreeableness and Prevention with gF and lure trials from the n-back tasks (2) substantial relationship between the WMcs and WMnb tasks and their relationship to gF (3) the high influence of error correlation between the OSPAN and RSPAN tasks, influencing the magnitude and ratio of the relationship between complex spans and n-backs on the overall results, (4) difficulty in replication of the simple personality latent structures and factor analytic models that have been shown in the literature (e.g. Digman, 1997).

The disparate relationship between personality and cognition can be illustrated by the pattern of results below. Two latent personality constructs, Approach (including the BAS scales) and Restraint (including Promotion and Conscientiousness), had consistent negative correlations with all three cognitive constructs (gF, WMcs, and WMnb). In contrast, Avoidance (including BIS and Neuroticism) had a positive correlation with the gF factor. Finally, Action (including Extraversion and Openness) had a positive correlation with both WM latent factors, but no relation to gF. In fact, the four personality constructs reflect multiple combinations through which the two domains may be related (to one or both constructs simultaneously). Most crucial is, though, that two disparate domains comprising diverse measures showed significant relation, allowing a conclusion that personality and cognition are, in fact, related. The complexity of this relationship was also captured by the four sets of SEM models. Interestingly, it was with the exception of the Approach factor that alters the relationship between cognitive constructs as also seen in zero-order correlation tables throughout the different aspects of the study, with its consistent relation to virtually all cognitive measures.

The choice of particular measures for this study could be seen both as strength and as a limitation. However, numerous arguments explain the reasons for the particular choice. The premise of the present study was to examine specific aspects of cognition and specifically attention control and gF, and thus the choice of the two specific types of WMC tasks. In the personality domain, carefully chosen questionnaires were chosen as such to examine specific relationships and dependencies within and between the latent constructs. At the same time, narrowly defining the examined constructs might be a limitation related to the difficulty of generalization of the results to other, more broadly defined cognitive and personality constructs.

The latent variable approach has also its strengths and weaknesses. On the one hand, latent variable approach is a powerful tool in search and investigation of the a-priori hypothesized relations between different constructs at a latent or abstract level. The importance of this approach is its reach above the level of singular tasks to allow for greater generalization and discussion at the level of constructs, not only the tasks. On the other hand, the definition and characteristic of the latent construct highly depends on the structure, features, and number of the manifest variables, and the similarity of the tasks defining latent constructs. As the relations between latent variables highly depend on the way the constructs are defined, caution is needed when interpreting the results and making conclusions. Another important aspect of latent variable approach is the existence of multitude possible alternative models that could account for the present data equally well as the model accepted in the study. Finally, the constructs rely on the properties of the measurement instruments, which include both cognitive tests and self-report questionnaires. Thus, the results can be attributed only to the processes, relations, and constructs represented by these particular measures.

The strength of the present study within the personality domain was to use multiple questionnaires across wide range of aspects of personality, including motivational-emotional, general, prospective and past experience related personality traits that demonstrated the ability to form a coherent latent structure and consistent relationships between and within the constructs. Within the personality domain, the limitation of the present study is using self-report measures of personality. Yet, all the measures incorporated in the present study are used across domains of psychology and demonstrate good reliability.

Additional strength of this study is to use large, variable, and diverse sample comprising communities from multiple universities and colleges as well as Atlanta community volunteers with roughly an equal split and close to half/half split across genders (refer to Tables 29, 34 and Figure 29 and 30 in Appendices). The specificity of the study associated with choosing a narrow definition of the cognitive constructs caused some of the variance having its source in task-related and administration-related similarities between the sets of tasks. On the contrary, the narrow definition of the constructs was desired and intended in this context as the question was specifically targeted to particular types of WM tasks. In addition, the narrow definition and focusing on specific aspects of WM construct may provide a clearer understanding of these specific relationships. The project was encouraged by lack of unequivocal conclusions from the literature but also by the fact that the existing literature suggests specific relations between personality and WM task performance as well as indicates that the brain areas and neurotransmitters are suggestive of the biological underpinnings of the relationship between cognition and personality.

Future studies may examine in more detail topics related to the various aspects discussed throughout this study. First topic considers the nature of the n-back and complex span relationship within tasks having different structure, e.g. n-back variations, that could gain knowledge about the specificity of the relationship and discuss what processes contribute to the lack of the relationship between complex span and n-back tasks. Secondly, the nature of the error correlation between RSPAN and OSPAN related to its influence on the magnitude of the relationship with other latent constructs. Third, the nature of the personality structure and interplay within and between the traits reflected in the difficulty to achieve a good-fitting model describing relationship between particular constructs. Furthermore, it would be interesting to examine the possibility to exploit the possibilities within neurotransmitter and brain-related projects to provide a deeper understanding of the nature of this relationship. Finally, future studies may focus on the role of situational factors and state-like variables on manifestation of personality traits and dispositions (e.g. Chamorro-Premuzic & Furnham, 2004) as well as their joint influence on cognitive task performance.

The present study offers a diverse set of discussed domains and relationships within a wide range sample, examined via a latent variable approach in a broad sample, allowing for studying relationship between constructs at the general level. Even if the relations between the two domains were not substantial, note that the specific relations have been found, and found at the latent level. Note also that no external manipulations were added, such as anxiety, pressure, incentives, that are known to influence cognitive performance. It might be that the differences at the latent level would be more pronounced if a manipulation would have been added. Note, however, that the present study explicitly was intended to examine the link between personality and cognition with no manipulations, to extend the knowledge and understand the basic link between personality, working memory and fluid intelligence.

In short, the results showed that 1) two types of working memory tasks are related but best described as two separate factors, which suggests that they may tap partially overlapping cognitive processes 2) the overall relation of the two types of working memory tasks to fluid intelligence is similar in magnitude 3) personality structure that resulted from the measures used in this study is best described by four factors depicting different aspects of personality broadly defined as: Self-discipline, Hesitation, Change, and Open-mindedness 4) specific relationships between these four aspects of personality, working memory and fluid intelligence have been found. In particular, Self-discipline and Change aspects were negatively related to fluid intelligence and working memory, Hesitation was positively related to fluid intelligence, and Open-mindedness was positively related to working memory. Thus, the four aspects of personality differentially related to the two cognitive constructs of fluid intelligence and working memory. These and additional analyses suggest that specific aspects of personality might play a role in different types of cognitive tasks.

The results of the present study might serve as a starting point for conducting more targeted studies that could examine the relationships implied here and motivated by the conclusions drawn based on the present research. For example, if we assume that attention control helps problems at extremes of approach and avoidance, we might examine processes (e.g. anxiety) and mechanism (e.g. orienting) related to motivational states and regulated by feedback and previous or future outcome, which also can be related to a trial-by-trial basis, as it was seen in the correlations between the n-back trial types across three successive n-back tasks and personality traits.

CHAPTER 5

CONCLUSION

The present study aimed to clarify the discrepancies related to the strength and the nature of the relationship between WM and personality, replicate and extend the results from the literature concerned with a higher-order personality structure and the relationship between two types of WM tasks and gF. The present study broadens the knowledge and extends the literature by simultaneous examination of different personality and cognitive measures. By using the comprehensive approach, the current project offers a better understanding of the relationship between higher-order cognition and personality. The results indicate the complex relationship between personality and higher-order cognition reflected by disparate interrelations within and between the constructs. Detailed analyses indicated that different personality traits and dispositions relate to different aspects of cognitive tasks and constructs, even on a trail-by-trail basis. Furthermore, diverse personality questionnaires successfully formed a latent structure that showed the nature of the connections and dependencies between traits and dispositions. Finally, the results contributed to the understanding of the relationship between complex span and n-back measures, and their relationship to gF at a construct level. Overall, the diverse aspects of this study show the relationship between personality and cognition from different perspectives, from the construct level to a trial-by-trial basis, and clearly show the feasibility of the link between the two domains responsible for everyday behaviors.

APPENDIX A

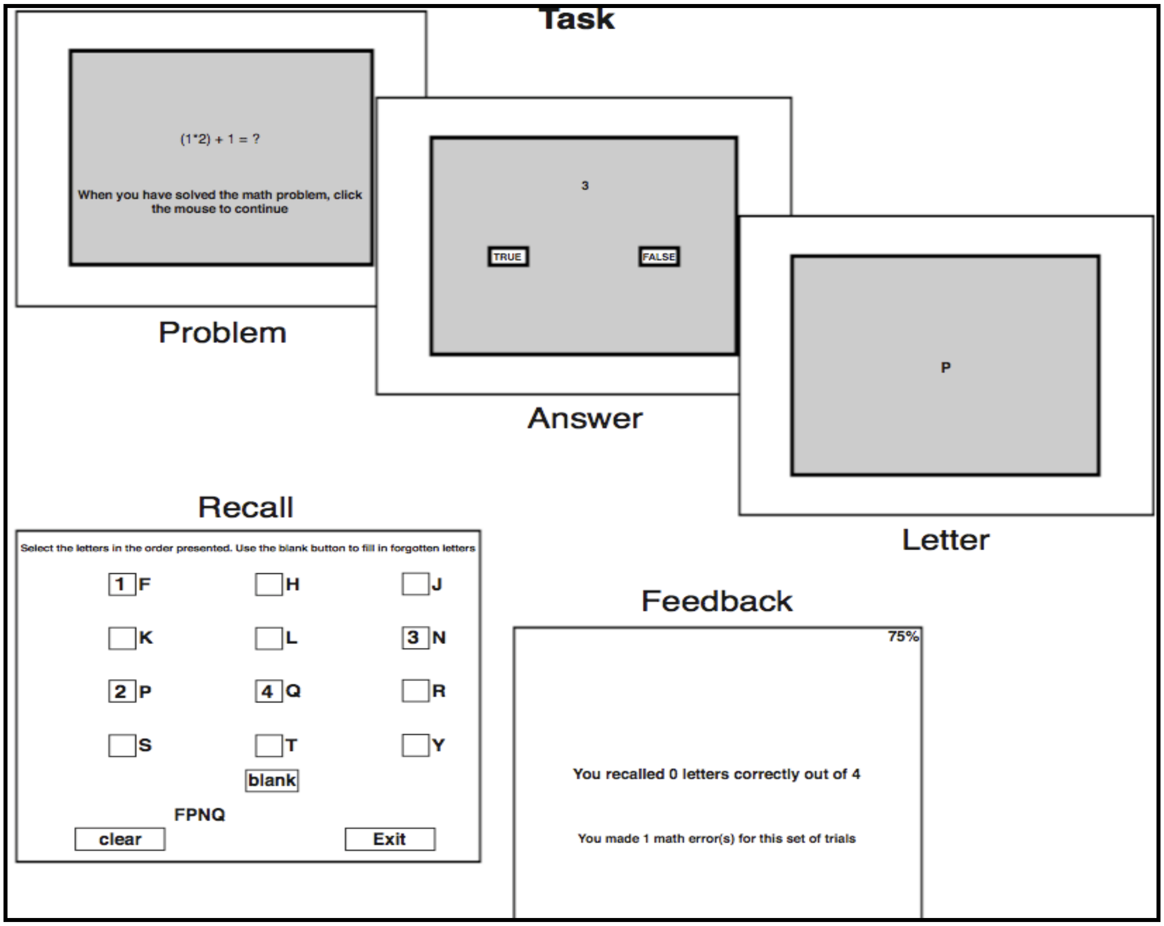


Figure 24. Screenshots of the OSPAN task. Three upper panels illustrate one trial set: a math Problem to solve, judgment Answer whether the result of the equation shown on screen is correct of not; and a Letter to remember later. The lower left panel illustrates the Recall screen for the letters from the latest set. The lower right panel illustrates the Feedback screen that shows only during the practice trials. The task procedure is similar in all three complex span tasks (symmetry, reading, and operation span tasks). Source: Unsworth, Heitz, Schrock, & Engle (2005).

