Published in final edited form as:

J Pers. 2016 June ; 84(3): 348–360. doi:10.1111/jopy.12163.

Specifying Associations between Conscientiousness and Executive Functioning: Mental Set Shifting, Not Prepotent Response Inhibition or Working Memory Updating

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Abstract

Objective—Conscientiousness is characterized by self-control, organization, and goal-orientation and is positively related to a number of health and professional outcomes. Thus, it is commonly suggested that conscientiousness should be related to superior executive functioning (EF) abilities, especially prepotent response inhibition. However, little empirical support for this notion has emerged, perhaps due to over-simplified and under-specified modeling of EF. The current study sought to fill this gap by testing relations between conscientiousness and three facets of EF using a nested factors latent variable approach.

Method—Participants ($N = 420$; M age = 22.5; 50% male, 91% Caucasian) completed a measure of conscientiousness and nine EF tasks designed to tap three related yet distinguishable facets of EF: working memory updating, mental set shifting, and prepotent response inhibition.

Results—Structural equation models showed that conscientiousness is positively associated with the EF facet of mental set shifting but not response inhibition or working memory updating.

Conclusion—Despite the common notion that conscientiousness is associated with cognitive abilities related to rigid control over impulses (i.e., inhibition), the current results suggest the cognitive ability most associated with conscientiousness is characterized by flexibility and the ability to adapt to changing environmental contingencies and task demands.

Keywords

executive functioning; conscientiousness; mental set shifting

Trait conscientiousness has been defined as the tendency to be self-controlled, responsible, planful, organized, hardworking, orderly, task and goal-oriented, to delay gratification, and to follow norms and rules for impulse control (Roberts, Jackson, Fayard, Edmonds, & Meints, 2009). Measurement of conscientiousness often emphasizes achievement, order, impulse control, or responsibility (Roberts, Chernyshenko, Stark, & Goldberg, 2005). Accordingly, conceptualizations of this trait suggest a meaningful role for top-down

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

behavioral control on a person's actions (Ahadi & Rothbart, 1994; DeYoung, 2010; DeYoung et al., 2010; Eisenberg, Duckworth, Spinrad, & Valiente, 2014).

Considerable evidence indicates associations between conscientiousness and numerous personal, interpersonal and health-related outcomes often associated with controlled behavior (see Ozer & Benet-Martinez, 2006). To note a few examples, conscientiousness relates positively to academic success (Higgins, Peterson, Pihl, & Lee, 2007; Noftle & Robins, 2007; Tross, Harper, Osher, & Kneidinger, 2000), career success (Dudley, Orvis, Lebiecki, & Cortina, 2006; Judge, Higgins, Thoresen & Barrick, 1999), workplace performance (Higgins et al., 2007), health-promoting behaviors (Bogg & Roberts, 2004) and longevity (Kern & Friedman, 2008; Weiss & Costa, 2005), and relates negatively to substance use disorder diagnoses (Kotov, Gamez, Schmidt, & Watson, 2010). Meta-analytic work demonstrates that the relationship between conscientiousness and job task performance is found across a wide range of job types, suggesting that conscientiousness facilitates performance for a variety of tasks across many divergent contexts (Ones, Viswesvaran & Schmidt, 1993). The breadth and significance of the beneficial outcomes related to high levels of conscientiousness has led some scholars to consider it the most important of the Big Five personality traits (Roberts et al., 2005).

These associations suggest that conscientiousness ought to covary with certain cognitive abilities that promote self-control. Along these lines, some theorists recently have posited that executive functions (EFs) are the primary mechanism by which conscientiousness affects behavior (e.g., Hall & Fong, 2013; Hall, Fong, & Epp, 2013). In fact, leading definitions of EF—a core set of control mechanisms that serve to regulate cognition and behavior in the service of higher-order goals (Miyake & Friedman, 2012)—are strikingly similar to the defining features of conscientiousness listed previously. Beyond their definitional similarities, studies showing that both constructs relate positively to health behavior suggest a potential relationship between EF and conscientiousness themselves (e.g., DeYoung, 2010; Hall et al., 2013). Specifically, superior EF abilities have been associated with weight loss, exercise, adherence to medical regimens, heart health, decreased stress, lower rates of substance use (Williams & Thayer, 2009), decreased fatty food consumption (Hall, 2012), and HIV medication adherence (Solomon & Halkitis, 2008); likewise, conscientiousness has been related to increased physical activity and healthy eating, and decreased alcohol, drug, and tobacco use, risky sex, risky driving, violence, and suicide (Bogg & Roberts, 2004; 2013). To the extent that these results reflect a common underlying mechanism, conscientiousness and EF might also be related.

It is commonly assumed that the kind of positive health outcomes just described rely on strong self-regulatory control (see Baumeister & Tierney, 2011), and in particular the inhibition of prepotent, habitual behaviors that serve short-term goals (e.g., ordering the French fries) and replacing them with behaviors that serve longer-term goals (e.g., ordering the fruit salad instead). Thus, the association of conscientiousness with these positive health behaviors is often thought to reflect a broader association between conscientiousness and inhibitory ability (see Halverson et al., 2003). Recently, Hall and colleagues (2013) provided evidence supporting this idea by simultaneously examining the predictive power of conscientiousness (among other personality traits) and EF on health behavior. In this study, EF was represented by performance on a Stroop color-naming task and a go/no-go task, both of which are considered measures of inhibitory ability (see Miyake et al., 2000; Nigg, 2000; Verbruggen & Logan, 2008). Results showed a modest positive association between conscientiousness and their EF variable (i.e., inhibition performance; $r = .138$, $p < .05$), and more importantly showed that this EF variable accounted for a considerable amount (24%) of the total effect of conscientiousness on health behavior ($r = .187$, $p < .01$). In contrast, however, Jensen-Campbell et al. (2002) reported no association between conscientiousness and Stroop performance alone.

Such apparently contradictory findings seem emblematic of the larger literature on conscientiousness and EF, in which their predicted association has proven elusive. It has been common practice in this literature to derive a composite "EF" variable from performance on a variety of divergent cognitive or "frontal lobe" assessments and to test the correlation between this composite variable and conscientiousness (see DeYoung, Peterson, & Higgins, 2005; Salthouse et al., 2004; Williams et al., 2010). For example, Salthouse and colleagues (2004) derived an "EF" variable representing performance on 6 neuropsychological assessments (e.g., sort recognition; categorical fluency; proverb interpretation); similarly, Williams and colleagues (2010) formed a composite "EF" variable from tasks designed to cover cognitive flexibility, initiation, inhibition, response selection, working memory, generative fluency, and attentional vigilance. A somewhat more nuanced approach was taken by Unsworth and colleagues (2009), who created latent variables meant to represent separable facets of EF (working memory capacity, response inhibition, fluency, and vigilance), each represented by performance on two behavioral tasks. In each of these prior studies, analyses revealed no association between conscientiousness and their respective "EF" variables.

