A Latent Variable Investigation of the Personality Correlates of Executive Functions Across Three Levels of the Big Five Hierarchy

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Abstract

A latent variable approach was used to examine the relationship between executive functions (EFs) and personality traits spanning three levels of the Big Five hierarchy (DeYoung, 2015). Specific hypotheses were made for two higher-order traits of the Big Five—Stability and Plasticity—based on their proposed links to self-control (Olson, 2005) and cognitive flexibility (DeYoung, Peterson & Higgins, 2002), respectively. It was hypothesized that (1) Stability would predict better response inhibition; and (2) Plasticity would predict better task switching. Participants (N=217) completed online questionnaires of the Big Five, Effortful Control, and trait impulsivity, and, in a separate laboratory session, they also performed nine tasks that were used to assess latent variables of response inhibition, task switching, and working memory capacity (WMC). Confirmatory factor analyses did not support the first hypothesis, but Stability was very strongly related to Effortful Control and trait impulsivity. Results for the second hypothesis were mixed; Plasticity was significantly related to better task switching when it was assessed using variables from the Big Five Aspect Scales (DeYoung, Quilty, & Peterson, 2007) but not the Big Five Inventory (John, Donahue, & Kentle, 1991). Other significant associations with EFs were found for the Big Five dimensions and their aspects, and Effortful Control. The results and their implications are discussed.

Table of Contents

List of Tables

List of Figures

Introduction

Executive functions (EFs) are a set of domain-general cognitive processes that have regulatory control over domain-specific psychological functions such as language, memory, emotional experience and motor skills. These EFs are critical to the ability to override automatic behavior in order to respond adaptively and flexibly to changing circumstances in the environment—so critical, in fact, that their dysfunction is a leading or major cause of many psychological disorders (Elliott, 2003). While no consensus has emerged on how many unique EFs exist, there is general support for at least three functions—switching between mental sets, inhibiting prepotent responses, and maintaining/updating information in working memory. Individual differences in these EFs appear to be moderately to strongly correlated with one another, potentially tapping into a common underlying ability, but they also demonstrate some degree of separability (Miyake et al., 2000; Miyake & Friedman, 2012). These common and separable components have been aptly described as the “unity” and “diversity” of EFs (Miyake et al., 2000).

Like many other psychological individual differences, EFs are not explicitly integrated into structural models of personality, such as the Big Five hierarchy. Understanding how they are related to other individual differences found within existing models of personality structure is an important task if one of the goals of personality science is to understand the psychological processes underlying the more superficial patterns of behavior and experience that are described by personality questionnaires. In line with this research goal, a growing number of studies have explored the relationship between objectively-measured EFs and the Big Five dimensions (for a brief review, see Murdock, Oddi, & Bridgett, 2013). However, the findings have generally been inconsistent across studies, owing largely to the use of different instruments across studies to measure the same EF. The use of different instruments is particularly problematic when EFs are measured with a single task because that task can only be an impure measure of its respective construct (Miyake et al., 2000). A response inhibition task, for example, will to some degree measure inhibitory processes but it will also measure non-inhibitory processes having to do with requirements that are specific to the task. This task impurity limits the construct validity of the measurement, thereby also limiting the chances that significant results will generalize to other tasks.

A well-known solution to the problem of task impurity is to assess each EF as a latent variable using two or more tasks (e.g., Engle, Tuholski, Laughlin, & Conway, 1999; Miyake et al., 2000). By statistically extracting the variance that is common across the set of tasks, the latent variable assessment excludes not only task-specific impurities but also measurement error, thereby improving reliability. To date, only a handful of studies have employed a latent-variable approach to examine the personality correlates of multiple EFs. Notably, Unsworth and colleagues (2009) used latent variables of working memory, fluency, response inhibition, vigilance, and fluid intelligence to investigate their associations with normal and abnormal personality traits. More recently, Fleming, Heintzelman, and Bartholow (2016) reported exploratory analyses, in which the Big Five traits were treated as simultaneous predictors of three latent EFs based on the unity/diversity model of Friedman et al. (2008).

In the current study, we extend this research by investigating the links between three latent EFs—response inhibition, task switching, and working memory capacity (WMC)—and personality traits spanning three levels of the Big Five hierarchy. At the top of this hierarchy, the metatraits, Stability and Plasticity (DeYoung, Peterson, & Higgins, 2002), represent the patterns of covariation among the Big Five dimensions, which themselves can be divided further into ten narrower aspects (DeYoung, Quilty, & Peterson, 2007). Although all three levels of the hierarchy were analyzed in this study, our investigation focused on testing hypotheses regarding the two metatraits, as described next.

Stability represents the variance shared between Conscientiousness, Agreeableness and Neuroticism (reversed), and it may reflect a general capacity for self-control, expressed across interpersonal (Agreeableness), task-oriented (Conscientiousness) and emotional (Neuroticism) contexts (Olson, 2005). Thus, the high end of this metatrait would describe individuals who are good at controlling negative emotions, aggressive or selfish behaviors, and impulses that undermine progress on effortful tasks. DeYoung et al. (2002) offered a more biological interpretation, according to which Stability in part reflects the functioning of the serotonergic system, based on evidence linking serotonin to the traits subsumed by this metatrait (e.g., Jang et al., 2001; Manuck et al., 1998). Serotonin has broad inhibitory effects on mood, behavior and cognition that serve to reduce impulsivity (e.g., Spoont, 1992), and in that sense, it can be described as a modulator of self-control. Given the proposed ties of Stability to various manifestations of self-control (see also Hirsh, DeYoung, & Peterson, 2009), we predicted that it would be related to better response inhibition.

Plasticity, on the other hand, represents the variance shared between Extraversion and Openness/Intellect, and it may reflect the general tendency to explore, either in pursuit of reward (Extraversion) or information (Openness/Intellect) (DeYoung, 2014). Since the tendency to engage with new information also entails to a certain extent the ability to incorporate that information by adjusting existing knowledge structures, higher Plasticity may also reflect greater cognitive flexibility (DeYoung et al., 2002). The high end of this metatrait would therefore describe someone who finds it rewarding to meet new people and try new things, as well as someone who is curious, driven to learn for its own sake, and quick to adapt to new information. At the neurobiological level, Plasticity may represent individual differences in the functioning of the dopaminergic system (DeYoung et al., 2002), given the central involvement of dopamine in potentiating cognitive and behavioral exploration (DeYoung, 2013) and its role in supporting the flexible updating and switching of representations in working memory (Cools & D'Esposito, 2011).