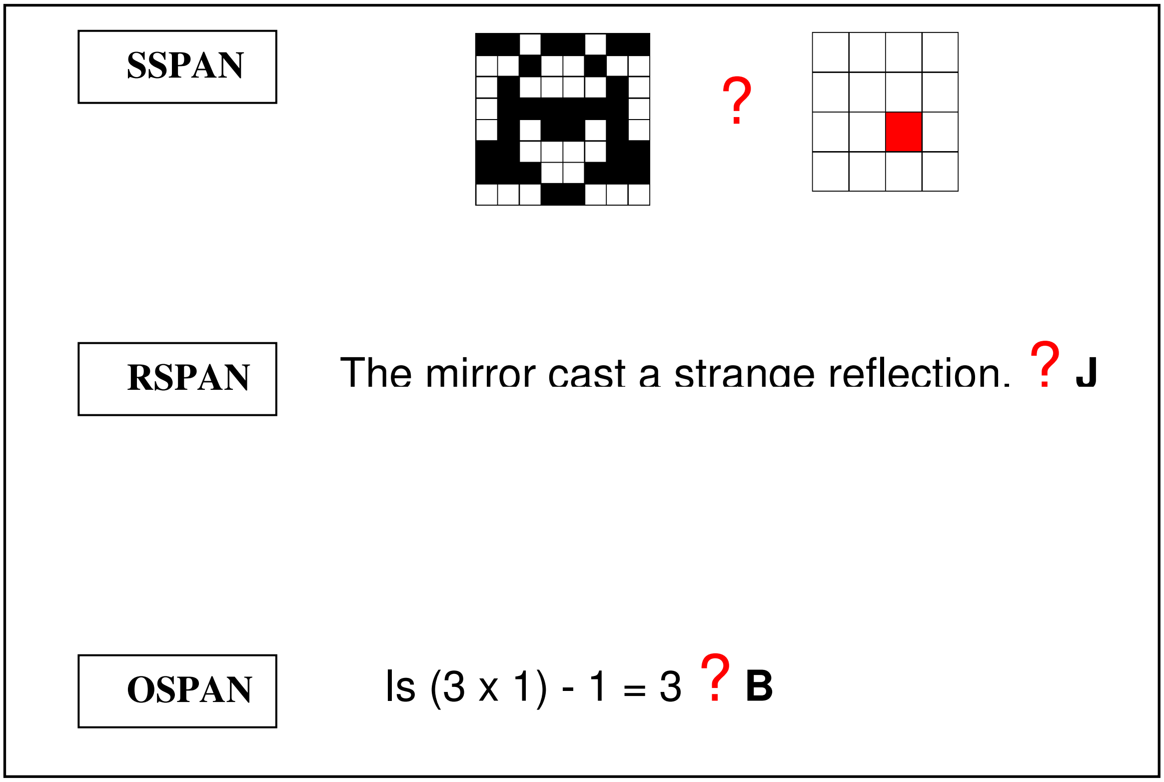


Figure 25. Comparison of the processing and storage components of the three complex span tasks: symmetry span (SSPAN), reading span (RSPAN), operation span (OSPAN).

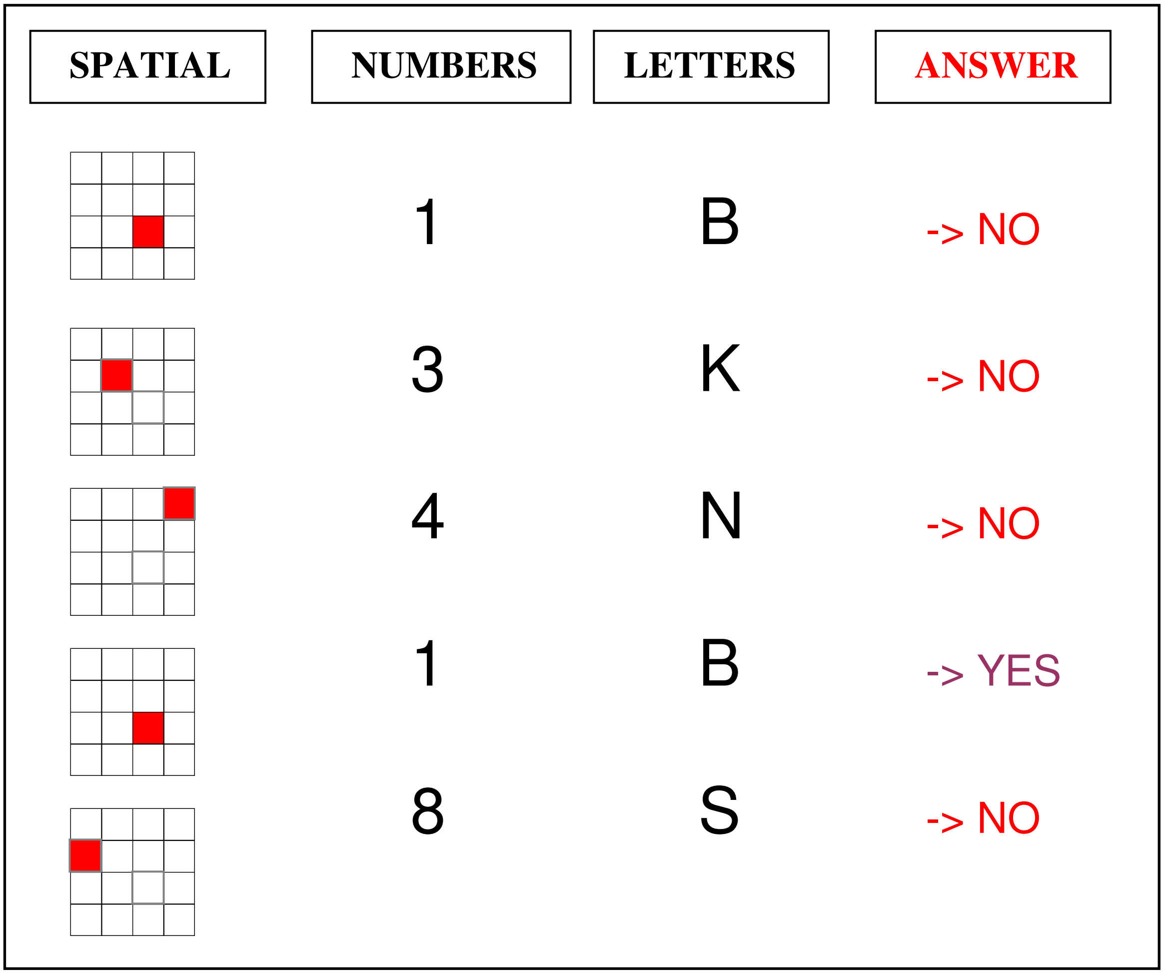


Figure 26. Comparison of five screens from each of the three 3-back tasks (spatial, numbers, letters) with the subsequent answers.

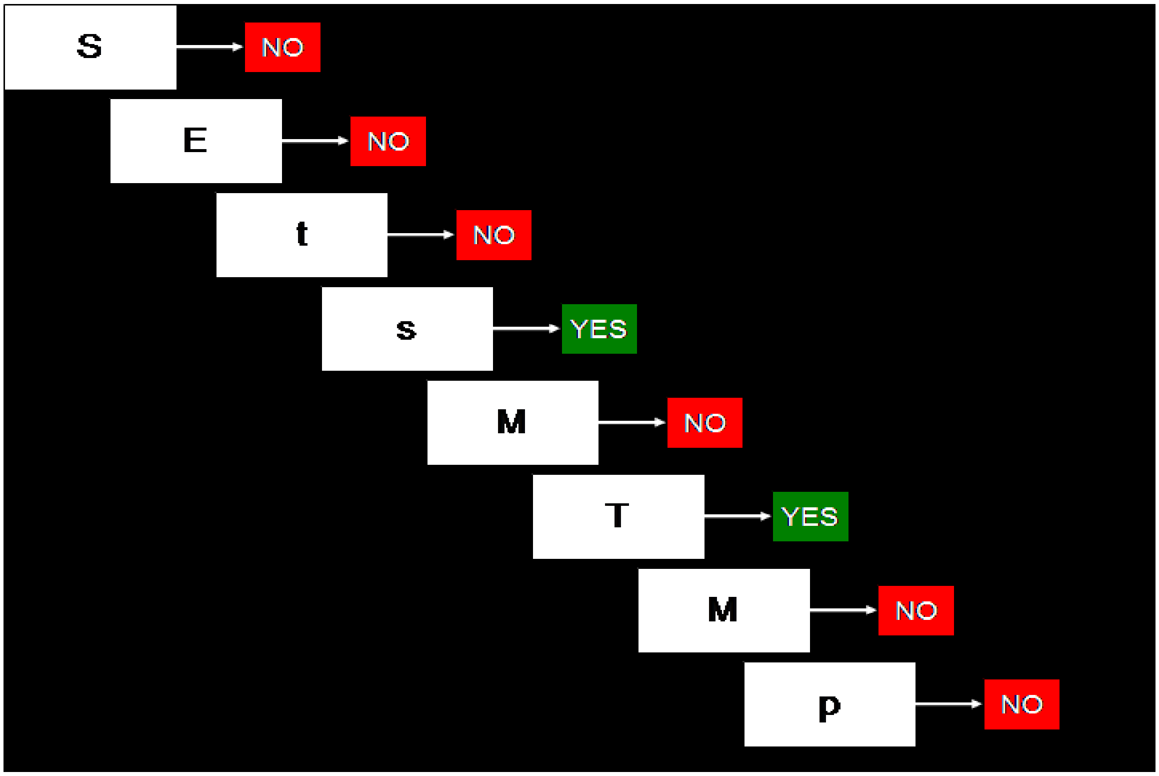


Figure 27. Screenshots of the n-back task procedure. This example shows a 3-back task. Each box represents the screen participant sees at a particular moment. The task is to compare the letter from the current screen with a letter three screens back; hence 3-back task. If the two letters match (regardless of the capitalization of a letter), the participant answer “yes”. If both letters do not match, the answer is “no”. For example, the letter from the fourth screen matches the letter from the first screen, so the answer is “yes”.