Why, then, do EF and conscientiousness appear to be so similar descriptively and to predict similar outcomes and yet seemingly show only inconsistent (at best) direct associations in empirical studies? One possibility suggested by the preceding review is that EF has been inconsistently assessed and improperly specified in previous studies. Historically, numerous mental operations, such as inhibition, attentional control, strategic planning, verbal fluency, planning, and working memory updating have been placed under the EF umbrella (see Baddeley & Della Sala, 1998; Milner & Petrides, 1984; Stuss & Benson, 1984), and this breadth has led to difficulties of both measurement and meaning. The use of varying "frontal lobe" or neuropsychological tasks to derive measures of EF, often with little consideration for the specific cognitive operations they measure or how those operations might relate to one another (e.g., Jurado & Rosselli, 2007; Miyake et al., 2000), is problematic both conceptually and empirically in that many such tasks are complex and likely tap multiple underlying facets of EF (see Miyake et al., 2000; Smith, Taylor, Brammer, & Rubia, 2004). This situation has contributed in large part to the low construct validity often associated with such tasks (Phillips, 1997; Rabbitt, 1997). A related problem is that researchers commonly assume EF to be a unitary construct (e.g., Giancola, 2004; Salthouse et al., 2004; Unsworth et al., 2009), despite converging evidence that EF is multifaceted and comprised of specific related yet separable component abilities (see Friedman, Miyake, Robinson, & Hewitt, 2011; Miyake et al., 2000; Miyake & Friedman, 2012). Thus, studies in which "EF" is measured with only a single task, or in which multiple tasks are used and performance is aggregated into a single "EF" factor, can produce results that are very difficult to interpret in terms of posited associations between EF and other constructs.

The Unity and Diversity of EF Abilities

Addressing this problem requires a more sophisticated approach to understanding and measuring EF and its association with other variables. Miyake and colleagues have argued for and shown empirical support for a latent 3-factor model of EF (see Miyake et al., 2000; Miyake & Friedman, 2012). In their model, the separable facets of inhibiting prepotent responses (inhibition), monitoring and updating the contents of working memory (updating), and shifting between tasks or mental sets (shifting) have been shown to correlate modestly (*r*s = .40 – .60) but not perfectly with one another and also have differential associations with other constructs; in other words, these EF facets display both "unity and diversity" (see Teuber, 1972). This basic pattern has been observed in numerous samples across a range of ages and cognitive abilities (see Friedman et al., 2011; Miyake & Friedman, 2012; Rose, Feldman, & Jankowski, 2011; Vaughan & Giovanello, 2010).

Application of the unity and diversity model requires assessment of each of the three EF facets with a different subset of cognitive tasks, which allows for derivation of separable yet correlated latent variables. The most recent conceptualization of the model uses a nested factors approach, in which the unity (i.e., shared variance) among EF tasks is captured by a latent "Common EF" factor indicated by performance on all of the EF tasks, while diversity (i.e., unique variance) is captured by additional "Updating-specific" and "Shifting-specific" latent factors. The lack of an "Inhibition-specific" latent factor indicates that once variance common to all three facets of EF is accounted for in the "Common EF" factor, the remaining correlations between the inhibition tasks are not large enough to create a separate latent variable (see Friedman et al., 2008, 2011). In one study using the same EF task battery employed in the current study, Friedman et al. (2008) estimated a hierarchical latent variable model where Updating-, Shifting-, and Inhibiton-specific latent variables indicated a higher order "Common EF" variable and found a perfect correlation (i.e., standardized loading = 1.0) between a stand-alone, Inhibition-specific factor and the Common EF factor, indicating that individual differences in inhibition are entirely explained by what is common to all of the EF tasks (also see Friedman et al., 2011). Such findings can be understood as indicating (a) that inhibitory control likely is involved in all three latent EF abilities, and (b) the Common EF factor represents this shared inhibitory component. More specifically, Friedman et al. (2008; 2011) propose that individual differences in the Common EF factor primarily reflect the ability to maintain goals as well as goal directed behavior in the face of interference and to use these goals to bias against competing processes (i.e., task control and top-down attention) (see also Herd et al., 2014). This conceptualization of the Common EF factor is consistent with a view of inhibitory control as a byproduct of goal maintenance (e.g., Chatham et al., 2012; Herd, Banich, & O'Reilly, 2006; Kane & Engle, 2003; Morton & Munakata, 2002; Munakata et al., 2011) and may help to explain why no inhibition task-specific variance is left over after accounting for the commonalities among all 9 EF tasks. Findings in support of the nested factors model have been replicated in numerous independent datasets (see Miyake & Friedman, 2012) as well as in the current dataset.

Overview of the Present Study

By applying the nested-factors unity and diversity model of EF (Miyake & Friedman, 2012) to performance on multiple, well-validated laboratory task measures of inhibition, updating and shifting in a relatively large, community-based sample of young adults, the current study represents the most comprehensive attempt to date to thoroughly examine the often predicted yet rarely observed association between conscientiousness and EF. Although the extant research has suffered from a general lack of specificity in terms of assessment of EF, careful consideration of previous studies provides the basis for some predictions. First and perhaps most surprisingly given the impulse control often ascribed to high levels of conscientiousness, we predicted no association between conscientiousness and inhibition, which would be reflected by a non-significant association between conscientiousness and the common EF factor in the nested factors EF model. This prediction is in-line with the weight of the evidence from previous studies, with one (Hall et al., 2013) reporting a modest positive association but at least three others (Jensen-Campbell et al., 2002; Murdock, Oddi, & Bridgett, 2013; Unsworth et al., 2009) reporting no association between conscientiousness and inhibition task performance. Second, and in-line with previous work showing that composite EF variables created from performance on a number of diverse EF tasks are unrelated to conscientiousness (e.g., Salthouse et al., 2004; Unsworth et al., 2009; Williams et al., 2010), we did not expect conscientiousness to relate to the Common EF factor in our model.