In the present study, we predicted that Plasticity would be related to better task switching, based on its conceptual ties to cognitive flexibility as well research findings from the literature on divergent thinking and verbal fluency tasks. In these tasks, the general instruction is to generate as many ideas (or words) as possible for a given concept (or letter) within a time frame of several minutes (e.g., naming all the uses for a brick). Importantly, one of the cognitive processes thought to underlie performance on these tasks is the ability to switch to new categories from which to generate items (Troyer, Moscovitch, & Winocur, 1997); thus, people who switch more frequently tend to generate more answers (Unsworth, Spillers, & Brewer, 2011) and more creative ones (Nusbaum & Silvia, 2011). The hypothesis for Plasticity rests on findings that performance on divergent thinking tasks is positively related to both Openness/Intellect and Extraversion[1] (Beaty, Chamorro-Premuzic, & Furnham, 2009; Chamorro-Premuzic & Reichenbacher, 2008; King, Walker, & Broyles, 1996; Schretlen van der Hulst, Pearlson, & Gordon, 2010), and more relevantly, Plasticity (Silvia et al., 2008; Silvia, Nusbaum, Berg, Martin, & O'Connor, 2009).

In addition to two Big Five questionnaires, the present study included multi-dimensional questionnaires of trait impulsivity and Effortful Control—a temperament construct based on the executive attention system (Rothbart & Rueda, 2005). The purpose of including these measures was to test whether Stability is related to other personality traits with more overt ties to self-control; and secondly, to test whether these related personality traits are associated with response inhibition. Effortful Control consists of three facets corresponding to the capacities to focus and shift attention, to inhibit inappropriate behavior, and to perform an action when there is a strong tendency to avoid it (Evans & Rothbart, 2007). We expected the Inhibitory Control facet to provide a relatively direct test of the correspondence between self-report and objective assessments of response inhibition.[2] Lastly, we expected to find a positive association between the

[1] The evidence is mixed for Extraversion. Some studies reported an association with Openness/Intellect but not Extraversion (e.g., McCrae, 1987; Unsworth et al., 2009).
[2] Although conceptually similar, there is also one important difference between these constructs in that the items assessing Inhibitory Control describe inappropriate behaviors (e.g., "I often avoid taking care of

Intellect aspect of Openness/Intellect and WMC, based on previous findings (DeYoung, Shamosh, Green, Braver, & Gray, 2009; Kaufman et al., 2010). No further predictions were made for the Big Five dimensions or their ten aspects.

Methods

Participants and procedure

The current sample consisted of 225 undergraduates from the University of Minnesota, ages 18 to 52 (M_{age}=20.9, SD=4.71; 56% female; 67% Caucasian), who received course credit for their participation. This sample was reduced to 217 individuals after data cleaning procedures were carried out, as described further below. The first part of the study was administered online and involved completing a series of personality questionnaires, followed by a brief measure of intelligence, which altogether took about 40 minutes to complete. The second part included nine EF tasks and was conducted in a single laboratory session lasting approximately 90 minutes.

Materials

All of the materials for this study were programmed using Inquisit 3 by Millisecond Software (Inquisit, 2012).

Personality questionnaires. Across all the questionnaires included in this study, questionnaire items consisted of statements to which respondents were asked to indicate their level of agreement on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

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responsibilities by indulging in pleasurable activities."), whereas response inhibition tasks are divorced of any such moral context.

The *Big Five Inventory* (BFI; John, Donahue, & Kentle, 1991) has 44 items and is a widely-used measure of the five major dimensions of personality: Extraversion, Neuroticism, Agreeableness, Conscientiousness, and Openness/Intellect.

The *Big Five Aspect Scales* (BFAS; DeYoung, Quilty, & Peterson, 2007) consists of 100 items selected from the International Personality Item Pool (Goldberg, 1999) to assess 10 aspects of the Big Five traits: Compassion and Politeness (aspects of Agreeableness); Enthusiasm and Assertiveness (aspects of Extraversion); Orderliness and Industriousness (aspects of Conscientiousness); and Openness and Intellect (aspects of Openness to Experience). The Big Five dimensions can also be assessed by averaging the scores for each pair of aspects. We used the average of the BFAS and BFI scores to measure the Big Five.

The *UPPS-P Impulsive Behavior Scale* is a measure of five traits that fall under the umbrella of impulsivity, and it consists of the original, 45-item scale of Whiteside and Lynam (2001) combined with the 14-item Positive Urgency scale of Cyders et al. (2007). The five traits include Negative Urgency (e.g., ‘‘When I feel bad, I will often do things I later regret in order to make myself feel better now’’), Positive Urgency (e.g., ‘‘When I am very happy, I can’t seem to stop myself from doing things that can have bad consequences’’), (lack of) Perseverance (e.g., ‘‘I tend to give up easily”), (lack of) Premeditation (e.g., ‘‘My thinking is usually careful and purposeful”), and Sensation Seeking (e.g., “I generally seek new and exciting experiences and sensations”).

The Effortful Control scale from the *Adult Temperament Questionnaire* (ATQ; Evans & Rothbart, 2007) consists of 35 items and three subscales, including Effortful

Attention (e.g., “When I am trying to focus my attention, I am easily distracted.”), Inhibitory Control (e.g., “I usually have trouble resisting my cravings for food drink, etc.”), and Activation Control (e.g., “I hardly ever finish things on time.”).

Executive function tasks

Working memory capacity. WMC was assessed using two complex span tasks and an N-back task. In the Operation Span task (OSPAN; Unsworth, Heitz, Schrock, & Engle, 2005), participants had to remember lists of 3, 4, 5, 6, or 7 letters (from a pool of 12) in serial order; whereas, in the Symmetry Span task (SSPAN; Kane, 2004), they had to recall the sequential locations of 2, 3, 4 or 5 squares, presented in a 4 by 4 matrix. Immediately after each memory item was presented, participants also performed a distracting processing task, which involved either verifying a mathematical equation (for OSPAN) or verifying that a matrix pattern was symmetric (for SSPAN). In total, 12 blocks (3 per list length) were completed for each task. The dependent variable (DV) was sum of memory items in all perfectly recalled sets.

In the *Letter Recall (N-back)* task (Jaeggi et al., 2010), participants were shown a sequence of letters and had to respond each time the current stimulus matched the one presented n positions back. They were tested on 2- and 3-back levels, with each level presented twice, hence a total of 4 blocks. A block consisted of 23 stimuli, of which 7 were targets and 16 were non-targets. The DV was *d'*, a signal-detection measure of accuracy based on the relative proportion of hits (i.e., responses to target letters) minus false alarms (i.e., responses to non-target letters).

Response inhibition. In the *Antisaccade task* (adapted from Roberts, Hager, & Heron, 1994), participants had to suppress the reflex of looking at a distractor stimulus (white square) that appeared for 175ms on one end of the screen, in order to detect the direction of an arrow (up, down, left, or right) that appeared for 165ms on the opposite end of the screen. They completed 90 trials in total. The DV was the proportion of trials on which they answered correctly.