Table 29. Characteristics of the present sample. Crosstabulations of span (low, medium, high), gender (female, male), and sample (GT, nonGT).

span * genderFM * sample Crosstabulation

sample			gender		
			Female	Male	Total
GT	Span	Low	6	3	9
		Med	47	50	97
		High	25	34	59
	Total		78	87	165
nonGT	Span	Low	25	24	49
		Med	30	40	70
		High	8	17	25
	Total		63	81	144

GaTech * gender Crosstabulation

		gender		
		F	M	Total
GaTech	GT	78	87	165
	no	63	81	144
Total		141	168	309

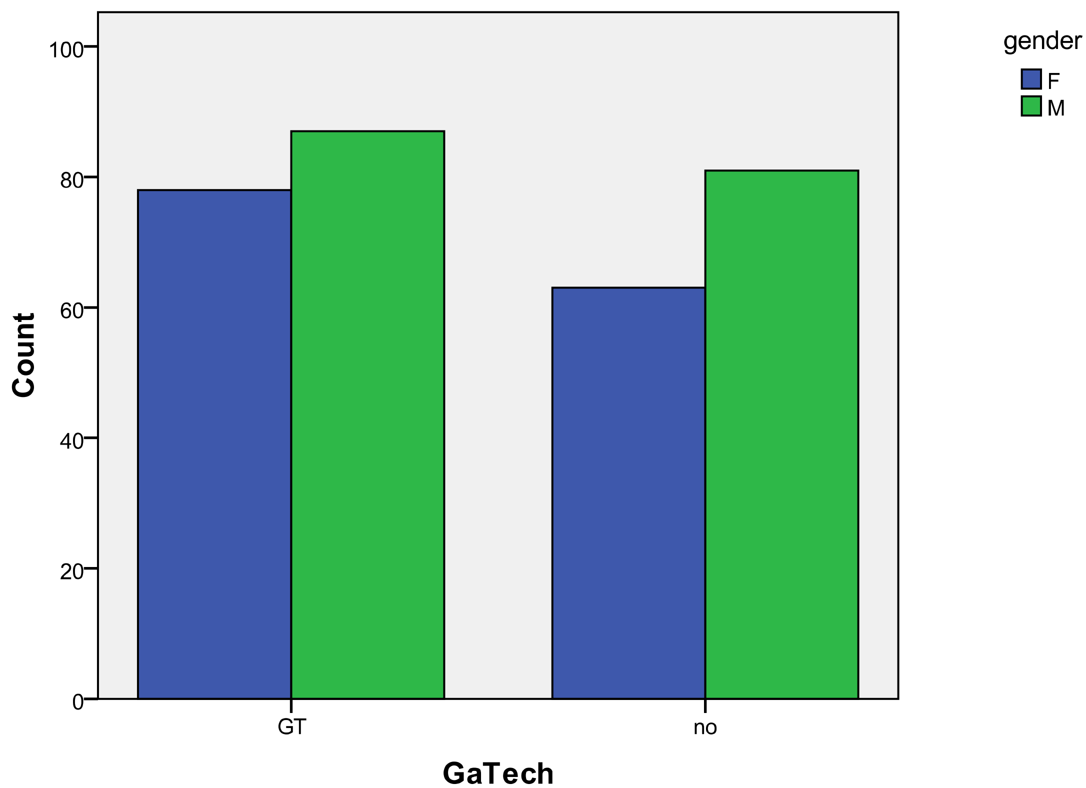


Table 30. Facets of the NEO-PI-R Questionnaire with their selected low versus high scores characteristics. Source: Costa & McCrae (1992).

NEO-PI-R facet	High scores	Low scores
Neuroticism		
1. Anxiety	worry, nervous	calm, relaxed
2. Angry Hostility	anger, frustration	easygoing slow to anger
3. Depression	guilt, hopelessness	absence of these
4. Self-Consciousness	shame, shyness, embarrassment	less disturbed in social situations
5. Impulsiveness	inability to control urges	easy resistance to temptation
6. Vulnerability	low ability to cope with stress, panic	handle difficult situations well
Extraversion		
1. Warmth	friendly, affectionate	reserved, distant
2. Gregariousness	enjoy others' company	loners, avoid social stimulation
3. Assertiveness	dominant, forceful	staying in the background of leadership
4. Activity	energetic, keeping busy	relaxed in tempo
5. Excitement-Seeking	excitement, stimulation	no need for thrills
6. Positive Emotions	joy, happiness, excitement	less high-spirited
Openness		
1. Fantasy	imagination, fantasy	prosaic, on-task-oriented
2. Aestetics	art appreciation	insensitive to art
3. Feelings	sensitive to own emotions and expressions	lower intensity and importance of experiencing emotions
4. Actions	experiencing variety of activities, novelty	stick with tried-and-true
5. Ideas	intellectual curiosity, open-mindedness	limited curiosity
6. Values	openness to different values, unconventional	traditional, conservative
Conscientiousness		
1. Competence	effective, capable, self-esteem, locus of control	unprepared
2. Order	neat, well-organized	unable to organize
3. Dutifulness	conscience, ethical principles	casual, unreliable
4. Achievement Striving	high aspiration, hard working towards the goal, workaholism	lazy, no ambition
5. Self-Discipline	motivation, ability to motivate yourself	procrastination, quitters
6. Deliberation	cautious, deliberate	hasty, spontaneous, makes decisions fast

Table 31. Dual theory approaches and hypothesized integration of personality measures into higher-order factors.

Approach (task)	Scale and characteristics		References	Theory	Sample questions
Affective states (BIS/BAS)	**Description**: Action control related to motivation. The scale represents reactivity measured by two affective personality traits, behavioral activation and inhibition, associated with individual differences in arousal levels related to emotional reactivity. The BAS assesses the strength of behavioral activation (approach motivation) system, sensitive to reward. The BAS scale comprises three subscales: Drive, Fun Seeking, and Reward Responsiveness. It can be compared with characteristic features of Extraversion, sociability, and positive affect. The BIS scale describes the strength of behavioral inhibition (withdrawal) related to sensitivity to threat. Its characteristic features are similar to Neuroticism, social anxiety, and shyness.				
	Behavioral activation	**Behavioral inhibition**			
	Positive affect Approach to reward, Energetic arousal Active goal pursuit (approach motivation)	Negative affect Avoidant, Inhibitory	Carver & White (1994) See also Carver, Sutton, & Scheier (200) Gable et al. (2000) Schmidt (1999)	Gray (1982) (RST) Approach and avoidance motivation	BIS: "I feel worried when I think I have done poorly at something important."
BAS Drive	Persistent pursuit of desired goals				BASD: "I go out of my way to get things I want."
BAS Fun Seeking	Desire for new rewards and approach rewarding events				BASF: "I crave excitement and new sensations."
BAS Reward Responsiveness	Focus on positive responses to anticipation of reward; like BIS expresses sensitivity towards previous or expected events; external world dependence; often correlates (+) BAS				BASR: "When I get something I want, I feel excited and energized."
Orientation (ACS-90)	**Description**: Self-regulation through motivation and volition related to action control. Represented by two regulatory modes pertained to state and action orientation, the scale assesses the inability to escape state-oriented mode when needed. The scale relates to conflict detection, and the ability to shield intentions to prevent loss (coping) in specific situations being under threat or high cognitive demands. ACS-90 comprises three subscales with 12 items each, named from the state-orientation perspective, AOF (failure or threat related), AOD (demand related), and AOP (performance related). Each item has two choices: action or state oriented coping.				
	Action	**State**			
	Change, Decisiveness, Initiative for action Action facilitation, Promotion to change High regulatory resources Facilitation of intentional action leads to higher goal efficiency Facilitation of regulatory resources under threat → leads to better performance (no such mechanism for supportive situations)	Inability to escape particular control mode causes behavior initiation difficult either through preoccupation or hesitation Stagnation, Perseveration, Prevention of change, Indecisiveness, Hesitation for action Low availability of resources Remain within maintenance state even when change needed → less resources available Performance improves under supporting and rewarding conditions	Kuhl & Beckmann (1994) AOF and AOD are correlated: equivalent scales as to the reduction of supervisory control of the initiation of overt activities not	Kuhl (2000) Personality Systems Theory (PSI)	"When I am told that my work has been completely unsatisfactory: Action orientation answer: "I don't let it bother me for too long". State orientation answer: I feel paralyzed." →When one scores L on failure and decision related action orientation (=high on preoccupation and hesitation) and are high on persistence (low on volatility), they take advantage of motivating effect of anticipatory state-oriented thoughts, at the same time avoids performance-impairing effect since action has already been initiated.

Table 31 (continued). Dual theory approaches and hypothesized integration of personality measures into higher-order factors.

AOF	In failure situations: Assesses preoccupation; failure-related scale; action=disengagement; state=preoccupation, rumination. High scores = able to return to action quickly after failing		under external control		When I am in a competition and have lost every time: I can soon put losing out of my mind.
AOD	After making decision: Assesses hesitation,prospective orientation; decision-related; action = initiative; state=indecisiveness, hesitation, stays within an oscillating state associated with timing of decision-making; High scores = Able to act upon decisions quickly				When I know I must finish something soon: I find it easy to get it done and over with.
AOP	In performance situations: Assesses volatility; performance-related; action=ability to stay active; state=perseveration; degree to which one stays in action-orientation mode; 1/persistence; High scores = Able to become immersed in pleasant activities without premature shifting to something else				When I have learned a new and interesting game: I can really get into it for a long time.
Approach (task)	**Scale and characteristics**		**References**	**Theory**	**Sample questions**
Regulatory focus (RFQ)	**Description**: Self-regulatory behaviors related to two motivational states, promotion (nurturance) and prevention (safety). It defines person's motivation and anticipation of action and the sensitivity to presence or absence of positive or negative outcomes.				
	Promotion (nurturance)	**Prevention (safety)**			
	Associated with openness to change, advancement, accomplishment Focus on anticipation of pleasure, Accomplishments, Aspirations, Well-being More likely with commission errors & hits	Preference for stability, reluctance to change resumes interrupted tasks, avoids mismatch Focus on anticipation of pain, Safety, Security, Responsibilities, Cognitive Dissonance More omission errors and correct rejections	E.T. Higgins (1997)	Higgins motivational approach	Promotion: Do you often do well at different things that you try? Prevention: How often did you obey rules and regulations that were established by your parents?
Big Five (NEO-PI-R)	**Description**: Assesses typical person behavior via five broad domains (OCEAN), with each domain representing six subscales (facets; see Table 3). NEO-PI-R measure summarizes emotional, interpersonal, experiential, attitudinal, motivational styles; measures broad, basic personality traits.				
	Plasticity (beta)	**Stability (alpha)**			
	Reflects tendency to explore or engage voluntarily with novelty, associated with flexibility/plasticity in behavior & cognition Capable of adjusting and processing novel information, adapting to novelty Personal growth vs personal constriction, open to new experiences, use intelligence, encounter life and its risks (Digman p. 1250) or superiority	Stability in emotional, social, and motivational spheres of life Capable of maintaining information and output in time and context, maintenance of stability Social desirability factor or socialization process and personality development (p.1249 Digman) A & C & -N Negative emotionality (see Tellegen,	McCrae, Costa (1992) Digman (1997) JPSP DeYoung et al (2002)	Grossberg (1987) in computer modeling of neural networks (names) Two distinct subsyste	

Table 31 (continued). Dual theory approaches and hypothesized integration of personality measures into higher-order factors.

	striving E & O: reduced latent inhibition, alteration in attention, mediation of cognitive flexibility through PFC and ACC; creativity, divergent thinking Positive emotionality (Tellegen)	1985)		ms Digman (1997p.1253) Digman (1990) Personality structure	
Extraversion (Surgency)	E: Sociable, assertive, active, talkative, excitement and stimulation, energetic, optimistic; (+) affectivity, incentive reward sensitivity, approach behavior, novelty and excitement seeking I: reserved, independent, prefer alone, not pessimistic though	N/A			E1: I really like most people I meet E2: I like to have a lot of people around me E3: I am dominant, forceful and assertive E4: My life is fast-paced E5: I often crave excitement E6: I laugh easily
Openness / Intellect	O: active imagination, inner feeling, variety, intellectual curiosity, sensitivity to art, independence of judgment, rich experientially, novel ideas, creative, unconventional, question authority, related to g (divergent thinking, creativity) Closed: narrow scope & intensity of interests, conservative, prefer familiarity				O1: I have a very active imagination O2: Poetry has little or no effect on me/R O3: I rarely experience strong emotions/R O4: I am pretty set in my ways/R O5: I enjoy solving problems or puzzles O6: I consider myself broad-minded and tolerant of other people's lifestyles
Approach (task)	**Scale and characteristics**		**References**	**Theory**	**Sample questions**
	Plasticity (beta)	**Stability (alpha)**			
Emotional Stability (reversed Neuroticism)	N/A	N: experiencing (-) affect states, irrational ideas, less control of impulses, poor coping with stress ES: calm, relaxed, immune to stress, even-tempered; free from (-) affect and motivational withdrawal			N1: I am easily frightened N2: I am an even-tempered person/R N3: Sometimes I fell completely worthless N4: I often feel inferior to others N5: I have trouble resisting my cravings N6: I am pretty stable emotionally/R
Conscientiousness		C: control of impulses, self-control (planning, organizing, task performance), purposeful, determined, strong-willed, "will to achieve", character, academic and occupational achievement, motivational stability, punctual, reliable, scrupulous, set and			C1: I am a very competent person C2: I am not a very methodical person/R C3: I adhere strictly to my ethical principles C4: I strive to achieve all I can C5: I waste a lot of time before settling down to work/R