Predictions concerning potential associations between conscientiousness and updating and shifting are less straightforward, with conceptual and empirical evidence leading to some competing predictions. Updating refers to one's ability to "actively manipulate relevant information in working memory" (Miyake et al., 2000, p. 57) and to engage in controlled retrieval processes (Miyake & Friedman, 2012). Jonides and Smith (1997) further suggested that updating involves "temporal tagging" and reflects one's ability to keep track of relevant information while ignoring irrelevant information. Importantly, as noted by Miyake et al. (2000), this EF component differs from individual differences in the amount of information that can be passively stored in working memory (i.e., working memory *span*). Unsworth and colleagues (2009) found no association between working memory *span* and conscientiousness. To the extent that holding and manipulating multiple pieces of information in memory and/or controlled retrieval are important for planning and orderliness, believed to be components of conscientiousness (Roberts et al., 2009), it is possible that updating and conscientiousness should be positively associated. However, conscientiousness was not associated ($r = -.15$) with performance on a 3-back working memory task (DeYoung, Shamosh, Green, Braver, & Gray, 2009) or with verbal fluency task performance ($r = -.02$) (Murdock et al., 2013). Accordingly, we might expect that the latent Updating-specific factor would not associate with conscientiousness in the nested factors EF model.

Shifting likely involves both the ability to "actively engage and disengage appropriate task sets" as well as "the ability to perform a new operation in the face of proactive interference or negative priming" (Miyake et al., 2000, p. 56). In other words, success on a new task (e.g., identifying the color of a shape) often necessitates the overriding of interference stemming from a previously activated set of task demands (e.g., identifying the name of a shape). The demands of shifting tasks seem to imply a balance between stability and flexibility (see Goschke, 2000), such that performance depends on an individual's ability to be both flexible (i.e., rapidly shifting back and forth between mental sets) and stable (i.e., actively maintaining a single task goal) (see also Miyake & Friedman, 2012). The complimentary abilities of flexibility and stability posited to underlie shifting ability seem to be quite similar the definitions of industriousness and order that are thought to underlie conscientiousness (Roberts et al., 2005). To the extent that this is true, shifting and conscientiousness should be positively related. Work utilizing the Wisconsin Card Sorting Task, (WCST; Curtiss & Tuttle, 1993) provides mixed evidence regarding the potential for a relationship between shifting and conscientiousness. In one sample, some indicators of performance on this task were related to conscientiousness (Jensen-Campbell et al., 2002) whereas in another sample there was no relationship (Murdock et al., 2013). This mixed evidence likely stems from evidence suggesting that WCST performance reflects multiple EF abilities, including shifting, processing speed, inhibition, and working memory (e.g., Ashendorf & McCaffrey, 2008; Fristoe, Salthouse, & Woodard, 1997; Hartman, Bolton & Fehnel, 2001; Miyake et al., 2000). In sum, a close examination of the trait of conscientiousness and conceptualizations of shifting suggest that they may be related, but there is a lack of empirical evidence testing this association using a model of EF specifically designed to isolate shifting specific task variance.

Method

Participants

Four hundred twenty adults aged 21–30 (*M* age = 22.5; 50% male, 91% Caucasian) were recruited from the Columbia, MO community to participate in a larger study on the effects of alcohol on cognition. Advertisements announcing the study were placed in mass email announcements sent to university students and employees, in online classifieds (e.g., Craigslist), and on message boards in the surrounding community. Interested individuals were instructed to call or email the lab and leave their contact information, after which a research assistant completed a telephone interview with each individual to determine their study eligibility. Individuals indicating medical conditions that contraindicated alcohol administration (e.g., abstention; history of alcohol or drug dependence or other serious mental or physical illness; prescription medication other than oral contraception; pregnancy) or issues that would make completion of laboratory tasks unusually difficult (e.g., colorblindness; a primary language other than English) were disqualified. Eligible individuals were scheduled for individual laboratory appointments, during which they completed a battery of EF tasks and self-report measures. Participants were compensated $35 for completion of these assessments.

Materials and Measures

Executive function measures—Participants completed a total of 9 computerized EF tasks—three tasks tapping each of the three component EF abilities under investigation (prepotent response inhibition, working memory updating, and mental set shifting). Descriptive statistics for all EF tasks can be found in Table 1.

Inhibition 1: Antisaccade: During each trial of the antisaccade task (adapted from Roberts, Hager, & Heron, 1994), a centrally located fixation cross appeared for a variable amount of time (one of nine presentation times between 1,500 and 3,500 ms, in 250 ms intervals). It was replaced with an initial cue (black 1/8 in. square) whose inner edge appeared 3.375 in. to the left or right of fixation (with equal probability), after which a numeric target (the digits 1–9, presented in a 7/16 in. square with its inner edge 3.25 in. from the fixation cross) appeared for 150 ms before being masked with gray cross-hatching. For each trial, the participant reported the target number (or provided a guess) to the experimenter, which initiated the next trial.

In the first block (prosaccade trials; $N = 25$), targets always appeared on the same side of the screen as the initial visual cue (175 ms post cue presentation) in order to build a prepotency to orient to the initial visual cue. In the following antisaccade blocks (3 blocks of 36 trials each), participants were instructed to not look at the initial visual cue, because the box containing the target number would quickly appear on the opposite side of the screen from the initial cue. The cue-to-target interval (i.e., time from initial visual cue to presentation of target number) was fixed within each antisaccade block, but decreased across blocks: 225 ms for the first block, then 200 ms, and 175 ms for the last block. Each number was pseudorandomly presented in each block. Additionally, numbers repeated in consecutive trials twice within each antisaccade block, though the repeat number always appeared on the opposite side as the previous trial. The prosaccade and first antisaccade blocks were each preceded by 12 practice trials, and each block contained 2 "warm up" trials that were not included in the analyses. The dependent measure was the proportion of correct responses across all 3 antisaccade trial blocks.

Inhibition 2: Stop Signal: The Stop-Signal Task (van den Wildenberg et al., 2006) is designed to measure individuals' ability to inhibit a prepotent response. The first block of trials is designed to build such a prepotent response. On each trial, participants focused on a fixation point (small black square) until a green arrow appeared that pointed to the right or left (each direction was presented equally often and pseudorandomly ordered). Participants were instructed to press either the left or right arrow on the keyboard (to match the direction of the arrow on the screen) as quickly and accurately as possible. Arrows disappeared once a response was made. After 10 practice trials, participants completed an initial block of 50 all-go trials, in which they simply responded to the direction of a series of green arrows.