The *Sustained Attention to Response Task* (SART; adapted from Smallwood et al., 2004) required withholding a response to the digit 3 (the NoGo target), while responding to all other digits from 1 to 9 (the Go targets). There were 209 Go trials and 26 NoGo trials. The DV was the number of commission errors on the NoGo trials.

Simon task (Bialystok, Craik, Klein, & Viswanathan, 2004). On every trial in this task, one of two stimuli was presented on either the left or the right side of the screen—a blue square that always required a left key press, and a red square that always required a right key press. On one half of the trials, the stimulus appeared on the side of the screen that is congruent with its keyed response (e.g., red square on the right), and on the other half the location was incongruent (e.g., blue square on the right), thus generating greater response conflict and longer latencies. These longer latencies reflect the additional processing needed to override the prepotent keyed responses; thus, the DV of interest was the difference in mean reaction time (RT) between congruent and incongruent trials, referred to the incongruency cost or Simon effect. Sixty trials of each type were presented in a pseudo-random, fixed order.

Task switching. Across three separate tasks (adapted from Wasylyshyn, 2010), participants had to switch between two task sets involving either digits (is the digit odd or even?—switch—is it greater or less than 5?), shapes (is it a circle or triangle?—switch—is it red or green?), or words (is it an animal or non-animal?—switch—is it greater or smaller than a basketball?). The task to be performed was always signaled at the beginning of each trial by one of two cues (e.g., "odd-even" and "parity" were used for the odd/even digit task). On 25% of the trials, the task performed on the previous trial was repeated; on another 25% of trials, the cue from the previous trial changed but the task to-be-performed remained the same; and on 50% of all trials, the task to-be-performed changed relative to the previous trial. Each of the three measures described consisted of 180 trials across three blocks, and the trial types were presented in pseudo-random, fixed order. The DV was the difference in mean RT between task-repeat and task-switch trials, which measures the additional time it takes to switch tasks, also known as the switch cost.

Intelligence. General intelligence was assessed for exploratory purposes using the International Cognitive Ability Resource (ICAR) 16-item sample test. The ICAR is a public-domain measure that has been validated in a large online sample (Condon & Revelle, 2014) and has four item types: Verbal Reasoning, Letter-Number Series, Matrix Reasoning, and 3D Rotation.

Data cleaning procedures

For RT data, we applied trimming procedures used in a previous study employing similar tasks (Friedman & Miyake, 2004) in order to improve the distributions and minimize the influence of outliers. For task switching data, RTs from error trials and RTs below 250ms were removed, while RTs above 4000ms were replaced with a value of 4000. The same procedures were carried out for the Simon data, except that the bottom and top cutoffs were lowered to 150ms and 3000ms, respectively. Additionally, RTs on post-error trials were excluded from the task switching data because switching is measured in relation to performance on the previous trial and so correct responses are required on both the present and previous trials. To ensure that the mean RT for each individual was not unduly influenced by extreme latencies, any latencies falling three standard deviations above their mean (i.e., the cutoff) were replaced with a value that was equal to the respective cutoff value.

For the purpose of removing invalid data, we determined the level of accuracy on each task that would have been attained by chance (e.g., by responding randomly) and established cutoff values marginally above that level. If any participant's accuracy on a task fell below the respective cutoff, his or her data for that specific task was deemed invalid and removed. This removal procedure affected 4% or less of the data for each task, with the exception of the SART data, which was affected at a rate of 9%. For this task, 16 participants did not follow instructions and failed to respond on most of the Go trials, and, of those, 6 participants misunderstood the instructions and responded only on NoGo trials. Additionally, participants' data was excluded in its entirety from the dataset if it was flagged as invalid on three or more EF tasks, or if the participant incorrectly answered 50% or more of the attention check items on the personality questionnaires (without their personality data, the rest of their data could not be used). Attention checks consisted of ten bogus statements one had to agree or disagree with (e.g., “I run 5000 miles every day”). In total, eight participants were excluded under the criteria described, leaving 217 individuals in the sample.

Results

Descriptive statistics

Descriptive statistics and reliability estimates are displayed in Table 1. As indicated in this table, reliability estimates for the Simon and task switching variables were quite low, with alphas ranging from .20 to .59. While it is generally known that RT difference scores tend to be unreliable,[3] these estimates are considerably lower than those reported in previous studies, as are the mean RT costs for each task. For instance, Paap and Greenberg (2012) reported a mean incongruence cost of 32ms for the Simon task and a reliability coefficient of .44; and for the color-shape (switching) task, they reported an average switch cost of 234ms and a reliability coefficient of .73. (Note, however, that direct comparisons to the current results cannot be made due to minor differences in task design). The amount of measurement error in the RT cost variables in this study can also be gauged by examining the concentration of RT costs that fall below zero. A negative score is not a valid indicator of any “cost” because it means that the individual responded faster on trials that required switching tasks or resolving conflict than on trials that did not. In the current sample, the proportion of individuals with negative RT costs was as high as 11% for the task switching measures and 33% for the Simon task, which may

[3] A common explanation for this unreliability is that difference scores are derived from two similar components (e.g. mean RT on task-switch and task-repeat trials) that tend to be highly positively correlated, often as high as $r = .90$, which means that there is relatively little unshared variance between, much of which is measurement error (cf. Draheim, 2015).

explain why these scores were particularly unreliable. Despite the low reliability estimates, the three switch cost variables were moderately correlated with one another, while the Simon DV did not appear to be correlated with other response inhibition variables. Bivariate correlations among all EF and personality variables are shown in Table 2.