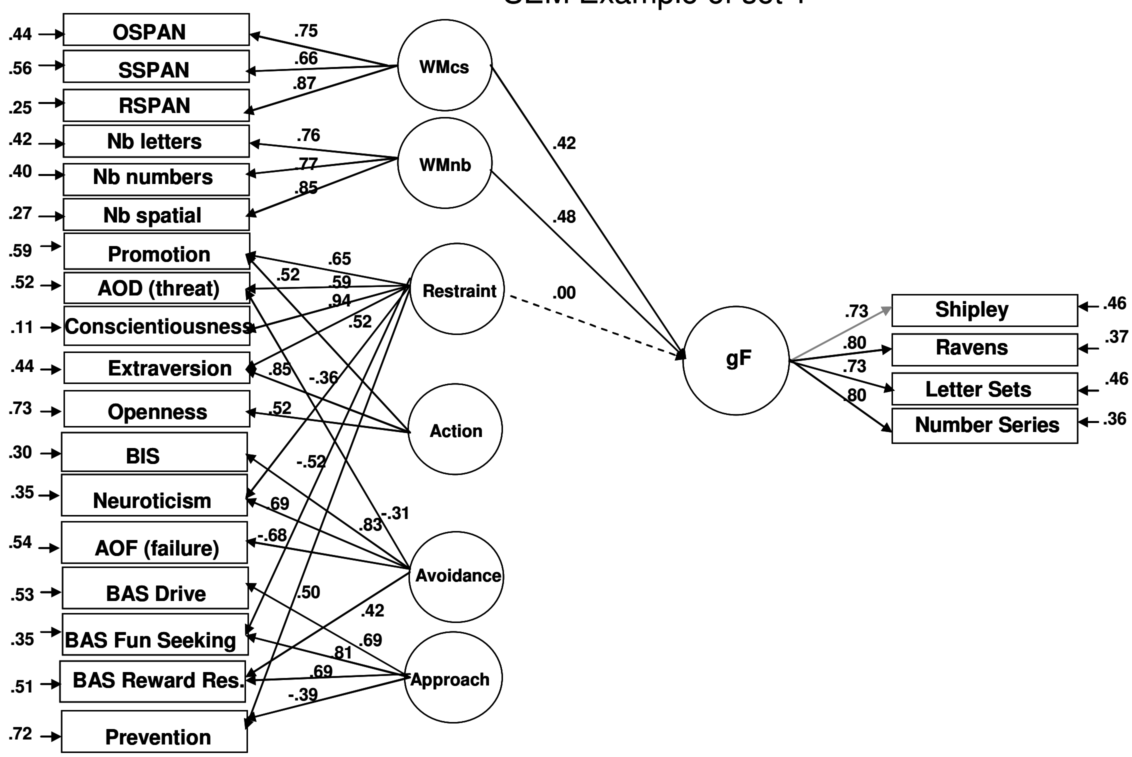
Table 31 (continued). Dual theory approaches and hypothesized integration of personality measures into higher-order factors.

		work towards goals, self-discipline lowC: annoying fastidiousness, compulsive neatness, workaholic behavior, less work toward goals, more hedonistic			C6: I rarely make hasty decisions
Agreeableness		Interpersonal tendencies as E, altruistic, sympathetic, eager to help, cooperative; maintenance of stable social relations Dis: antagonistic, egocentric, mistrustful, skeptical of others' intentions, competitive, skeptical and critical thinking (important features in science)			A1: my first reaction is to trust people A2: If necessary, I am willing to manipulate people to get what I want/R A3: I'm not known for my generosity/R A4: I would rather cooperate with others than compete with them A5: I would rather praise others than be praised myself A6: I believe all human beings are worthy of respect
Neurotransmitter	**DA system**	**5-HT system**			
Projections to	Limbic, motor system, ACC, PFC	Limbic system, basal ganglia	DeYoung et al (2002) MacDonald (2008) Carver et al. (2006; 2008)		
Mediates and characterizes	Approach behavior Positive affect Incentive reward sensitivity Response to novelty (E explore behaviorally, concretely: limbic; O esthetically: ACC/PFC DA projections)	Emotion regulation, motivation, circadian; control of helplessness & depression; stability (aggression and impulsivity); vital to behaviors & emotional constraint & control (general stability of person)			
Possible paths	DRD4->E->PA brain regions->PA->BAS Thus,DRD4 expresses tendency to approach	5-HT->N->moderating NA brain areas->NA->BIS->avoidance motivation Thus, 5-HT expresses tendency to avoid	Larsen & Augustine (2008)		
Approach (task)	**Scale and characteristics**		**References**	**Theory**	**Sample questions**

Table 32. Types of the n-back task examined by the direct studies.

Study	N-back type	Stimulus type	Practice trials	Instructions
Gevins & Smith (2000)	0,2-back	Spatial or verbal (letters)		Match the position, answer to match and non-match
Gray & Braver (2002)	3-back	Verbal (words), nonverbal (faces)	30 familiarization trials	Press target; press nontarget button for any other item
Gray et al. (2005)	3-back	Verbal (words), nonverbal (faces)		Item matches or does not match
Gray (2001)	2-back	Spatial, verbal (letters)	12 trials repeated if necessary	Location of the box, ignore letter identity; identity in the box
Kumari et al. (2004)	0,1,2,3-back	Spatial, verbal (numbers)		Indicate location; indicate number
Lieberman & Rosenthal (2001)	0,1,2,3-back	Verbal	20 practice trials	Yes or No response to letters
Patrick, Blain & Baggs (2008)	0,1,2,3-back	Verbal (letters)		Same-different response
Chavanon et al. (2007)	0,1,2,3-back	Verbal (letters)	20 practice trials	Respond to each letter (incentives)

SEM Example of set 1



SEM Example of set 2

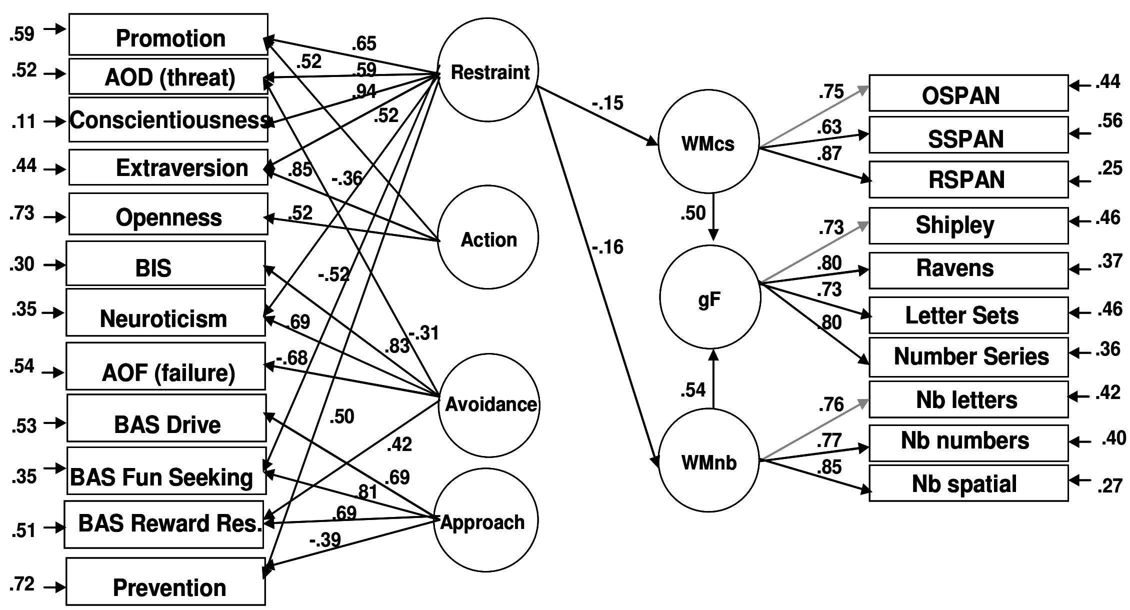
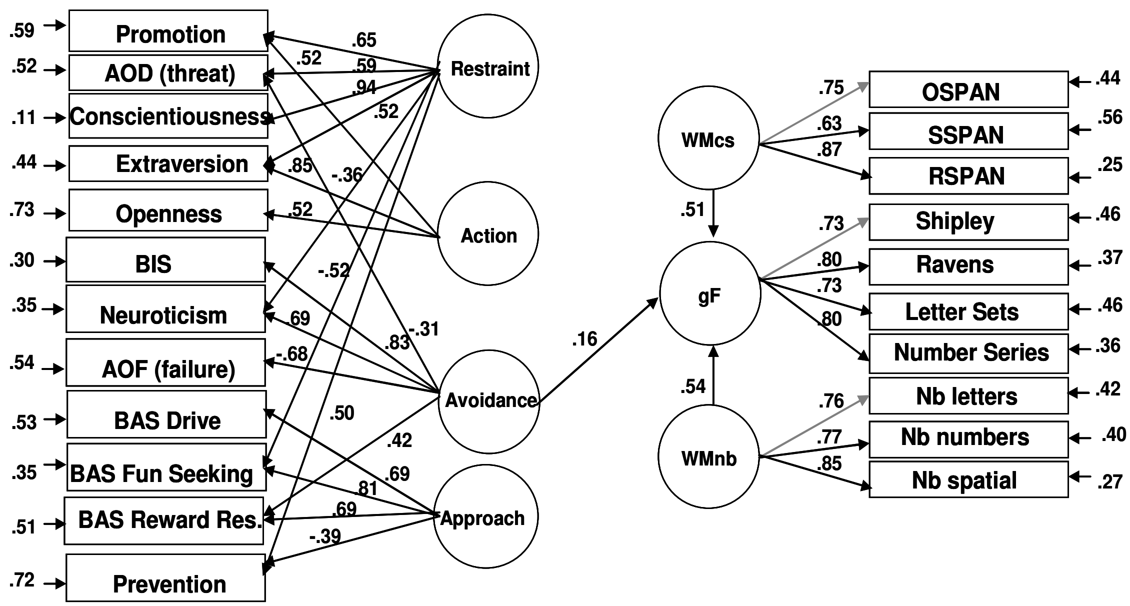


Figure 28. Examples of SEM model sets: Sets 1 to 6.