After these initial trials, a stop signal was introduced and continued for 1 block of 48 practice trials and 2 blocks of 80 experimental trials. In these blocks, arrows initially appeared as green on each trial and changed to red on 25% of trials, indicating that no keyboard response should be made. The time before the arrow turned red was determined by a staircase-tracking algorithm: each successfully inhibited response resulted in the stop signal appearing 50 ms later on the next stop trial, whereas failed stops resulted in the next signal appearing 50 ms earlier. The onset of stop signals adjusted so that participants would be able to inhibit responding on about 50% of stop trials. Any participants whose stopping percentage was outside of a 40–60% accuracy range were administered additional blocks until their accuracy fell within this range (< 2% of participants). The dependent measure was the *stop signal reaction time* (SSRT; Logan, 1994), which estimates the amount of time required to stop an already-initiated response. Consistent with van den Wildenberg and colleagues (2006), we computed the SSRT as the difference between median reaction time on go trials (which estimates the time when a response *would have occurred* in the absence of the stop signal) and the average stop signal delay (i.e., the delay between the appearance of the green arrow and the appearance of the red arrow on stop trials). Larger SSRT values thus indicate that a participant needed more warning in order to avoid responding on stop trials.

Inhibition 3: Stroop: On each trial of the Stroop color-naming task (Stroop, 1935), three types of trials were presented in the following order: (1) one block of 20 neutral trials with strings of 3–5 asterisks printed in blue, green, or red; (2) one block of 20 congruent trials where color words were printed in matching font color (i.e., “BLUE” printed in blue); and (3) one block of 60 incongruent trials where color words were printed in non-matching font color (i.e., “BLUE” printed in green). Participants were asked to name the font color aloud into a microphone in order to record response latency while the experimenter recorded the accuracy of responses. On each trial, a white fixation cross appeared for 250 ms on a black background followed by the stimulus, which remained on screen until the participant responded. Stimulus lists were presented in a pseudorandom fixed order so that the three color words (or sets of asterisks) and three stimulus colors occurred with equal probability in each block and to ensure that no more than three trials in a row would involve the same word or stimulus color. The first two blocks (i.e., asterisk and congruent) were preceded by 10 practice trials each, and every block included 2 "warm-up" trials that were not included in the analyses. The dependent measure was the reaction time difference between incongruent and asterisk trials.

Updating 1: Keep track: The keep track task (adapted from Yntema, 1963) required participants to track a series of exemplar words belonging to six different categories (relatives, countries, colors, animals, metals, and distances). Each trial began with a list of 3–5 target categories (presented at the bottom of the screen). Participants were instructed to keep track of the *last* word from each category that was presented onscreen and that they would need to report these at the end of each trial. When the participant indicated readiness, the experimenter pressed the space bar to start the trial. "GET READY" appeared for 2 s, then after 1 s, the categories appeared at the bottom of the screen and remained there while a stream of 15–25 exemplar words from the various categories appeared in the center of the screen, at the rate of one word every 2000 ms. At the end of the trial, "???" appeared in the center of the screen, indicating the participant should verbally recall the most recent exemplar from each target category. Participants were not permitted to say the words or categories aloud during the course of each trial. The dependent measure was the proportion of correct responses across all trials. There were a total of 9 trials, 3 of each difficulty level. These were preceded by two practice trials with 2 categories each.

Updating 2: Letter memory: On each trial of the letter memory task (adapted from Morris & Jones, 1990), a stream of consonants appeared at the rate of one every 3000 ms. With each new letter, participants were asked to repeat aloud the last four letters that had appeared on screen (including the current letter), in the correct order. Letters were accumulated until the fourth letter was reached, after which the fifth letter back was dropped (i.e., “L”, “L-S”, “L-S-K”, “L-S-K-D”, “S-K-D-H”, etc.). After 9, 11, or 13 letters had appeared (the series length was unpredictable), "???" appeared on the screen, indicating the participant should report the final 4 letters in the correct order. For both the rehearsal and the final recall, if a letter could not be recalled, participants were instructed to substitute “blank” where the missing letter should have been. The task involved a total of 9 trials, 3 of each sequence length. To begin the task, participants completed three practice trials, two 7-letter and one 9-letter sequence. The dependent measure was the accuracy of the strings repeated after each new letter was presented, with one point given for each correctly reported set.

Updating 3: Spatial 2-back: In the spatial 2-back task (Friedman et al., 2008), boxes flashed in 12 locations on the computer screen, and participants reported for each flash whether the location of the current stimulus was the same or different as the location of the stimuli presented two trials previously (i.e., after the appearance of the 3rd stimulus in a series, participants compared its location to that of the 1st stimulus in the series). Participants pressed one of two buttons to indicate their response.

Locations consisted of 12 open squares (5/8 in.) in a fixed pseudorandom location on the monitor, such that if the screen were divided into quadrants, 3 squares were positioned within each quadrant. These 12 boxes were displayed throughout the task and the quadrant structure was not obvious. In each block of trials, 24 squares flashed, one at a time with each flash necessitating a response from the participant. When a square flashed, it became solid black for 500 ms and then returned to open for 1500 ms until the next square flashed. There were six “yes” responses in each block. Of the remaining 18 “no” responses, a few flashes were lures, (i.e., the square that flashed was the same as the 3-back trial) included to increase task difficulty ($N = 5$ per block). Each square was equally represented as a target, nontarget, or lure, and sequences of flashes were made to appear random, avoiding circular patterns or clustering in one spatial location. A practice block of 20 flashes was administered prior to 4 blocks of twenty-four actual trials. The dependent measure was the proportion of correct responses across all trials. Omissions were counted as incorrect responses.