Table 1

Descriptive statistics and reliability estimates for all measures

	N	Mean	SD	Range	Skewness	Kurtosis	α
Letter recall	213	2.33	.65	0.3–4.5	-.09	.87	.68
Operation span	216	41.64	15.94	0–72	-.30	-.23	.78
Symmetry span	216	21.87	9.13	2–42	.03	-.41	.65
Antisaccade	208	.66	.14	0.32–0.96	-.12	-.61	.89
SART commissions	201	8.11	4.94	0–24	.69	.16	.81
Simon effect	215	15.18	42.77	-116–147	-.21	1.72	.20
Digit switch cost	217	187.51	163.53	-253–680	.66	.24	.59
Shape switch cost	216	152.45	137.51	-263–568	.49	.76	.47
Word switch cost	214	124.02	118.47	-219–483	.54	1.06	.34
ICAR IQ	213	.65	.19	0.2–1	-.23	-.41	.72
Extraversion	215	3.38	.60	1.7–4.8	-.19	-.41	.87
Openness/Intellect	215	3.57	.50	2.4–5	.00	-.22	.81
Neuroticism	215	2.84	.58	1.5–4.4	.20	-.43	.81
Agreeableness	215	3.89	.46	2.2–5	-.85	1.44	.73
Conscientiousness	215	3.51	.50	2–4.5	-.31	-.14	.80
Assertiveness	215	3.40	.61	1.7–5	-.21	-.17	.84
Enthusiasm	215	3.68	.56	2.1–5	-.36	.04	.80
Intellect	215	3.55	.57	2.1–5	-.16	-.16	.81
Openness	215	3.73	.59	2.1–5	-.23	-.12	.77
Volatility	215	2.69	.71	1–4.7	.30	-.61	.88
Withdrawal	215	2.91	.58	1.4–4.4	.12	-.01	.78
Industriousness	215	3.27	.59	1.8–4.7	.11	-.64	.82
Orderliness	215	3.41	.50	1.8–4.7	-.33	.00	.80
Compassion	215	4.03	.54	1.5–5	-1.16	3.67	.78
Politeness	215	3.70	.58	1.7–4.9	-.77	.62	.87
Negative Urgency	215	2.74	.68	1–4.5	.36	-.27	.87
Positive Urgency	215	2.42	.67	1–4.3	.52	.06	.91
Perseverance	215	2.35	.56	1.1–4.1	.24	.37	.84
Premeditation	215	2.39	.51	1.2–4.3	.81	1.37	.83
Sensation Seeking	215	3.44	.73	1.3–4.9	-.37	-.13	.86
Effortful Attention	215	3.03	.64	1.6–4.8	.24	-.63	.86
Activation Control	215	3.40	.56	1.6–4.6	-.23	-.07	.80
Inhibitory Control	215	3.30	.58	1.6–5	-.10	-.04	.61
Effortful Control	215	3.24	.51	1.7–4.7	.04	-.12	.90

Table 2

Correlations between all measures

		1	2	3	4	5	6	7	8	9	10	11
1.	Letter recall	–										
2.	Operation span	.26	–									
3.	Symmetry span	.27	.32	–								
4.	Antisaccade	.37	.11	.29	–							
5.	SART commissions	-.27	-.18	-.12	-.35	–						
6.	Simon effect	.02	-.10	.00	-.08	.06	–					
7.	Digit switch cost	-.01	.04	-.16	-.16	.02	.03	–				
8.	Shape switch cost	-.04	-.03	-.02	-.08	-.04	-.04	.22	–			
9.	Word switch cost	-.04	-.12	-.18	-.17	.09	-.08	.31	.38	–		
10.	ICAR IQ	.36	.22	.24	.19	-.23	-.02	-.01	.01	-.04	–	
11.	Extraversion	-.17	-.09	-.02	-.08	.17	-.06	.00	.01	-.05	-.05	–
12.	Openness/Intellect	.09	.09	.09	.10	-.19	-.02	-.06	-.06	-.13	.21	.20
13.	Neuroticism	-.09	-.03	-.18	-.05	-.06	-.06	.00	.11	.00	-.05	-.23
14.	Agreeableness	-.06	-.05	.03	.04	.12	-.05	.02	-.09	-.02	-.09	.20
15.	Conscientiousness	-.10	-.10	-.02	-.07	.07	.12	.04	-.06	-.09	-.08	-.04
16.	Assertiveness	-.13	-.10	.02	.00	.11	-.06	-.05	-.03	-.05	.00	.78
17.	Enthusiasm	-.20	-.12	.02	-.07	.13	-.01	-.02	-.02	-.09	-.12	.75
18.	Intellect	.09	.01	.14	.10	-.03	.03	-.10	-.15	-.18	.14	.32
19.	Openness	.06	.11	.02	.09	-.21	-.05	.01	-.07	-.07	.12	-.01
20.	Volatility	-.15	-.05	-.19	-.07	-.03	-.03	-.02	.16	.02	-.08	-.02
21.	Withdrawal	-.06	-.05	-.20	-.10	-.01	-.01	.01	.07	.05	-.07	-.38
22.	Industriousness	-.07	-.06	.00	.02	.09	-.01	.01	-.10	-.03	-.12	.30
23.	Orderliness	-.08	-.03	.04	-.01	.07	-.08	.04	-.06	.01	-.03	-.03
24.	Compassion	-.12	-.10	.01	.02	-.04	.07	-.04	-.01	-.14	-.02	.06
25.	Politeness	-.01	-.02	-.04	-.02	-.02	.07	.05	-.02	-.04	-.05	-.29
26.	Negative Urgency	-.12	-.05	-.19	-.02	-.01	.05	.08	.06	.02	.02	.00
27.	Positive Urgency	-.10	-.04	-.10	-.09	.04	.03	.03	.07	.02	-.04	.05
28.	Perseverance	-.03	.07	-.08	-.08	.03	.01	.06	.09	.04	.02	-.19
29.	Premeditation	.01	.00	-.14	-.08	.11	-.10	.11	-.01	-.06	.01	.29
30.	Sensation Seeking	.20	.09	.18	.13	.00	-.03	-.14	-.13	-.09	.18	.20
31.	Effortful Attention	.06	-.07	.04	.13	-.09	-.02	-.03	-.05	-.02	.03	.11
32.	Activation Control	.03	-.07	.11	.12	.01	-.09	-.10	-.09	-.09	-.07	.25
33.	Inhibitory Control	.09	-.02	.10	.17	-.15	-.04	-.14	-.07	.01	.00	-.06
34.	Effortful Control	.07	-.06	.09	.16	-.09	-.06	-.10	-.08	-.04	-.01	.12

Note. Correlations exceeding .14 are significant at $p < .05$. Correlations exceeding .18 are significant at $p < .01$.

Table 2

Continued

	12	13	14	15	16	17	18	19	20	21	22
1. Letter recall											
2. Operation span											
3. Symmetry span											
4. Antisaccade											
5. SART commissions											
6. Simon effect											
7. Digit switch cost											
8. Shape switch cost											
9. Word switch cost											
10. ICAR IQ											
11. Extraversion											
12. Openness/Intellect	–										
13. Neuroticism	-.03	–									
14. Agreeableness	.01	-.41	–								
15. Conscientiousness	-.04	-.20	.14	–							
16. Assertiveness	.32	-.19	.33	-.16	–						
17. Enthusiasm	.02	-.32	.20	.31	.41	–					
18. Intellect	.62	-.32	.31	-.14	.47	.15	–				
19. Openness	.81	.16	-.12	.06	.05	-.07	.26	–			
20. Volatility	-.07	.83	-.28	-.35	.01	-.21	-.23	.03	–		
21. Withdrawal	-.01	.83	-.37	.02	-.34	-.34	-.33	.23	.50	–	
22. Industriousness	.07	-.58	.82	.06	.37	.27	.45	-.11	-.39	-.53	–
23. Orderliness	-.16	-.11	.73	.05	.11	.01	-.04	-.15	-.03	-.09	.40
24. Compassion	.20	.04	-.03	.70	.03	.22	.00	.29	-.12	.15	-.05
25. Politeness	-.13	-.12	.13	.83	-.38	.07	-.23	.00	-.28	.09	.02
26. Negative Urgency	.04	.67	-.52	-.35	-.03	-.19	-.14	.12	.64	.47	-.56
27. Positive Urgency	-.02	.39	-.49	-.46	.02	-.11	-.16	-.01	.45	.24	-.43
28. Perseverance	.01	.47	-.78	-.17	-.29	-.25	-.30	.10	.38	.37	-.69
29. Premeditation	.15	.13	-.45	-.16	.15	.14	.06	.03	.18	.01	-.29
30. Sensation Seeking	.19	-.19	-.10	-.24	.22	.09	.23	.07	-.15	-.23	-.05
31. Effortful Attention	.10	-.52	.52	.08	.19	.14	.39	-.05	-.44	-.43	.64
32. Activation Control	.02	-.42	.76	.08	.34	.28	.31	-.12	-.28	-.39	.69
33. Inhibitory Control	.07	-.45	.52	.14	.05	.01	.26	.00	-.42	-.34	.51
34. Effortful Control	.07	-.54	.69	.12	.22	.17	.37	-.07	-.44	-.45	.71