SEM Example of set 3



SEM Example of set 4

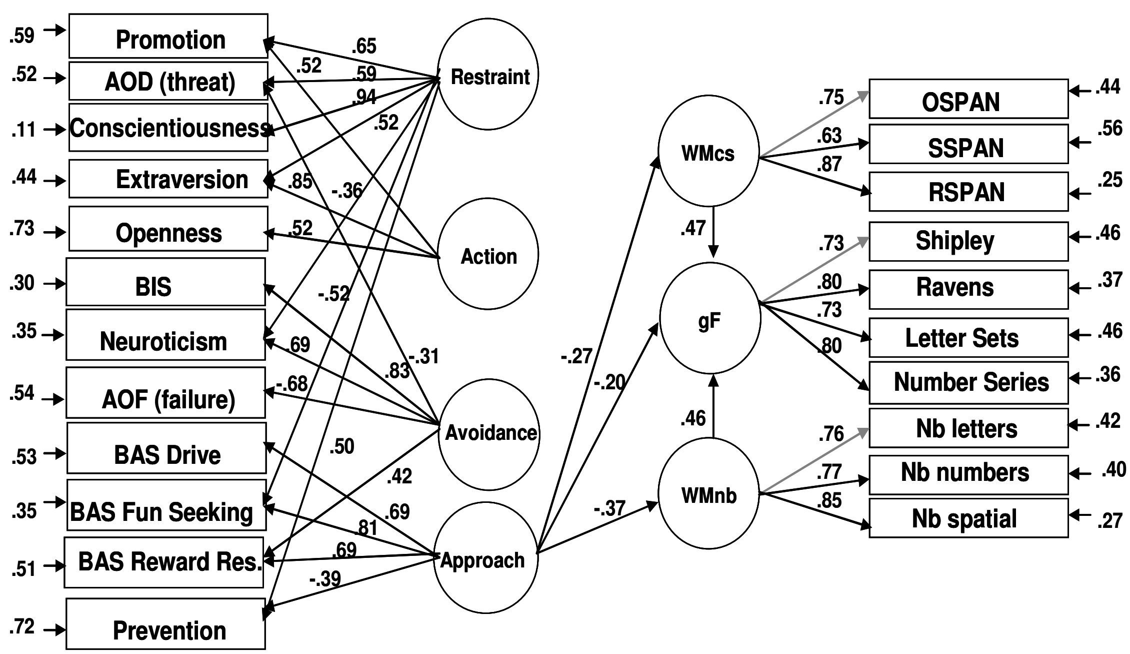
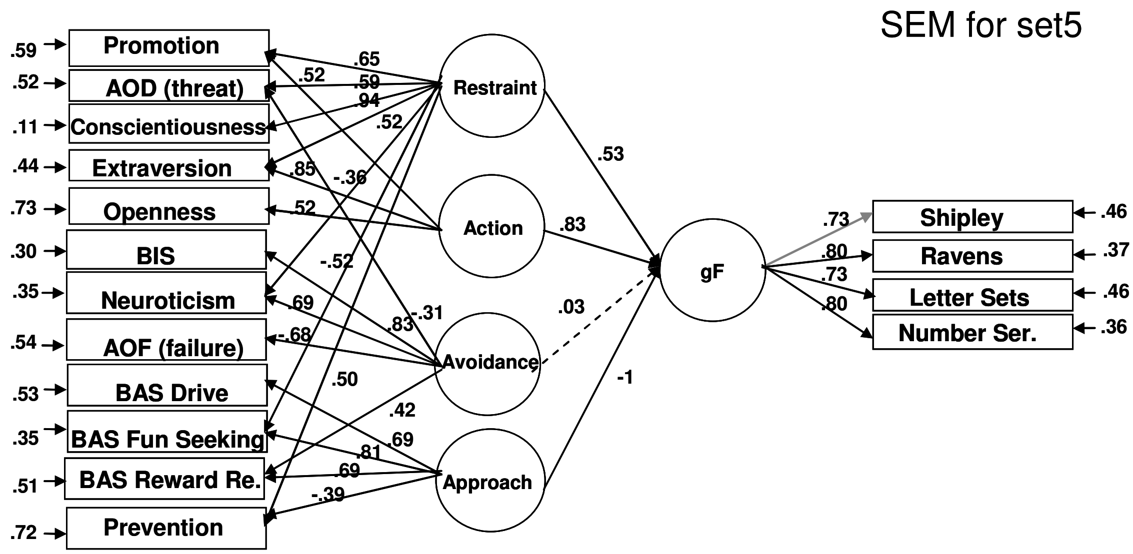


Figure 28 (continued). Examples of SEM model sets: Sets 1 to 6.



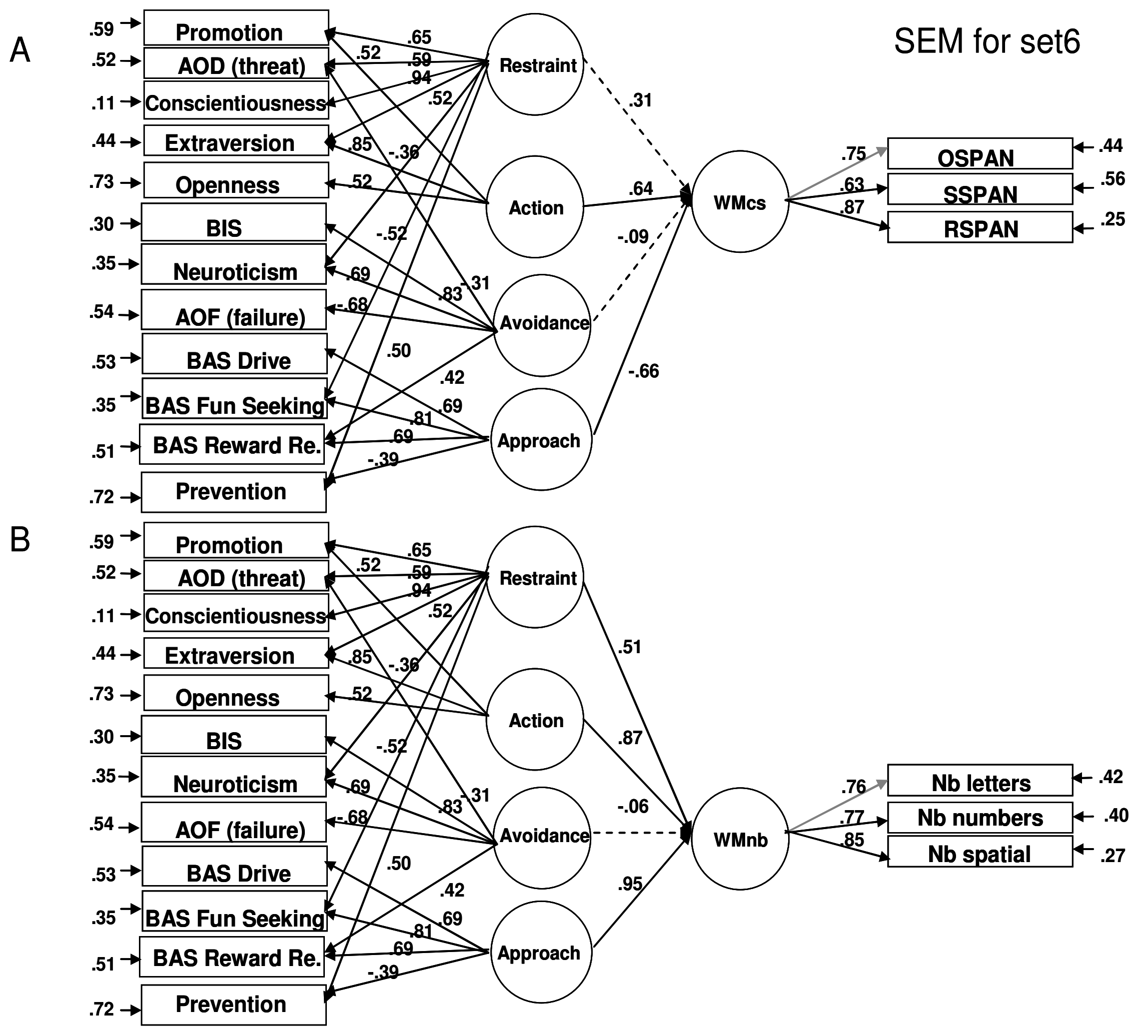


Figure 28 (continued). Examples of SEM model sets: Sets 1 to 6.

APPENDIX B

Table 33. Zero-order correlation tables for GT and nonGT subsamples.
Note: The gray areas indicate the highest differences between correlations across the two samples. Other colors indicate areas of correlations within the groups of tasks. The most surprising is lack of correlation between the OSPAN and Shipley.

A. Zero-order correlations for nonGT sample (N=144) for cognition

	Ship	Rav	LetS	NumS	OSP	SSP	RSP	Nlet	Nnu	Nsp
Ship	1									
Raven	.612	1								
LettS	.508	.568	1							
NumbS	.597	.647	.635	1						
OSPAN	.363	.379	.294	.400	1					
SSPAN	.307	.475	.373	.457	.490	1				
RSPAN	.457	.434	.413	.409	.714	.563	1			
NBlett	.384	.318	.431	.410	.209	.260	.260	1		
NBnum	.435	.311	.342	.432	.366	.295	.375	.589	1	
NBspat	.444	.461	.456	.575	.356	.482	.401	.588	.690	1

B. Zero-order correlations for GT sample (N=165) for cognition

	Ship	Rav	LetS	NumS	OSP	SSP	RSP	Nlet	Nnu	Nsp
Ship	1									
Raven	.299	1								
LettS	.354	.360	1							
NumbS	.227	.335	.508	1						
OSPAN	-.009	.175	.108	.142	1					
SSPAN	.199	.430	.369	.277	.169	1				
RSPAN	.284	.359	.327	.239	.514	.383	1			
NBlett	.250	.311	.368	.205	.141	.254	.329	1		
NBnum	.151	.212	.306	.156	.180	.258	.272	.547	1	
NBspat	.268	.288	.296	.326	.190	.338	.434	.527	.557	1

C. Zero-order correlations for the entire sample (N=309) for cognition

	Ship	Rav	LetS	NumS	OSP	SSP	RSP	Nlet	Nnu	Nsp
Ship	1									
Raven	.447	1								
LettS	.683	.548	1							
NumbS	.279	.353	.366	1						
OSPAN	.362	.347	.389	.626	1					
SSPAN	.376	.488	.479	.622	.663	1				
RSPAN	.356	.372	.475	.434	.400	.464	1			
NBlett	.425	.543	.490	.438	.367	.492	.606	1		
NBnum	.308	.441	.439	.482	.392	.453	.516	.554	1	
NBspat	.412	.475	.431	.433	.396	.545	.564	.628	.634	1

Table 33 (continued). Zero-order correlation tables for GT and nonGT subsamples.

D. Zero-order correlations for nonGT sample for personality

BIS	1													
BASD	-.21*	1												
BASF	-.09	.37**	1											
BASR	.074	.49**	.453**	1										
Pro	-.18*	.261**	.124	.259**	1									
Pre	-.07	-.18*	-.27**	-.049	.146	1								
AOF	-.43**	.032	.016	-.040	.275**	.085	1							
AOD	-.31**	.300**	-.099	.080	.396**	.230**	.404**	1						
AOP	.15	.134	-.057	.217**	.323**	.082	.032	.249**	1					
N	.63**	-.090	-.025	-.043	-.42**	-.34**	-.44**	-.49**	-.110	1				
E	-.12	.404**	.406**	.424**	.402**	.027	.103	.208*	.088	-.34**	1			
O	.042	-.047	.326**	.023	.208*	-.19*	.060	-.132	.045	.052	.255**	1		
A	.084	-.34**	-.29**	-.103	.100	.424**	.130	.163	.134	-.23**	.044	.092	1	
C	-.18*	.202*	-.26**	.192*	.40**	.38**	.157	.65**	.29**	-.50**	.24**	-.27**	.21**	1

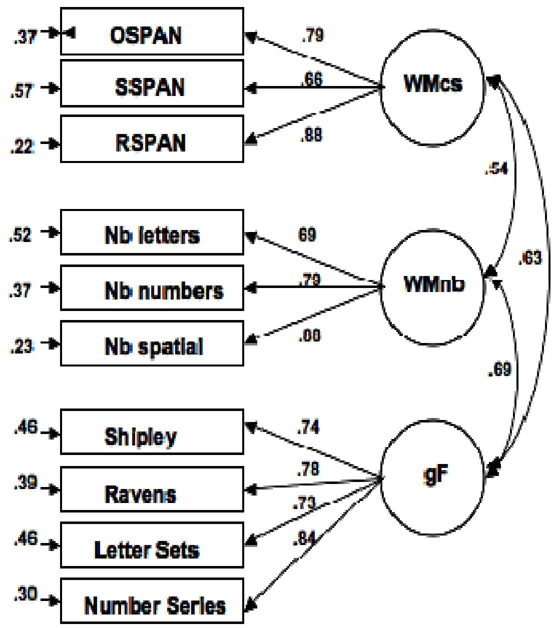
E. Zero-order correlations for GT sample for personality

BIS	1													
BASD	-.116	1												
BASF	-.083	.529**	1											
BASR	.391**	.297**	.255**	1										
Pro	-.129	.307**	.220**	.22**	1									
Pre	.115	-.376**	-.342**	.030	-.007	1								
AOF	-.60**	.092	.182*	-.24**	.132	-.08	1							
AOD	-.22**	.24**	.039	.059	.37**	.10	.32**	1						
AOP	.032	-.021	-.015	.154*	.23**	.12	-.082	.160*	1					
N	.609**	-.115	-.056	.161*	-.29**	-.17*	-.57**	-.33**	-.06	1				
E	.020	.33**	.50**	.37**	.41**	-.14	.035	.30**	.10	-.090	1			
O	.111	.086	.32**	.22**	.185*	-.08	-.089	-.009	.15	.20**	.34**	1		
A	.24**	-.29**	-.076	.107	.073	.34**	.023	.064	.17*	-.077	.18*	.101	1	
C	.040	.058	-.22**	.241**	.390**	.36**	-.006	.522**	.24**	-.28**	.09	-.15*	.16**	1

Table 33 (continued). Zero-order correlation tables for GT and nonGT subsamples.