Shifting 1: Color–shape: In the color-shape task (Miyake, Emerson, Padilla, & Ahn, 2004), participants task was to categorize circles and triangles, presented in either red or green, as quickly and accurately as possible. Participants pressed either the rightmost or leftmost button on a button box to classify the stimulus (left to indicate circle or red, right to indicate green or triangle). On each trial, the target was presented along with a cue that indicated whether participants should use the dimension of color ("C") or shape (“S”). This cue was presented directly above the target and both the target and cue remained onscreen until a response was made. The next trial started 350 ms after the response. A 200 ms buzz sounded for incorrect trials. Participants completed two single task blocks (color then shape, 12 trials each, plus 8 practice trials each). They then completed two mixed-task blocks of 48 trials each (24 trials with each dimension, pseudorandomly ordered). The first of the mixed-task blocks was preceded by a 24-trial practice block, and each block included four "warm-up" trials that were not analyzed. The number of switch trials (a trial with a cue that does not match the cue from the previous trial) and repeat trials (the current cue matches the previous cue) were the same in each mixed block. The dependent measure was the switch cost—the difference between average reaction time for correct switch trials and correct repeat trials in the mixed-task blocks. Trials that followed errors were eliminated from analysis, as it was not clear the participant was using the correct task set (so the repeat vs. switch categorization of the following trial would be unclear).

Shifting 2: Category switch: The category switch task (adapted from Mayr & Kliegl, 2000) used a similar structure and the same timing parameters as the color–shape task. One word was presented on each trial. Words could be classified both as describing living or non-living and things smaller or larger than a soccer ball (e.g., alligator, coat, knob, lion). A cue (either a heart or crossed arrows) appeared directly above the word to indicate which dimension (living/non-living vs. small/large, respectively) was relevant for the current trial. Participants pressed either the rightmost or leftmost button on a button box to classify the word (left to indicate nonliving or small, right to indicate living or big), and a 200 ms error buzz sounded for incorrect trials. The next trial started 350 ms after the response. Participants began by completing two blocks during which they categorized objects along a single dimension (living, then size, 14 trials each, preceded by 12 practice trials for each dimension and two "warm up" trials per block). Next, participants completed 24 practice trials in which the tasks were mixed (i.e., categorizations switched between living and size), followed by two mixed blocks of 48 trials each (not including 4 “warm-up” trials per block). The dependent measure was the switch cost: the difference between average reaction time for correct switch trials and correct repeat trials during the mixed blocks. Trials that followed errors were eliminated from analysis.

Shifting 3: Number–letter: On each trial of the number-letter task (adapted from Rogers & Monsell, 1995), a number–letter or letter–number pair was presented in one quadrant of a square (numbers ranged from 2–9 and letters included A, E, I, U, G, K, M, and R). If the set appeared in the top half of the square, participants were instructed to categorize the *number* as odd or even. If the set appeared in the bottom half, participants were instructed to categorize the *letter* as a consonant or vowel. Participants pressed a button to classify the target character (left to indicate even/vowel, right to indicate odd/consonant). Participants completed two blocks (12 trials each) in which the stimulus first appeared exclusively in the top half of the square, then exclusively in the bottom half. Each of these single-task blocks was preceded by 12 practice trials and included 2 additional "warm-up" trials. Next participants completed 12 practice trials of predictable-switches in which the pair of characters were presented in a clockwise pattern so that participants knew which task to perform next, followed by 2 blocks following this pattern (48 trials each), each with 4 additional "warm-up" trials. Finally, they completed two random-switch blocks (48 trials each) in which the next location was randomly determined, but was cued for 350 ms before the trial occurred. The cue was a thick black square that appeared over the quadrant in which the character pair would be presented. A block of 24 practice trials preceded these blocks, and each block included 4 additional "warm-up" trials. As with the other switch tasks, each new trial began 350 ms after the end of the previous trial, and a 200 ms buzz signaled errors. The dependent measure was the switch cost in only the random-switch blocks: the difference between average reaction times for correct switch trials and correct repeat trials. Trials that followed errors were eliminated from analysis.

Self-Report Personality Measure—Personality was assessed using the NEO-Five Factor Inventory (NEO-FFI) (Costa & McCrae, 1992). The NEO-FFI consists of 60 items that are rated on a scale from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). This measure produces subscales for each of the Big Five personality domains (agreeableness, conscientiousness, extraversion, neuroticism, and openness). For each personality domain, an overall score was computed by averaging responses across the 12 subscale-specific items (see Table 2).

Procedure

Testing sessions began at 9:00 A.M. and lasted approximately 3–4 hours. Participants were required to abstain from alcohol and drug use for 24 hours prior to their session; compliance was assured by signed affidavits completed upon arrival at the lab. After providing informed consent, participants were shown to a private room where they completed a battery of baseline individual difference and personality measures. Next, participants completed the battery of 9 EF tasks in a randomized order (fixed for all participants). Following task completion, participants who consented to do so provided a saliva sample for use in future genetic analyses. Participants were then debriefed, paid and dismissed. The University of Missouri Campus Institutional Review Board approved all experimental procedures.

Data Trimming and Transformation

Following previous studies incorporating the tasks used in this study (e.g., Friedman et al., 2008; 2011), we applied appropriate trimming and transformation to the EF task data to improve the distributions and reduce the influence of outliers. For all RT measures depending on mean RT (i.e., all RT measures except for the stop signal), RT values < 200 ms and values from error trials were automatically discarded. For the three shifting tasks, all post-error trials were discarded, as it is likely that the participant did not achieve the desired mental set on such error trials, meaning that the following trials may not actually represent a "mental set shift" as is critical to the validity of the task. To obtain the best measures of central tendency, response latencies on RT-based tasks were trimmed according to Wilcox and Keselman (2003; equation 3). After this within-subject trimming, we also conducted between-subject trimming: For each measure, scores greater than 3 *SD* from the group mean were replaced with a value that was equal to 3 *SD* above or below the group mean, as appropriate. This replacement technique aimed to preserve each participant's rank ordering, while preventing extreme outliers from unduly influencing correlations or model parameters. Accuracy-based measures (i.e., keep track, letter memory, spatial 2-back, antisaccade) were arcsine transformed to improve data normality (see Friedman et al., 2008). In all analyses, EF variables were coded so that for all measures, higher scores indicated better performance.

Results

Executive functioning model

Latent variable analyses were performed using MPlus version 7 (Muthén & Muthén, 1998–2012). Consistent with previous work (e.g., Friedman et al., 2011; Miyake & Friedman, 2012) a model specifying a Common EF factor, a shifting-specific factor, and an updating-specific factor fit the data well. Although one of the tasks (keep track) did not load significantly onto the Common EF factor with the data from the current sample (indicating that the variance associated with this task is best explained by its relation to the updating-specific factor), the model provided good fit to the data, (χ^2 (21) = 30.36, $p = 0.085$, RMSEA = 0.033, RMSEA 90% C. I. = 0.00 – 0.056, CFI = 0.974, TLI = 0.956. This model was utilized in the subsequent analyses[1].