Note. Correlations exceeding .14 are significant at $p < .05$. Correlations exceeding .18 are significant at $p < .01$.

Table 2

Continued

	23	24	25	26	27	28	29	30	31	32	33
1. Letter recall											
2. Operation span											
3. Symmetry span											
4. Antisaccade											
5. SART commissions											
6. Simon effect											
7. Digit switch cost											
8. Shape switch cost											
9. Word switch cost											
10. ICAR IQ											
11. Extraversion											
12. Openness/Intellect											
13. Neuroticism											
14. Agreeableness											
15. Conscientiousness											
16. Assertiveness											
17. Enthusiasm											
18. Intellect											
19. Openness											
20. Volatility											
21. Withdrawal											
22. Industriousness											
23. Orderliness	–										
24. Compassion	-.09	–									
25. Politeness	.10	.46	–								
26. Negative Urgency	-.31	-.09	-.33	–							
27. Positive Urgency	-.26	-.32	-.47	.67	–						
28. Perseverance	-.48	.01	-.15	.46	.42	–					
29. Premeditation	-.48	-.05	-.26	.43	.39	.44	–				
30. Sensation Seeking	-.12	-.12	-.33	.13	.26	-.05	.23	–			
31. Effortful Attention	.14	.06	.08	-.53	-.53	-.59	-.21	-.01	–		
32. Activation Control	.47	.02	.07	-.48	-.46	-.77	-.35	.00	.66	–	
33. Inhibitory Control	.29	.03	.18	-.62	-.54	-.52	-.44	-.09	.63	.57	–
34. Effortful Control	.34	.04	.13	-.63	-.59	-.72	-.38	-.04	.89	.85	.85

Note. Correlations exceeding .14 are significant at $p < .05$. Correlations exceeding .18 are significant at $p < .01$.

Factor analyses of executive functions and personality traits

An exploratory factor analysis (EFA) was first carried out to identify the structure of the EF variables. To determine the number of factors to extract, a parallel analysis[4] (Horn, 1965; O'Connor, 2000) was run and the results suggested extracting two factors. Table 3 displays the two-factor solution obtained using maximum-likelihood estimation and oblimin rotation. Whereas the first factor explained variation in switch costs, the second factor explained variation shared by response inhibition and WMC tasks and may have represented a common ability underlying both types of tasks. The two factors exhibited a weak negative correlation of -.10. Importantly, the Simon DV did not have any significant loadings and was subsequently removed from any further analyses, which meant that response inhibition would be indicated by two variables instead of three.

Table 3
Structural matrix for the two-factor solution of EF measures

	Factor	
	1	2
Word switch cost	.81	-.12
Digit switch cost	.47	-.16
Shape switch cost	.45	-.06
Letter recall	.01	.61
Antisaccade	-.17	.59
Symmetry span	-.17	.45
SART commissions	.03	-.45
Operation span	-.09	.40
Simon effect	-.04	-.04

[4] Parallel analysis is a statistical procedure that extracts factors until the eigenvalues of the actual data are less than the 95th percentile of the corresponding eigenvalues of X samples of random data with the same number of observations.

We next used confirmatory factor analysis (CFA) to test two alternative structural models of the EF variables in AMOS 21 (Arbuckle, 2012) using full information maximum-likelihood estimation. Since the EFA results suggested the presence of a general factor (albeit one that did not have much in common with task switching performance), we first tested a model in which one factor was specified to explain the variance shared among all the observed EF variables, and another factor was specified with paths to the three task switching variables. This model thus accounted for the unity and diversity among the EF variables. Model fit was acceptable but not great: $\chi^2(16) = 33.15$, $p = .01$, RMSEA = .07, CFI = .90. Adding a correlation between the uniqueness factors of the complex span tasks, which shared method variance, improved the fit significantly ($\chi^2_{diff}(1) = 7.76$, $p < .01$; $\chi^2(16) = 25.39$, $p = .06$, RMSEA = .06, CFI = .94). The improved model is displayed in Figure 1, and with the exception of the Digits and Shapes task variables, all EF variables had significant loadings on the common factor.

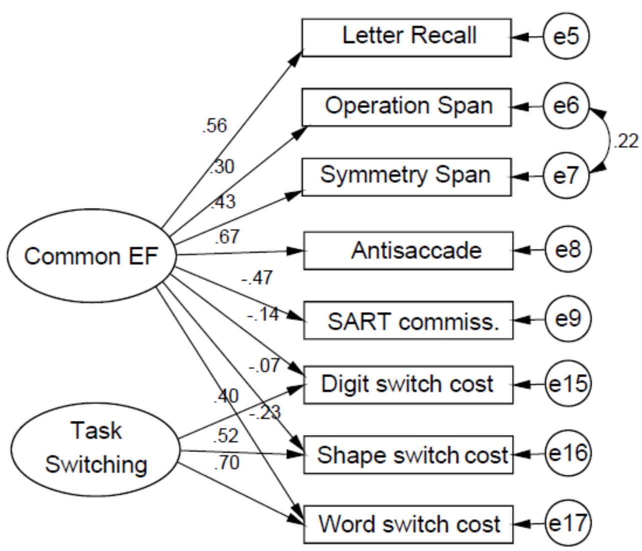

Figure 1. Confirmatory factor analysis for the two-factor structure of EFs, showing unity and diversity among EF variables.

A second CFA was run to assess a theoretical model in which WMC, response inhibition, and task switching were specified as correlated factors with loadings from their respective task variables (see Figure 2). As before, a residual correlation was added between the complex span variables. Model fit was very good: $\chi^2(17) = 23.09$, $p = .11$, RMSEA = .05, CFI = .96). In this model, WMC was strongly positively correlated with response inhibition but not significantly correlated with task switching. We next tested whether WMC and response inhibition were identical factors, as suggested by the EFA results, by fixing their correlation to one. Compared to the previous model, the new model did not fit the data significantly worse ($\chi^2_{diff}(1) = 3.01$, $p = .08$), which implies that the aforementioned EF factors were indeed not distinct from one another. Nonetheless, the models were nearly significantly different, and previous theoretical work suggests the value of investigating WMC and response inhibition separately.