F. Zero-order correlations for the entire sample for personality

BIS	1													
BAS D	-.18**	1												
BAS F	-.11*	.47**	1											
BAS R	.22**	.40**	.36**	1										
Pro	.144*	.267*	.15**	.23**	1									
Pre	.063	-.31*	-.34**	-.041	.089	1								
AOF	-.54**	.094	.134*	.132*	.186**	-.014	1							
AOD	-.28**	.28**	-.011	.083	.38**	.14*	.37**	1						
AOP	.099	.037	-.048	.17**	.28**	.114*	-.043	.19**	1					
N	.623**	-.11*	-.054	.051	-.35**	-.23**	-.51**	-.41**	-.080	1				
E	-.058	.37**	.464**	.399**	.394**	-.080	.078	.265**	.086	-.21**	1			
O	.033	.062	.354**	.152**	.179**	-.19**	.022	-.046	.077	.099	.31**	1		
A	.178**	-.31**	-.18**	.012	.087	.376**	.061	.106	.154**	-.15**	.123*	.086	1	
C	-.072	.131*	-.23**	.22**	.39**	.35**	.072	.59**	.26**	-.39**	.16**	-.20**	.18**	1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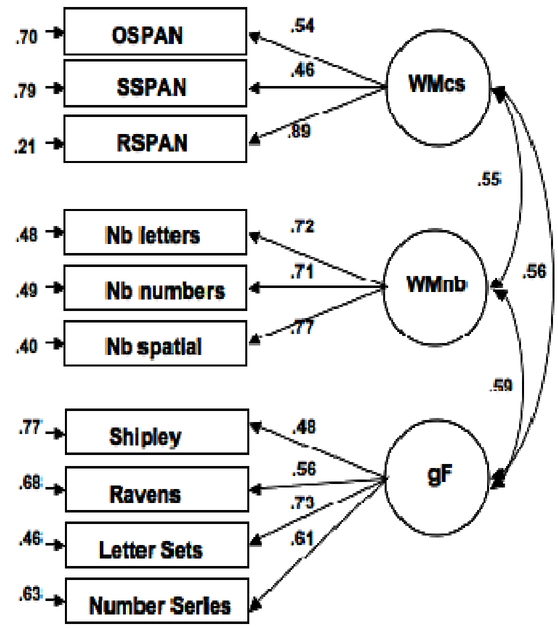
.57 SSPAN .66
.22 RSPAN .88
WMcs
.54
.52 Nb letters 69
.37 Nb numbers .79
.23 Nb spatial .00
WMnb
.63
.69
.46 Shipley .74
.39 Ravens .78
.46 Letter Sets .73
.30 Number Series .84
gF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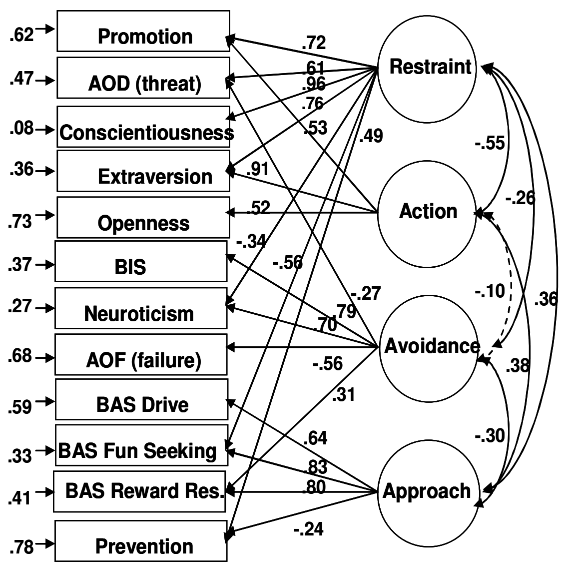
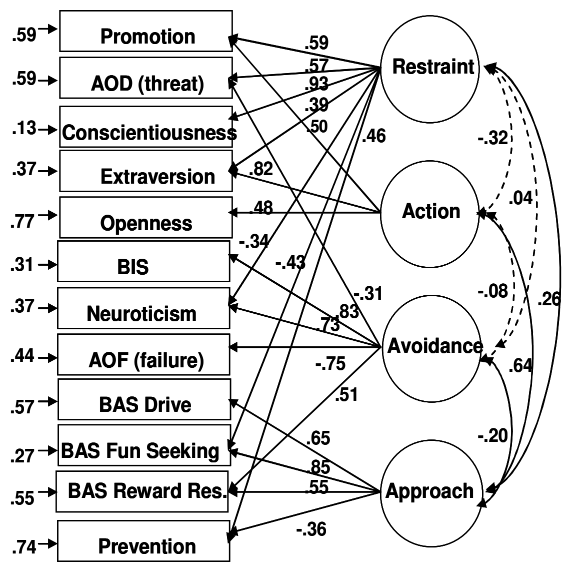
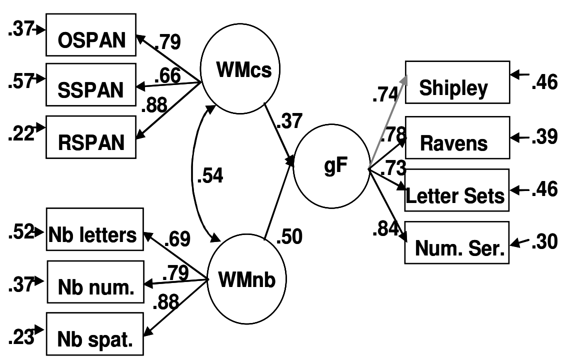
.21 RSPAN .89
WMcs
.55
.48 Nb letters .72
.49 Nb numbers .71
.40 Nb spatial .77
WMnb
.56
.59
.77 Shipley .48
.68 Ravens .56
.46 Letter Sets .73
.63 Number Series .61
gF


.62 Promotion
.47 AOD (threat)
.08 Conscientiousness
.36 Extraversion
.73 Openness
.37 BIS
.27 Neuroticism
.68 AOF (failure)
.59 BAS Drive
.33 BAS Fun Seeking
.41 BAS Reward Res.
.78 Prevention
.72
.61
.96
.76
.53
.49
.91
.52
-.34
-.56
-.27
.79
.70
-.56
.31
.64
.83
.80
-.24
Restraint
Action
Avoidance
Approach
-.55
-.26
-.10
.36
.38
-.30


.59 Promotion
.59 AOD (threat)
.13 Conscientiousness
.37 Extraversion
.77 Openness
.31 BIS
.37 Neuroticism
.44 AOF (failure)
.57 BAS Drive
.27 BAS Fun Seeking
.55 BAS Reward Res.
.74 Prevention
.59
.57
.93
.39
.50
.46
.82
.48
-.34
-.43
-.31
.83
.73
-.75
.51
.65
.85
.55
-.36
Restraint
Action
Avoidance
Approach
-.32
.04
-.08
.26
.64
-.20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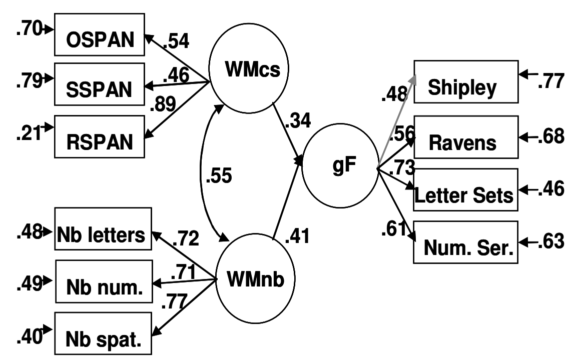
.57 SSPAN .66
.22 RSPAN .88
WMcs
.37
.54
.52 Nb letters .69
.37 Nb num. .79
.23 Nb spat. .88
WMnb
.50
gF
.74 Shipley .46
.78 Ravens .39
.73 Letter Sets .46
.84 Num. Ser. .30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WMcs
.34
.55
.48 Nb letters .72
.49 Nb num. .71
.40 Nb spat. .77
WMnb
.41
gF
.48 Shipley .77
.56 Ravens .68
.73 Letter Sets .46
.61 Num. Ser. .63

Figure 29**.** Two CFA and two SEM cognitive models as well as two CFA personality models for nonGT (left panels) and GT part of the sample (right panels). For the SEM, note that the overall relationship is quite similar across the two samples as are the verbal tasks (RSPAN, n-back letters, Letter Sets). However, the numerical observable variables, such as OSPAN, Number Series as well as the spatial tasks (SSPAN, Ravens, and Shipley) show the highest differences across the samples. Interestingly, the loadings across the three n-back tasks remain similar across the two samples.