Conscientiousness predicting latent EF factors

A latent conscientiousness variable was created using 4 item parcels each consisting of 3 NEO-FFI conscientiousness items. Empirically derived parcels were created by grouping items together based on the subscale of the NEO-PI-R from which they originated (i.e., order, self-discipline, dutifulness, achievement striving). The addition of conscientiousness as a predictor resulted in good model fit, (χ^2 (56) = 66.13, $p = 0.167$, RMSEA = 0.021, RMSEA 90% C. I. = 0.00 – 0.038, CFI = 0.989, TLI = 0.984. Conscientiousness was found to be a significant predictor of the Shifting-specific factor ($\beta = .16$, $p = .013$), but not the Updating-specific factor ($\beta = -.03$, $p = 0.691$) or the Common EF factor ($\beta = .01$, $p = 0.825$) (see Figure 1). When directly comparing this model with an alternative model where paths from conscientiousness to the EF factors were constrained to be zero, the chi-square difference test was significant ($\chi^2_{diff} = 11.34(3)$, $p = .010$), indicating that the structural model where the paths from conscientiousness to EF facets are allowed to be free fits the data better than if the relationships between conscientiousness and EF facets are assumed to be zero.

The primary goal of the current report was to investigate the associations between conscientiousness and EF, but because data from the entire NEO-FFI were collected, we conducted ancillary analyses testing associations between all NEO-FFI personality domains and EF. Specifically, we report bivariate correlations between NEO-FFI domains and EF tasks (see Table 3) as well as fit indices and standardized path estimates for structural equation models where each of these domains were used as predictors of EF facets in the same nested factors model used in the conscientiousness analyses (see Table 4). It is important to note that these analyses are exploratory in nature and outside of the scope of the current report. As such, they are provided for the sake of aiding future research on these topics.

[1]While we recognize that alternative scoring procedures are available for several of the EF tasks used in the current report, including the use residual scores in place of a reaction time difference scores (i.e., category switch, color shape, number letter, Stroop) and the use of d prime in place of proportion correct (i.e., spatial 2-back), the use of these alternate approaches is not standard practice within the EF literature that formed the conceptual basis for this study (see also Kiesel et al., 2010; Monsell, 2003; Vandierendonck, Liefooghe, & Verbruggen, 2010). Thus, in order to maintain our ability to conceptualize the findings of this study in the context of the unity and diversity model of EF, we elected to use the standard scoring procedures for all tasks (e.g., Friedman et al., 2008).

Discussion

This study provides the most thorough test to date of the hypothesized relation between conscientiousness and EF. Previous work addressing this question has suffered from two primary limitations. First, the array of methods and measures that have been used to assess EF (e.g., DeYoung et al., 2005; Hall et al., 2013; Jensen-Campbell et al., 2002; Salthouse et al., 2004; Williams et al., 2010) betrays an over-simplified and under-specified conceptualization of the construct. Following recent theoretical and empirical developments indicating both unity and diversity among EF abilities (Miyake et al., 2000; Miyake & Friedman, 2012), it was assumed here that resolving inconsistencies in the literature examining this hypothesis required modeling the multi-faceted nature of EF, thereby permitting targeted tests of associations between conscientiousness and specific EF abilities as well as a broader latent EF construct representing what those component abilities have in common. It was further assumed that, because any single task is an imperfect measure of the underlying construct it is meant to assess (e.g., Jurado & Rosselli, 2007), latent variables indicated by performance on multiple tasks provide better estimates of specific EF abilities than any single task can, in part by controlling for task-specific measurement error (e.g., Friedman et al., 2008, 2011; Miyake & Friedman, 2012). The advantages conveyed by the “unity and diversity” approach (Miyake & Friedman, 2012) allowed the relation between conscientiousness and EF to be observed here, where it hasn’t been in previous attempts (see DeYoung et al., 2005; Hall et al., 2013; Jensen-Campbell et al., 2002; Murdock et al., 2013; Salthouse et al., 2004; Williams et al., 2010).

The second primary limitation of previous work stems from an under-appreciation of the possibilities concerning which cognitive abilities might be represented in conscientiousness. The popular notion of a conscientious person as a controlled, well-focused, “nose-to-the-grindstone” type (Roberts et al., 2009), coupled with numerous reports linking high levels of conscientiousness to positive health and life outcomes that often are associated with the ability to overcome urges and control behavior (e.g., Bogg & Roberts, 2004; 2013), has led many to assume that inhibitory control is an important—if not *the most* important—cognitive ability associated with conscientiousness (see Halverson et al., 2003). Indeed, some limited evidence in support of this assumption has been reported in recent work (Hall et al., 2013). Within the current unity and diversity framework of EF (Miyake & Friedman, 2012), evidence supporting this assumption would be indicated by a significant association between conscientiousness and the Common EF factor, which best represents variance in EF task performance most closely associated with inhibitory control-related abilities (see Friedman et al., 2008, 2011).

Standing in opposition to such an assumption, the current results indicate that the cognitive ability most associated with conscientiousness is shifting. In contrast to the rigid control often associated with inhibition, shifting involves flexibility—the ability to adapt to changing contingencies and attend to relevant stimulus features that only moments earlier where irrelevant, while simultaneously ignoring now irrelevant features that previously were important. This finding suggests that current conceptualizations of conscientiousness ought to focus more on those aspects of the trait that deal with cognitive agility and rule learning and less on characterizations of this trait as synonymous with impulse control. Consistent with this idea, Jensen-Campbell et al. (2002) found that conscientiousness positively predicted efficiency in rule learning and the ability to maintain the proper sorting principle, the latter of which is considered an element of shifting within the Wisconsin Card Sorting Task.