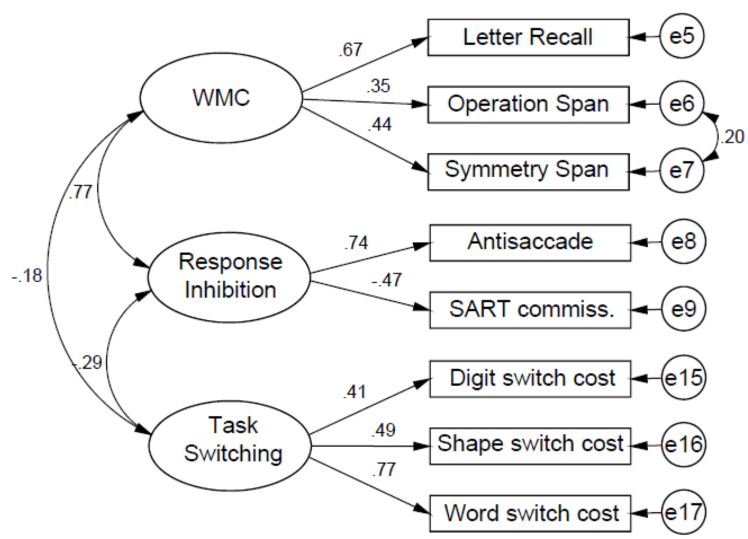

Figure 2. Confirmatory factor analysis for the three-factor structure of EFs, including WMC, response inhibition and task switching.

The next step taken was to confirm the measurement of several latent personality traits. Stability and Plasticity were first modeled as correlated factors, and path loadings for Extraversion and Openness/Intellect were constrained to be equal. The model initially showed poor fit: $\chi^2(5) = 12.07$, $p = .03$, RMSEA = .08, CFI = .88. Modification indices revealed that the sources of bad fit lied in unspecified residual correlations between Extraversion and Neuroticism, and Extraversion and Conscientiousness. Once those correlations were allowed, the model fit extremely well ($\chi^2(3) = .73$, $p = .87$, RMSEA = .00, CFI = 1.0), and there was no significant association between Plasticity and Stability. Next, we confirmed a one-factor model of the three Effortful Control subscales, all of which showed significant loadings. We then tried fitting a one-factor model for the five UPPS-P traits, but the initial fit was poor: $\chi^2(5) = 36.43$, $p < .01$, RMSEA = .17, CFI = .88. After removing Sensation Seeking, which had a weak loading on the general factor, and allowing the uniqueness terms for Positive Urgency and Negative Urgency to correlate, there were no more sources of misfit, and all factor loadings were strong and significant. Since the general factor was indicated by only four of the five subscales (Negative Urgency, Positive Urgency, lack of Premeditation, and lack of Perseverance), it is referred to as UPPP impulsivity.

Finally, the latent correlations among Stability, Effortful Control, and UPPP impulsivity were examined by combining all three factors into a single model (in which Plasticity was not included). This model was highly restricted in the sense that the observed traits for each construct were constrained to load only on their construct's respective factor. Without these constraints, the covariation among the observed traits would have been modeled very differently, as the results of a parallel analysis and EFA suggested the existence of three underlying factors: one factor was marked by Neuroticism, Negative Urgency, and Positive Urgency, among other traits; another was marked by Conscientiousness, Activation Control, and Perseverance, among other traits; and the last factor was almost identical to Premeditation. An empirically-driven model would therefore have split the covariation among these traits into at least two factors that are highly representative of Neuroticism and Conscientiousness.

In light of the EFA results noted, it is not surprising that the constrained three-factor model did not initially provide an acceptable fit to the data: $\chi^2(32) = 310.52$, $p < .01$, RMSEA = .20, CFI = .77. In order to obtain a good fit, residual correlations had to be modeled among several pairs of traits, as indicated by modification indices. In some cases, these correlations were expected based on shared content (e.g., Conscientiousness and Neuroticism were correlated with traits that have similar content), and in other cases they were not expected. One by one, each residual correlation was specified according to the largest modification index, and, subsequent to each modification, another CFA was conducted to obtain new indices until no further modifications were recommended. Although this approach probably resulted in an overfitted model, it was used solely to obtain the correlations among the three factors; and, furthermore, it provided a conservative test of the similarity among these factors, because adding residual correlations will tend to reduce the factor correlations. The final model, displayed in Figure 3, had excellent fit ($\chi^2(20) = 16.90$, $p = .67$, RMSEA = 0, CFI = 1) and revealed that Stability was very similar to Effortful Control ($r = .92$) and practically identical to (reverse) UPPP impulsivity. Despite the excellent fit, two out of the three factor correlations exceeded -1 in magnitude and could not be reduced through additional modifications to the model.

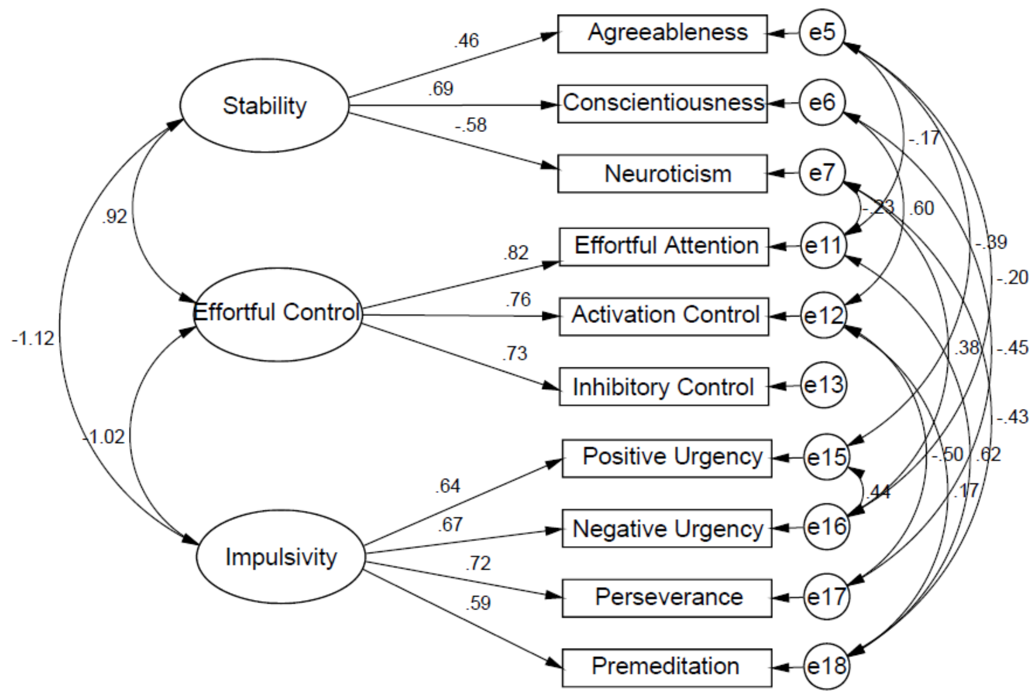

Figure 3. Confirmatory factor analysis for the relationship between Stability, Effortful Control, and UPPP impulsivity.