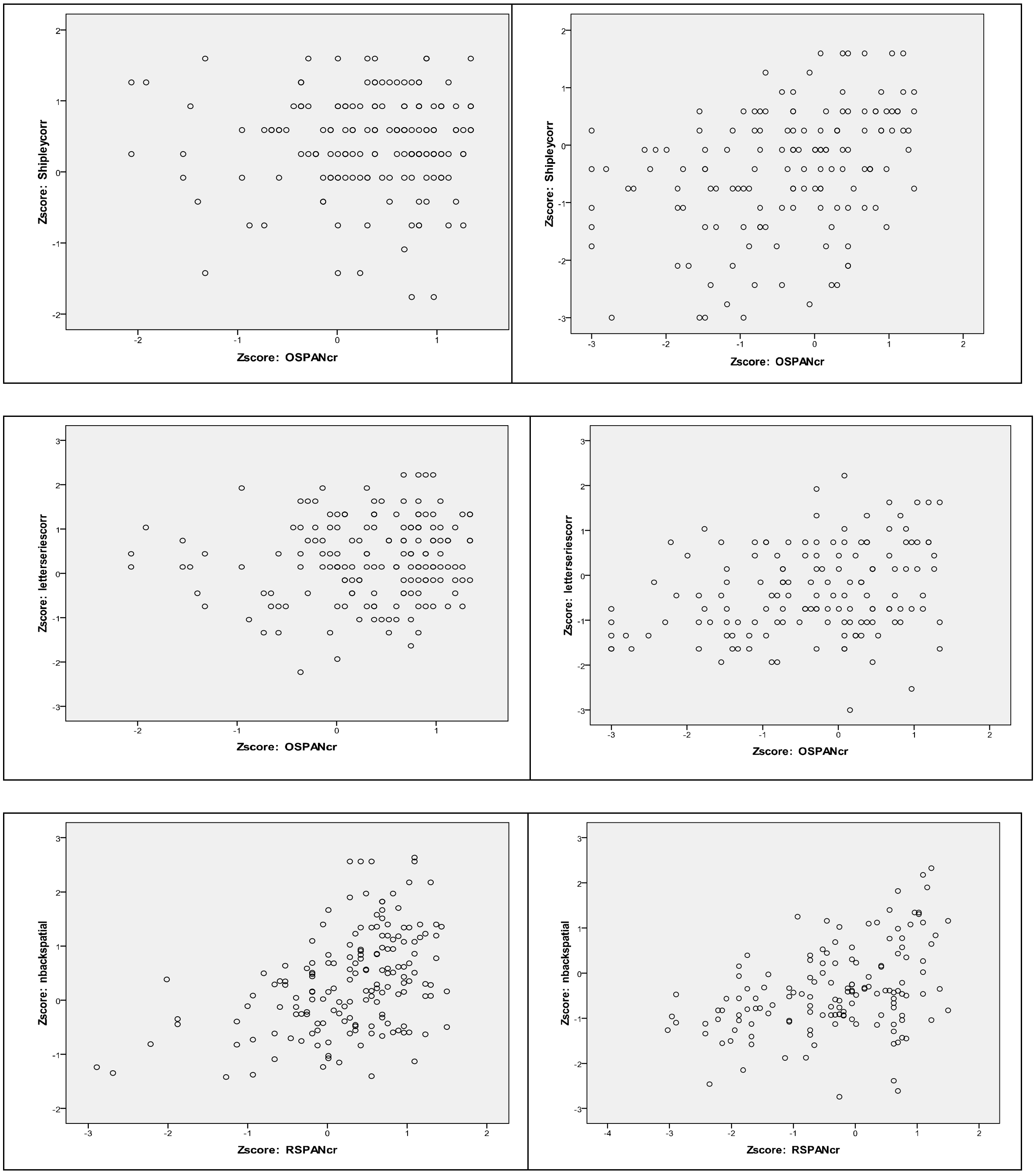

Figure 30. Scatterplots of example correlations for GT and nonGT. Upper panels depict the highest difference in correlations between the samples as illustrated by correlation between OSPAN and Shipley [GT (left panel) vs nonGT (right panel)]. Middle panels depict moderate difference in correlations between the samples as illustrated by correlation between OSPAN and Letter Sets [GT (left panel) vs nonGT (right panel)]. The bottom panels depict comparable correlations between the samples as illustrated by correlation between RSPAN and n-back spatial [GT (left panel) vs nonGT (right panel)].

APPENDIX C

Cluster analysis provided the basis for determining the number of clusters in each group. First, the Ward's (1963) agglomerative hierarchical clustering method with squared Euclidean distance as a similarity measure was applied to determine the number of clusters for each group. Range of clusters from 2 to 6 was examined (see also Feild & Schoenfeldt, 1975; Klecka, 1980). The hierarchical cluster method suggested that 3 or 4 clusters might be the best solution for both groups. The inference about the number of clusters as an outcome was based on examination of the coefficient values in the agglomeration schedule and studying dendrograms.

This analysis was followed by the divisive k-means clustering method with squared Euclidean distance to examine specific cluster solutions. As a specified number of clusters was required, a series of k-means cluster analyses was performed with the number of clusters ranging from 2 to 6 for each group (Higher and Lower WMC), that is, 3-4 +/- two as suggested by the hierarchical clustering method. The output comprised of cluster membership and distance from cluster center for each individual. The results of the k-means analyses indicated that a 5- or 4- cluster solution seemed to be the best for the lower WMC group, whereas a 3- or 4- cluster solution seemed to be the best for the higher WMC group.

To verify and extend the analysis, the next step in profile analysis involved discriminant analysis. Discriminant analysis informs if there is any unique contribution of the variables and discrimination between the clusters, which variables contribute to the model, and how well the model works by showing the percent of correct classifications.

Solutions from the k-means analysis for the two groups were entered as the criterion in respective discriminant function analyses. The output comprised of sets of discriminant functions that differentiated between the clusters, their structure, and percentage of correct and incorrect classification of each individual to the respective clusters accordingly to the scores on the discriminant functions. After examining the results of the discriminant analyses, the final solution comprised of 4-cluster solutions for both Higher and Lower WMC groups. Thus, discriminant function analysis provided additional important information about classification accuracy and discrimination between the clusters.

The results of discriminant analysis indicate that, for the Lower WMC group, three resulting discriminant functions, which are defined as added variables that differentiate between the clusters, had significant eigenvalues and percentage of variance explained by each function, as seen in Table 34. Multivariate analyses revealed that the three discriminant functions accounted for 38%, 34.4%, and 27.7%, respectively, of the between-group variability. In terms of classification, the results revealed that five cases were initially incorrectly classified, with overall 96.8% originally grouped cases classified correctly to their respective clusters (97%(1), 100%(2), 97%(3), and 94%(4)). Table 34.C illustrates distribution of each case and cluster centroids on the first and second discriminant functions for the Lower WMC group.

The first function discriminated between the two first clusters and the fourth cluster, where larger centroids illustrate greater discriminability between the clusters[23]. In

---

[23] Alternative solutions were also tested. Justification of choices of particular number of cluster and discriminant functions is as follows.

addition, as suggested by the structure matrix representing correlations between predictors and discriminant functions, the best predictors for distinguishing these clusters were BASD, Promotion, BASR, and Extraversion. The second discriminant function differentiated between the first and second cluster, and the best predictors here were BIS, Neuroticism, AOF, AOD, and Openness. The third function discriminated between the first and fourth versus third cluster, and the best predictors for distinguishing these clusters were Prevention, Conscientiousness, and BASF. The BASD had the highest loading on function 1 suggesting that BASD contributed the most with the highest structure coefficient as revealed by the structure matrix (Table 34.B). BASR loaded the highest on the second discriminant function. However, in the structure matrix BASR was highly related to both functions 1 and 2. The third function had Promotion with the highest loading.

For the Higher WMC group, six cases were initially incorrectly classified, with overall 96.1% originally grouped cases classified correctly to their respective clusters

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1. Cluster analysis: 2, 5, and 6 clusters were tested for both groups but were not clear in their interpretation.
2. Discriminant analysis:
    a. For low group, k=6: too big, two clusters were smaller (17, 19), which makes the clusters slightly imbalanced in terms of the number of cases in each cluster, eigenvalue % of variance for the 5th discrimimant function =2.9%, and it wasn't discriminating well between any of the groups.
    b. For low group, k=5: as cluster analysis also showed, two clusters were very similar in its composition and values. In addition, the fourth discriminant function adds only 6.9% of the variance, and in terms of group centroids, the fourth function does not discriminate well between the clusters.
    c. For high group, k=5: too big, smaller cluster (2) meaning highly imbalanced groups, 3.8%, nothing significant within the structure matrix for the 4th function
    d. For high group, k=3: it is difficult to interpret the structure matrix in terms of compositions of the discriminant functions.

(94.1%(1), 93%(2), 100%(3), 97.4%(4)). Table 34.F illustrates distribution of each case and cluster centroids on the first and second discriminant functions for the Higher WMC group. The three resulting discriminant functions had significant eigenvalues and percentage of variance explained by each function, as seen in the Table 34.D. Multivariate analyses revealed that the three discriminant functions accounted for 46.6%, 42%, and 11.4%, respectively, of the between-group variance accounted for by the model. The first function discriminated between two first and two second clusters (Table 34.F). In addition, as suggested by the structure matrix in how strongly each variable correlates with discriminant function, the best predictors for distinguishing these clusters were BASF, Extraversion, and BASD, as seen in Table 34.E. The second discriminant function differentiated between the third and fourth cluster, and the best predictors here were Conscientiousness, Neuroticism, AOD, Promotion, and Prevention. The third function discriminated between the first and second cluster, and the best predictors for distinguishing these clusters were BASD, BASF, BASR, Neuroticism, Openness, and Conscientiousness. Group centroids for each cluster and representation of three discriminant functions in 3D space is presented in Figure 31.

Table 34. Results of cluster and discriminant analysis for Lower (LOWER WMC) and Higher (HIGHER WMC) group (A-F) and Distances between Final Cluster Centers (G).

A. Eigenvalues. LOWER WMC.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.564[a]	38.0	38.0	.781
2	1.416[a]	34.4	72.3	.766
3	1.140[a]	27.7	100.0	.730

Table 34 (continued). Results of cluster and discriminant analysis for Lower (LOWER WMC) and Higher (HIGHER WMC) group (A-F) and Distances between Final Cluster Centers (G).

B. Structure Matrix. LOWER WMC.

	Function		
	1	2	3
BASD	.596*	.002	-.292
Promote	.572*	-.130	.328
BASR	.492*	.467	.186
Extraversion	.461*	.107	-.093
BIS	-.059	.652*	.356
AOF	.106	-.544*	-.345
Neuroticism	-.169	.532*	-.114
AOD	.370	-.440*	.286
Openness	.226	.282*	-.244
Prevent	-.154	-.101	.530*
Conscientiousness	.299	-.213	.526*
BASF	.410	.126	-.421*

* Largest absolute correlation between each variable and any discriminant function. Pooled within-group correlations between discriminating variables and standardized canonical discriminant functions. Variable ordered by abosolute size of correlation within function.

C. Functions at Group Centroids. LOWER WMC.

Cluster Number of Case	Function		
	1	2	3
1	-1.533	1.340	-.955
2	-1.114	-1.903	.317
3	.395	.861	1.674
4	1.477	-.228	-.823

Unstandardized canonical discriminant functions evaluated at group means.

D. Eigenvalues. HIGHER WMC.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.063[a]	46.6	46.6	.821
2	1.857[a]	42.0	88.6	.806
3	.502[a]	11.4	100.0	.578

Table 34 (continued). Results of cluster and discriminant analysis for Lower (LOWER WMC) and Higher (HIGHER WMC) group (A-F) and Distances between Final Cluster Centers (G).

E. Structure Matrix. HIGHER WMC.

	Function		
	1	2	3
BASF	.619*	-.244	.028
Extraversion	.534*	.097	-.039
BASD	.413*	.125	-.090
Conscientiousness	.087	.659*	.394
Neuroticism	-.189	-.575*	.450
AOD	.208	.566*	.017
Promote	.311	.380*	.071
Prevent	-.185	.335*	.198
BASR	.503	-.042	.520*
BIS	-.192	-.343	.424*
AOF	.182	.304	-.370*
Openness	.324	-.189	-.342*

* Largest absolute correlation between each variable and any discriminant function. Pooled within-group correlations between discriminating variables and standardized canonical discriminant functions. Variable ordered by abosolute size of correlation within function.