Variability in the switch cost, the primary dependent measure gleaned from shifting tasks, is thought to index individual differences in both the activation of the relevant task set (i.e., rule retrieval; Mayr & Kliegl, 2000) and the ability to override and reconfigure a previous task set (i.e., task-set reconfiguration; e.g., Meiran, Chorev, & Sapir, 2000; Monsell, 2003). It has been argued that the difficulty in successful Shifting task performance lies in the necessity to simultaneously execute differing processes—inhibiting the activation of the previously used task set while at the same time holding that task set in mind for future use in service of the larger task goal (see Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2002). In other words, shifting ability appears to share some features in common with both of the other EF facets we examined. Considered from this perspective, it could be assumed that conscientiousness should relate to all EF facets, or that representing EF with a hodgepodge of tasks that tap any of these facets should produce some associations with conscientiousness. But the variance in common across these facets, here represented by the Common EF factor, was not related to conscientiousness in our analyses. Miyake and Friedman (2012) proposed that individual differences in Common EF tap the ability to actively maintain task goals, particularly in the face of interference, and use these goals to direct ongoing processing. This ability is key to all EF tasks and may be particularly important in response inhibition tasks (Munakata et al., 2011). In contrast, they proposed that performance on the Shifting-specific facet may be more related to the ability to quickly let go of these goals when necessary, to flexibly adapt ongoing behavior. The current results suggest that this kind of flexible adaptation is specifically associated with conscientiousness, whereas maintaining task goals and overcoming interference, as well as efficiency in gating of working memory and episodic retrieval, posited to be reflected in the Updating-specific facet (Miyake & Friedman, 2012), are less crucial.

Still, although the current study revealed a relationship between conscientiousness and EF that was specific to the Shifting-specific facet, the magnitude of this effect was perhaps smaller than might be expected if these observed variables represent the same latent construct, as has been suggested elsewhere (e.g., Hall et al., 2013). Rather, it seems evident that conscientiousness is a trait that extends far beyond its association with executive functioning abilities as measured by this set of behavioral tasks. One possibility in this regard is that conscientious people tend to have stronger motivations that encourage persistent engagement in the sorts of behaviors that produce positive health and professional outcomes (e.g., Judge & Ilies, 2002). Arguably, EF (i.e., ability) and motivation are separate factors that can independently influence outcomes. For example, in order to maintain a healthy diet or exercise regimen, one needs both the ability to flexibly adapt to changing contingencies and maintain long-term goals (i.e., EF) and the drive to do what is necessary to attain those goals (i.e., motivation). The EF tasks utilized here do not measure aspects of motivation that might help to explain the disparity between the conceptual and empirical overlap between EF and conscientiousness.

Some additional limitations of the current study warrant consideration. Most notably, we used the NEO-FFI to measure conscientiousness, precluding a direct test of associations between EF and the lower-order facets of conscientiousness. Second, the data used in the current analyses were drawn from a baseline testing session of a larger study on the effects of alcohol on EF. Because of the time limitations inherent in alcohol administration work (e.g., ensuring task completion within a given range of blood alcohol concentration), the EF tasks had to be shortened somewhat (i.e., fewer trials in each task than is typical), which could have implications for the reliability of these measures. Finally, the sampling frame for the current study likely restricted the range of cognitive abilities in the participants given that participants were drawn from a university community, and therefore their cognitive abilities are arguably somewhat stronger than average, and that individuals with certain conditions (e.g., psychiatric illness, symptoms of alcohol or drug abuse, history of head trauma) were precluded from study participation.

In conclusion, despite these limitations the current study makes an important contribution by providing the most comprehensive assessment to date of the commonly proposed relationship between conscientiousness and executive functioning. By utilizing a multifaceted analytic approach, including a well-validated, latent variable conceptualization of EF, the results of the current study help to disentangle the nuanced relationship between conscientiousness and EF, showing that conscientiousness is uniquely related to the attention shifting or switching component of EF but not to working memory updating or prepotent response inhibition. This rather surprising finding has considerable implications for understanding the cognitive abilities that might link high levels of conscientiousness to positive life outcomes related to health and wealth. Primarily, the current results point to flexibility and adaptability as more important than rigid adherence to rules and overcoming impulses in determining aspects of personality that might foretell success and well-being.

Acknowledgments

The authors wish to thank J. Scott Saults and Naomi P. Friedman for their assistance with various aspects of data coding and analysis and Laura A. King for helpful feedback on a previous version of this manuscript.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Preparation of this manuscript was supported by Grants P60 AA011998 and F31 AA022551 from the National Institute on Alcohol Abuse and Alcoholism.

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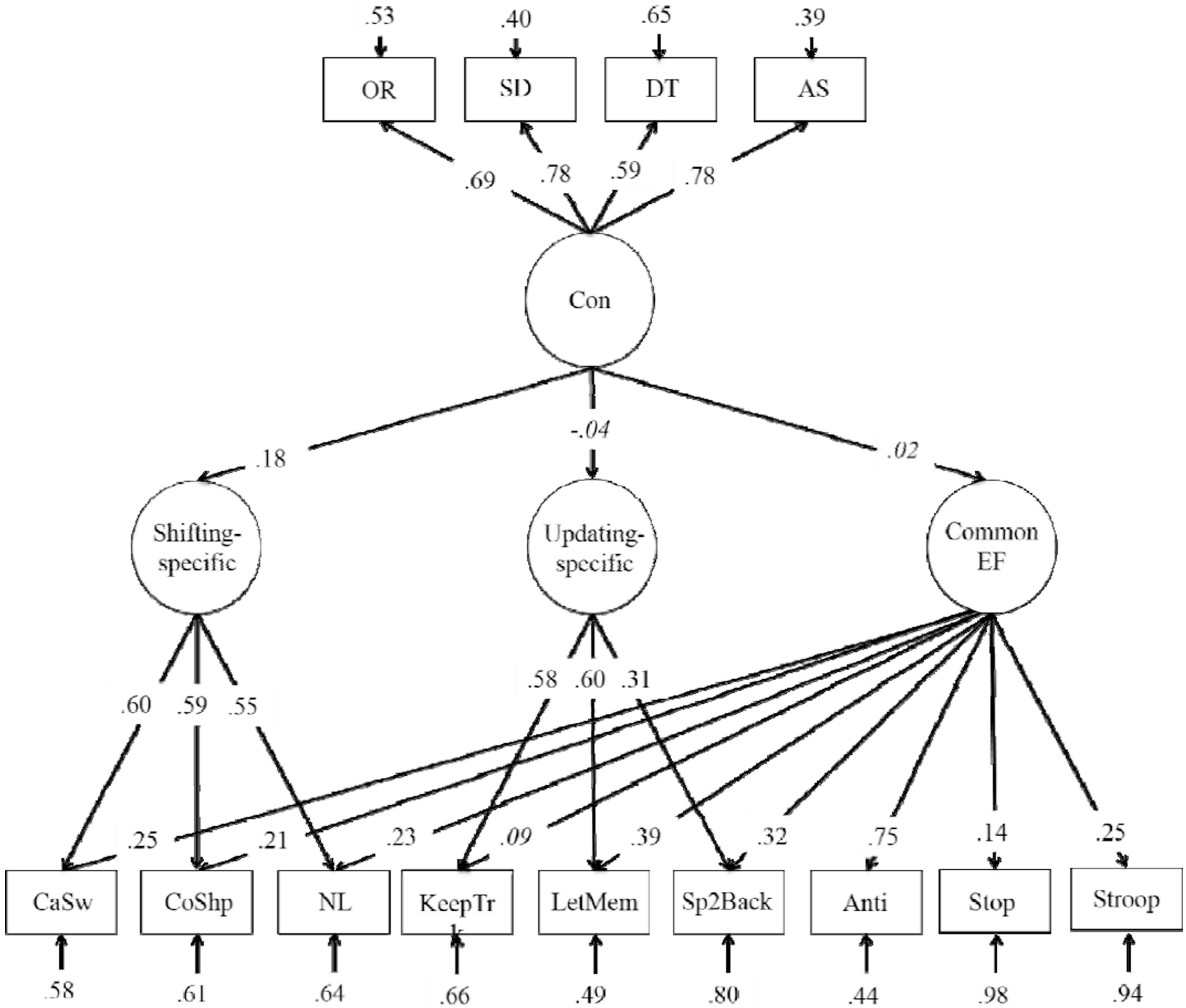