Associations between executive functions and personality traits

Having established the basic measurement models, we next used them to obtain the latent correlations between the personality variables and the factors obtained from the correlated EFs and unity/diversity models. A total of six CFAs were conducted whereby the measurement models for the metatraits, Effortful Control, and UPPP impulsivity were combined with each of the two EF models, and correlations were allowed between each personality trait and EF. (These latent personality traits were examined separately to reduce model complexity). Subsequently, two more CFAs were performed in which all of the observed personality variables, including the Big Five dimensions and aspects, impulsivity traits, and Effortful Control facets, were added to the EF models and correlations were specified between all latent and observed variables. Due to the covariations among the Big Five dimensions, we regarded it as useful to also examine their independent associations with each EF; therefore, using structural equation modeling (SEM), the Big Five were specified as simultaneous predictors of the unity/diversity EF factors (model 1) and correlated EF factors (model 2). Each of the CFA and SEM models tested showed acceptable fit (CFI > .90, RMSEA <.05). Table 4 displays the latent correlations obtained from the aforementioned CFAs, and in brackets are included the standardized regression coefficients for the Big Five obtained from the SEM analyses. Note that the task switching factor from the correlated EFs model is omitted from Table 4 because it included common EF variance, and, as such, its associations with personality were not as meaningful as those of the task switching factor that excludes this common variance.

Table 4
Latent correlations between personality traits and EFs, including standardized regression coefficients for the Big Five

Personality trait	WMC		Inhibit		cEF*		Switch*	
Stability	.23		.08		.15		-.04	
Plasticity	.00		.05		.05		-.24	
Extraversion	**-.22**	(**-.32**)	**-.22**	(**-.26**)	**-.22**	(**-.32**)	-.10	(-.12)
Openness/Intellect	.17	(**.22**)	**.23**	(**.24**)	**.21**	(**.25**)	-.10	(-.08)
Neuroticism	**-.19**	(**-.35**)	-.01	(-.11)	-.13	(**-.25**)	-.03	(-.10)
Agreeableness	-.14	(**-.20**)	-.13	(-.14)	-.14	(-.18)	-.14	(-.16)
Conscientiousness	-.07	(-.12)	-.09	(-.02)	-.07	(-.08)	-.04	(-.05)
Assertiveness	-.16		-.10		-.12		-.08	
Enthusiasm	**-.24**		-.18		**-.21**		-.15	
Intellect	.16		.11		.16		**-.17**	
Openness	.12		**.26**		**.18**		-.04	
Volatility	**-.26**		-.05		**-.19**		-.02	
Withdrawal	-.16		-.07		-.15		.02	
Industriousness	-.09		-.07		-.08		-.06	
Orderliness	-.08		-.09		-.08		-.01	
Compassion	-.14		.06		-.05		**-.17**	
Politeness	-.03		-.01		-.03		-.06	
UPPP impulsivity	-.17		-.13		-.16		.03	
Negative Urgency	**-.21**		.01		-.13		-.02	
Positive Urgency	-.16		-.10		-.15		-.03	
Perseverance	-.03		-.06		-.06		.02	
Premeditation	-.06		-.13		-.11		-.08	
Sensation Seeking	**.32**		.12		**.26**		-.07	
Effortful Control	.09		**.23**		**.19**		-.07	
Effortful Attention	.04		.17		.12		.01	
Activation Control	.04		.07		.08		-.07	
Inhibitory Control	.12		**.25**		**.20**		.05	

Note. *Correlations for the common EF and task switching factors are based on the unity-diversity model, while correlations for WMC and response inhibition factors are based on the correlated EFs model. Bolded coefficients are significant at $p < .05$. In brackets are the standardized regression coefficients for the Big Five.

Contrary to what was predicted, Stability was not related to response inhibition and neither was UPPP impulsivity. A positive association was found, however, for

Effortful Control and the Inhibitory Control facet, as predicted. To determine whether the association with Effortful Control was driven exclusively by Inhibitory Control, a structural model was tested in which both variables were treated as simultaneous predictors of response inhibition, while the uniqueness factor of this EF (i.e., variance unexplained by the predictors) was allowed to correlate with the other EFs. The model fit the data well: $\chi^2(36) = 45.48$, $p = .13$, RMSEA = .04, CFI = .98). As suspected, only Inhibitory Control remained a significant predictor in this model. Another recent study failed to confirm an association between Effortful Control and response inhibition (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013; study 2), but it is questionable whether this EF was adequately measured, since its assessment was based on three performance variables from a color-word interference task (similar to the Stroop task).

Although in the expected direction, the negative association observed between Plasticity and switch costs (implying better task switching) did not reach significance ($r = -.24$, $p = .09$). Of the lower order traits related to Plasticity, only Intellect was related to better task switching. Additional analyses revealed, however, that the predicted relationship between Plasticity and task switching was significant if Plasticity was estimated using only BFAS scores for Openness/Intellect and Extraversion ($r = -.34$, $p = .03$), rather the average of BFAS and BFI scores, or just the BFI scores ($r = -.15$, $p = .37$). In other words, the relationship was significant depending on which Big Five measure was used. These results are discussed in more detail in the discussion.

We expected a positive correlation between Intellect and WMC based on previous work (e.g. DeYoung et al., 2009), but it was not significant. Upon further inspection, structural equation analyses showed that the association between these two variables was significant, when controlling for Extraversion, which was negatively related to WMC.

As indicated in Table 4, the independent associations of the Big Five with EFs were consistent with and somewhat stronger than the respective correlations, which are likely to have been suppressed to some extent by variation shared among the Big Five. Neuroticism was a negative predictor of WMC, consistent with previous studies that measured negative affectivity traits (Bridgett et al., 2013; Linnenbrink, Ryan, & Pintrich, 1999; Robison, Gath, & Unsworth, 2017), and it was also negatively related to common EF, as two studies on older adults found (Williams, Suchy, & Kraybill, 2010; Schretlen et al., 2010). Conscientiousness did not predict any EF, and Agreeableness was a negative predictor of WMC. Lastly, Extraversion and Openness/Intellect were associated in opposite directions (Extraversion = negatively) with WMC, response inhibition, and common EF, which by and large represented the common variance of the these two EFs. The result for Openness/Intellect and common EF is consistent with other studies that found a positive association between the two constructs in young adults (DeYoung, Peterson, & Higgins, 2005) and older adults (Williams et al., 2010; Schretlen et al., 2010). Other CFAs that were conducted for exploratory purposes and are not reported in detail showed that Openness/Intellect was also positively related to latent intelligence, which was in turn strongly related to common EF and especially WMC, corroborating previous research (e.g., Brydges, Reid, Fox, & Anderson, 2012; Friedman et al. 2006). These analyses also revealed that intelligence and common EF were not independently associated with Openness/Intellect.