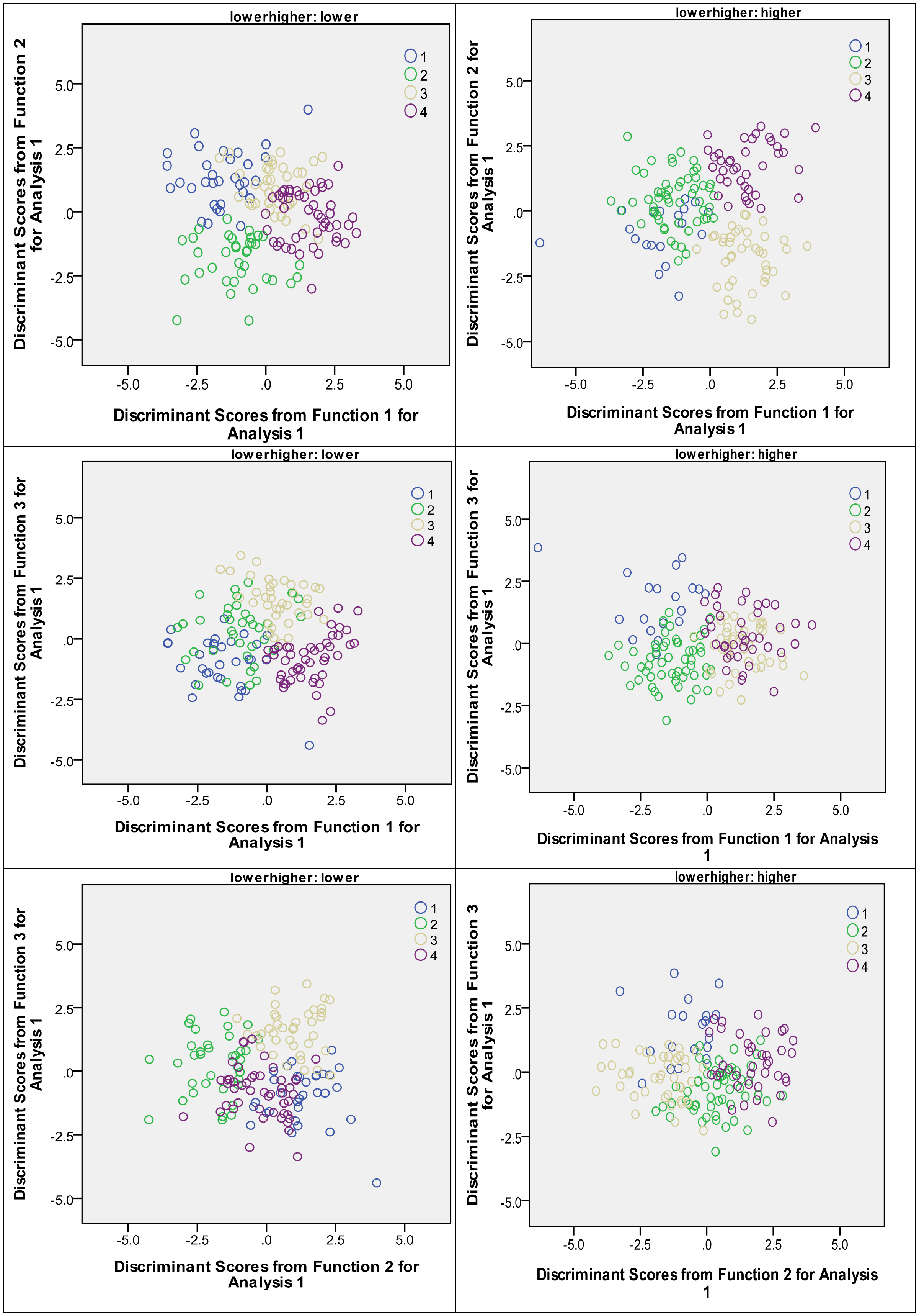
F. Functions at Group Centroids. HIGHER WMC.

Cluster Number of Case	Function		
	1	2	3
1	-2.102	-.878	1.640
2	-1.270	.380	-.640
3	1.300	-1.805	-.154
4	1.372	1.771	.386

Unstandardized canonical discriminant functions evaluated at group means.

G. Distances between Final Cluster Centers. HIGHER (left panel) and LOWER (right panel).

Cluster	1	2	3	4	Cluster	1	2	3	4
1		2.754	3.680	5.044	1		3.552	3.183	3.518
2	2.754		2.953	3.164	2	3.552		3.285	3.372
3	3.680	2.953		3.630	3	3.183	3.285		2.873
4	5.044	3.164	3.630		4	3.518	3.372	2.873	


lowerhigher: lower
Discriminant Scores from Function 2 for Analysis 1
Discriminant Scores from Function 1 for Analysis 1
lowerhigher: higher
Discriminant Scores from Function 2 for Analysis 1
Discriminant Scores from Function 1 for Analysis 1
lowerhigher: lower
Discriminant Scores from Function 3 for Analysis 1
Discriminant Scores from Function 1 for Analysis 1
lowerhigher: higher
Discriminant Scores from Function 3 for Analysis 1
Discriminant Scores from Function 1 for Analysis 1
lowerhigher: lower
Discriminant Scores from Function 3 for Analysis 1
Discriminant Scores from Function 2 for Analysis 1
lowerhigher: higher
Discriminant Scores from Function 3 for Analysis 1
Discriminant Scores from Function 2 for Analysis 1
1
2
3
4
-5.0
-2.5
.0
2.5
5.0

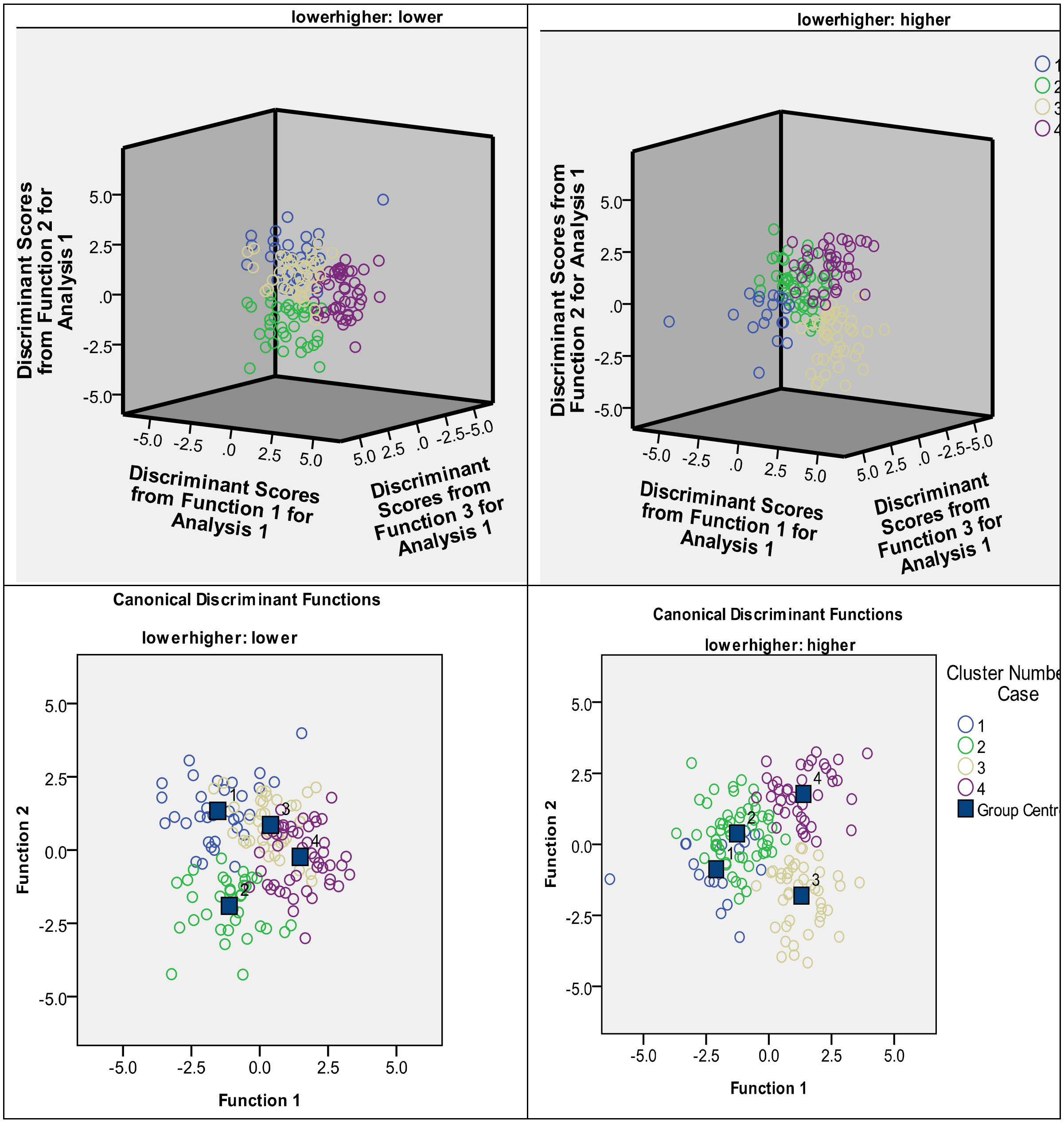


Figure 31. Discriminant functions for LOWER (left panel) and HIGHER (right panel) groups.

When comparing the two groups the first, second, and to some extend fourth cluster have a similar overall shape. However, as shown by the discriminant function analysis, different personality traits might play the greatest role for each cluster for each group. For the lower group, the first cluster was dominated by high Neuroticism and low (below the average) AOD; second by low BASR and high (above the average) Openness; third by high BIS and AOF; and fourth by high BASD values of the final cluster centers. For the Higher group, the first cluster was dominated by high BIS, Neuroticism, Extraversion, Openness, and low BASD and AOF; second by low BASR; third by low Conscientiousness and high BASF; and fourth by high PRO, AOD, Conscientiousness, and low Neuroticism values of the final cluster centers. As the next step, multivariate analysis was performed to test for the differences between the Higher and Lower WMC groups on 12 personality variables for each cluster.

The multivariate tests revealed that all four clusters differed significantly between the two groups, with cluster 1, $F(12)=3.48$, $p=.002$; cluster 2, $F(12)=3.74$, $p=.000$; cluster 3, $F(12)=3.92$, $p=.000$; cluster 4, $F(12)=7.393$, $p=.000$). Specifically, the multivariate tests of between-subject effects revealed that Higher and Lower groups significantly differed on the means of the BIS, BASD, BASF, Prevention, Openness and Conscientiousness traits for cluster 1 (dark blue in Figure 23). That is, Higher WMC individuals who share similar personality profile and group together to form cluster 1 are more than average inhibitory, less persistent in pursuit of desired goals, desire less new rewards, are more prevention-oriented, and less open but more conscientious or self-disciplined as compared to Lower WMC individuals in cluster 1. The overall cluster 1 personality profile for both groups reflected high BIS and Neuroticism, overall low BAS, Promotion, Action Orientation, Extraversion, Openness and Conscientiousness.

For cluster 2 (green), Higher and Lower groups differed significantly in BIS, AOD, Openness and Conscientiousness. That is, Higher WMC individuals that shared similar personality profile by forming cluster 2 were less than average inhibitory, less decisive, more open and less conscientious as compared to Lower WMC individuals in cluster 2. The overall characteristic of cluster 2 shared by the two groups consisted of low BAS and Promotion, higher Prevention, as both groups were also less neurotic and extraverted. The third cluster (yellow) was the least similar for both groups, and as such, significant differences were found for almost all traits with exception of BASD, Neuroticism and Extraversion (both above average). These three traits then characterized personality profile of the third cluster shared by two groups. Finally, for cluster 4 (light blue), Higher and Lower groups differed significantly in BIS, BASF, Promotion, Prevention, AOD, Neuroticism, and Conscientiousness. That is, higher WMC individuals that shared similar personality profile by forming cluster 2 were less inhibited, less desired new rewards, were more Promotion- and Prevention-oriented, more decisive, as they were also much less neurotic and more conscientious or self-disciplined as compared to Lower WMC group.

It should also be mentioned that the clusters comprised different number of individuals so that representations of particular profiles were not balanced. For example, cluster 4 characterized by high BAS, AOD, AOF, Extraversion, and low Prevention had the greatest representation within the Lower group (50), whereas cluster 2 characterized by low BAS scales, Neuroticism and Extraversion, and overall moderate changes across the levels of personality traits, had the greatest representation within the Higher group (57). One might speculate that the difference between the largest clusters in terms of the level of the BAS scales might have influenced the negative relationship between the BAS and WMC.

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