Figure 1.

Nested Factors EF Model Including Conscientiousness as a Predictor of Latent EF Variables. Because the Common EF factor encapsulates all variance common among the 9 individual tasks, the Shifting-specific and Updating-specific factors capture the variance that is unique to shifting and updating, respectively, after accounting for common variance. Therefore, these factors are uncorrelated with each other or with Common EF. Numbers on arrows are standardized factor loadings and numbers under smaller errors represent standardized residual variances. All paths are significant ($p < .05$) except for the loading of keep track onto the Common EF variable and the paths from conscientiousness to the Updating-specific and Common EF latent variables; these non-significant paths are indicated with italics. The fact that keep track does not load onto the Common EF factor reflects that, for this sample, the variance associated with keep track performance is better explained by the Updating-specific latent factor. CaSw = category-switch; CoShp = color-shape; NL = number letter;

KeepTr = keep track; LetMem = letter memory; Sp2Back = spatial 2-back; Anti = antisaccade; Stop = stop signal; Con = conscientiousness; OR = order; SD = self-discipline; DT = dutifulness; AS = achievement striving.

Table 1

Descriptive Statistics for Executive Functioning Tasks

Measure	Mean (SD)	*N*	Skewness	Kurtosis
Inhibition				
Antisaccade	0.71 (0.20)	417	−0.32	−0.33
Stop Signal	250 ms (38)	408	0.30	0.36
Stroop	132 ms (69)	414	−0.56	1.02
Updating				
Keep track	0.79 (0.15)	420	0.16	−0.15
Letter memory	0.90 (0.24)	420	0.48	−0.37
Spatial 2-back	0.96 (0.14)	391	0.76	1.21
Shifting				
Color-shape	217 ms (180)	418	−1.12	1.78
Category-switch	146 ms (115)	410	−1.07	1.60
Number letter	259 ms (180)	418	−1.12	1.62

Note. SD = standard deviation; ms = milliseconds.

Table 2

Descriptive Statistics for NEO-FFI Personality Domains

Domain	*N*	Mean (SD)	Range	Cronbach's α
Agreeableness	420	3.72	2.08 – 4.75	.70
Conscientiousness	420	3.84	1.50 – 5.0	.85
Extraversion	420	3.52	1.25 – 5.0	.79
Neuroticism	420	2.31	1.08 – 4.08	.86
Openness	420	3.55	1.75 – 4.83	.80

Note. SD = standard deviation.

Table 3

Bivariate Correlations Among EF Measures and NEO-FFI Personality Domains

Measure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Antisaccade	–												
2. Stop signal	.09	–											
3. Stroop	**.17**	**.11**	–										
4. Keep track	.05	.08	.02	–									
5. Letter Memory	**.29**	.06	**.15**	.38	–								
6. Spatial 2-back	**.24**	.00	.08	**.20**	**.31**	–							
7. Number-letter	**.18**	.05	.08	.02	.03	.07	–						
8. Color shape	**.18**	−.04	.08	.05	.05	−.01	**.37**	–					
9. Category switch	**.18**	**.15**	.08	.08	.08	.06	**.39**	**.40**	–				
10. Agreeableness	−.03	.07	.01	.01	−.03	−.01	−.03	−.09	−.05	–			
11. Conscientiousness	.00	.08	.04	−.02	.00	−.08	.06	**.12**	**.10**	**.14**	–		
12. Extraversion	.06	.00	−.03	−.04	.02	.00	.07	.02	.03	**.40**	**.18**	–	
13. Neuroticism	−**.16**	−.07	−.06	.02	−.08	−.06	−**.10**	.04	−.09	−**.27**	−**.35**	−**.37**	–
14. Openness	−.03	**.10**	.04	.06	.02	−.03	−.06	−.08	−**.13**	**.15**	−**.20**	.02	.03

Note. Significant correlations ($p < .05$) are in boldface.

Table 4

Fit Statistics and Standardized Parameter Estimates of all NEO-FFI Personality Domains as Predictors of EF Facets in the Nested Factors Model

NEO-FFI Domain	χ2 (df)	Prob (χ2)	TLI	CFI	RMSEA [90% CI]	Effect on U	Effect on S	Effect on C
Agreeableness	53.22 (56)	.190	.979	.986	.02 [.00 – .04]	−.003	−.113	−.026
Conscientiousness	66.13 (56)	.167	.984	.989	.02 [.00 – .04]	−.035	**.180**	.023
Extraversion	49.83 (56)	.287	.989	.993	.02 [.00 – .04]	−.057	.040	.100
Neuroticism	64.20 (56)	.032	.967	.978	.03 [.01 – .05]	.055	.012	−**.262**
Openness	67.56 (56)	.016	.960	.973	.04 [.02 – .05]	.060	−**.155**	−.280

Note. TLI = Tucker-Lewis index; CFI = comparative fit index; RMSEA = root mean square error of approximation; C. I. = confidence interval; U = Updating-specific facet; S = Shifting-specific facet; C = Common EF facet. Significant paths (p <.05) are indicated in boldface.