Discussion

The present study investigated links between EFs and personality across three levels of the personality hierarchy, focusing in particular on the two metatraits, Plasticity and Stability. In support of the interpretation of Stability as a self-control factor (Olson, 2005), Stability was very strongly associated with latent variables of Effortful Control and trait impulsivity, and CFA results suggested little if any discrimination among these traits. To a certain extent, this lack of discrimination is reflected in the content overlap between the lower-order traits of each factor. Neuroticism, for instance, shares content with Negative Urgency, and Conscientiousness (particularly Industriousness) overlaps substantially with Perseverance and Activation Control. The seeming redundancy among these pairs of traits is furthermore confirmed in the strong bivariate correlations between them, which ranged from .67 to .78. Since Neuroticism and Conscientiousness are the strongest markers of Stability, any two traits that share significant content with these Big Five traits are also likely to be good markers of Stability.

The absence of any positive association between Stability and response inhibition suggests that this particular EF cannot be counted as one of the mechanisms by which Stability is related to greater self-control. At the same time, this conclusion should be tempered by the finding that trait impulsivity was also not significantly related to response inhibition, despite the obvious relevance of this EF to one's ability to control impulsive behavior. A meta-analysis of 27 studies demonstrates that there is, in fact, very little overlap between self-report and behavioral assessments of impulsivity (Cyders & Coskunpinar, 2011). Of particular interest to the present discussion, the authors reported a mean effect size of only r = -.10 between three of the UPPS-P traits (Negative Urgency, Premeditation, and Perseverance) and response inhibition. Given this small effect size, it is quite possible that the latent correlation observed for the UPPP impulsivity factor in the present study (r = -.13) represented a real effect, but the study was underpowered to detect it as significant.

Effortful Control was the only significant predictor of response inhibition in this study, and upon further analysis, the relationship was entirely accounted for by the Inhibitory Control facet, as we predicted. One could conclude from this that any robust relationship between this EF and personality measures of self-control is likely to be confined to personality constructs that are overtly conceptualized as measures of inhibitory ability. Yet, it is also possible that response inhibition is only one specific example of inhibitory ability, and perhaps a more comprehensive assessment of this ability, using a more diverse set of tasks, would yield associations with a broader range of personality traits. A more appropriate test of the Stability hypothesis, for instance, would include a battery of tasks that purport to measure inhibitory control over behaviors that are uniquely relevant to Neuroticism, Agreeableness, and Conscientiousness (i.e., negative emotion, aggressive impulses, and impulses driven by task-irrelevant distraction, respectively).

We found mixed support for the hypothesized association between Plasticity and task switching; the association was significant using Big Five variables from the BFAS but not the BFI. Firstly, the lack of significance in the latter case may simply reflect a lack of statistical power, for even when Plasticity was assessed using only the BFI scores, the correlation was still negative and far from zero. Beyond this limitation, however, the difference in the size of the correlations most likely stems from differences in each instrument's content coverage of the Big Five domains. Unlike the BFI, the BFAS was designed to measure the two primary aspects of each domain, and so the BFAS-derived Plasticity factor includes variance shared among the specific aspects of Extraversion and Openness/Intellect. In previous work, DeYoung (2013) suggested that Plasticity represents primarily the covariance of Intellect and Assertiveness, consistent with the patterns of covariation among the aspects: Intellect is moderately correlated with Assertiveness but only weakly related to Enthusiasm, while Openness is very weakly if at all related to either aspect of Extraversion (DeYoung et al., 2007). The same pattern was observed in the current study, which raises the possibility that the Plasticity finding may have been driven by the covariance of Intellect and Assertiveness. In a follow-up CFA, we found that a factor representing their covariance was indeed significantly related to task switching, but the effect size was slightly weaker than the one for Plasticity, so it is likely that the other aspects of Openness/Intellect and Extraversion contributed relevant variance as well. Future research will want to use both the BFI and BFAS instruments to confirm these findings with a larger sample, as they were unexpected.

At lower levels of the personality hierarchy (i.e., Big Five, ten aspects), several traits were related to one or more EFs, but we did not make any predictions regarding those associations with the exception of Intellect and WMC. By and large, any significant correlations were weak to moderate in size, which is to be expected when comparing constructs measured with different methods, because those measurements lack common method variance that would otherwise inflate their correlations with one another (Campbell & Fiske, 1959). It is worth noting that many of the EF-personality associations discovered through latent-variable analysis were not detectable in the zero-order correlations among the observed variables, which speaks to the critical advantage of using latent variables to eliminate task-specific and error variance.

To our knowledge, this is the first study to examine the relations between the metatraits and executive functioning. Major strengths of this study include the measurement of EFs as latent variables, the measurement of personality traits found at several levels of the personality hierarchy, and the inclusion of other instruments (i.e., Effortful Control and UPPS-P scales) for convergent validation. At the same time, the college-age sample limits the generalizability of the results to other populations, and several EF variables showed unusually low levels of reliability, which may have contributed to some of the non-significant results.

It is important to also point out that although we discovered unity and (some) diversity among the three EFs measured, the unity/diversity model in this study departs from similar models reported in other work (e.g. Miyake et al., 2000; Friedman et al., 2008) with respect to the measurement of working memory. Only one of the working memory tasks employed in this study was an “updating” task (i.e., the Letter Recall N-back), the other two being complex span tasks. Accordingly, the factor underlying performance on these tasks reflects executive processes that are common to all working memory tasks, namely, the active maintenance and retrieval of information in the face of distraction.[5]

Conclusion

Plasticity and Stability were discovered 20 years ago (Digman, 1997) and represent meaningful, non-artifactual relationships among the Big Five (DeYoung, 2006), yet their psychological and neurobiological underpinnings remain largely unknown. The primary aim of this study was to advance current understanding of these metatraits by testing their association to two executive abilities that are arguably important sources of psychological stability (or self-control) and plasticity (or cognitive flexibility). Although unrelated to response inhibition, Stability appears to have much in common with other self-control traits, and we found partial evidence that Plasticity predicts better task switching. Future work should examine how these metatraits are related to other behavioral measures of self-control and cognitive flexibility.

[5] The generality of this factor likely explains why we did not find evidence for a residual factor that might represent working memory-specific functions like updating.

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