Exploring the Relations Among Executive Functions, Fluid Intelligence, and Personality

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Abstract. Executive functions (EFs) are important for goal-directed behavior and have been linked with a number of important constructs like intelligence. The current study examined the link between EFs and aspects of normal and abnormal personality. Latent variables of working memory, fluency, response inhibition, and vigilance EFs were examined along with fluid intelligence (gF). It was found that the EFs were separate yet correlated, and that each was related to gF. Furthermore, it was found that aspects of personality as measured by the Five-Factor Model and the BIS/BAS were differentially related to the EFs and gF. Examination of personality disorder measures also demonstrated differential relationships with the EFs and gF. The results suggest a number of systematic and important links between EFs and personality and suggest the need for a more unified field of individual differences.

Keywords: executive functions, fluid intelligence, personality

Introduction

Executive functions (EFs) refer to the set of general-purpose control processes that regulate thought and action in a wide variety of situations. These EFs are critically important in situations where novel responses have to be carried out in the presence of more habitual dominant responses, and when task goals have to be actively maintained in the face of potent internal and external distraction, ranging from low-level attention tasks to higher-order social interactions. Recent work suggests that EFs represent a family of interrelated functions rather than a single function (Miyake et al., 2000). These separate functions include working memory, response inhibition, fluency, and vigilance to name a few.

Given the theoretical importance of EFs, much recent work has been devoted to examining the relationships among various EFs and their relationships with important constructs like intelligence (Friedman et al., 2006). The link between EFs and broader personality structures, however, has been studied far less. How are individual differences in personality linked to the broader set of individual differences in EF? The present research outlines the broader relationship between a range of personality functions, both normal and disordered, and a range of EFs. To this end, we use a latent-variable approach to EFs in order to observe the links between personality and the different EFs, in the hope of establishing the strength and diversity of the personality–EF link, and to provide a guide for further work in this area.

Given the breadth of functions believed to be related to EFs, one might suspect that these individual differences would be related to differences in personality. Recent research has in fact documented several associations between potentially EF-related behaviors and personality. For instance, impulsivity has been linked with a number of personality traits (Whiteside & Lynam, 2001) as well as personality disorders (PDs; Saulsman & Page, 2004). Nevertheless, although it seems likely that individual difference systems as broad and multifaceted as EF and personality would be connected in some manner, data addressing these specific connections are relatively scant. For example, research has suggested a link between extraversion and working memory (WM; Lieberman, 2000). Likewise, several recent studies have suggested a link between WM and the behavioral approach system (BAS), and this relationship has been linked with activation in anterior cingulate cortex (Gray & Braver, 2002). In short, specific instances of personality–EF links have been identified, but no broad-based effort to map these relationships has been undertaken.

A number of studies have suggested that various EFs are also related to more maladaptive personality traits or PDs. In particular, the inability to maintain goal states in WM and to prevent distraction via response inhibition might be related to certain PDs. This suggests that the ability to control thought and behavior as indexed by EF laboratory tasks should be related to a variety of PDs. Substantive relationships between EFs and PDs would not be surprising given that, according to the Diagnostic and Statistical Manual-IV (DSM-IV; American Psychiatric Association, 2000), PDs are characterized by

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poor impulse control as well as difficulties in emotion regulation and cognitive processing. Empirically, several studies have reported significant relationships between EFs and Schizotypal and Antisocial PDs (Dolan & Park, 2002; Matheson & Langdon, 2008). In addition, behaviors related to Antisocial PD such as aggression (Giancola, 2004) and antisocial behavior (Morgan & Lilienfeld, 2000) are linked to poor EF. A recent meta-analytic review suggests that Borderline PD is also associated with broad deficits in "executive neurocognition," although the performance may be moderated by affective arousal (Fertuck, Lenzenweger, Clarkin, Hoermann, & Stanley, 2006).

Although these three PDs have received the most attention, there are some preliminary data suggestive of a broader link between EFs and PDs (Ruocco & Swirsky-Sachetti, 2007). The notion that EFs should be associated with both "normal" and "abnormal" aspects of personality is consistent with newer models of PD that conceptualize these disorders as extreme and problematic configurations of general personality traits (Widiger & Trull, 2007).

The present study conducts a comprehensive examination of EFs relationships via a latent variable analysis of EFs and personality in a college sample. One limitation with several of the previous studies is that the relationship between EFs and personality was typically examined using a single EF task and a single personality construct, and thus may not provide the best evidence for more general constructs. It is important, therefore, to examine these relationships at a latent level with multiple EF and personality measures. Two recent studies have specifically examined the relationship between EFs and personality at a latent level. DeYoung, Peterson, and Higgins (2005) found that the personality construct of Openness was related to a broad EF factor derived from seven tasks. Similarly, Salthouse, Berish, and Siedlecki (2004) found that a broad EF factor was related to Openness and Agreeableness. However, research suggests that EFs represent a family of related functions rather than a single dominant function, so that it is unclear what aspect of EF is being indexed in these studies.

The current study examined EFs using seven EF tasks to derive four separate EF factors and two tasks to derive a *general fluid intelligence (gF)* factor. The four EF factors were *WM* (the ability to maintain information in an active state), *Response Inhibition* (the ability to execute a non-dominant response while preventing a habitual-dominant response), *Fluency* (the ability to generate unique examples from memory), and *Vigilance* (the ability to sustain attention on a task). Additionally, given that several personality constructs have been linked with EFs in the past, we conducted a comprehensive personality assessment. Specifically, we used the *NEO PI-R* (Costa & McCrae, 1992) to assess the general personality traits covered by the FFM and their relationships with EFs. Furthermore, given the recent work arguing for a link between WM and the BAS, the *BIS/BAS scales* (Carver & White, 1994) were also used. Finally, given some evidence for a link between certain PD constructs and EFs, a broad-based PD measure (*Personality Diagnostic Questionnaire*; Hyler, 1994) was used. For each personality measure, separate confirmatory factor analyses (CFAs) were run examining the relationship among the EFs and the personality variables. It should be noted that the goal of the current study was not to explain personality with EFs or vice versa, but rather to explore the relationships among them.

Method

Participants

Participants in the current study were 138 students from the University of Georgia (85 women, 53 men) with a mean age of 19.1 years (*SD* = 1.11 years); they received course credit for their participation. The participants were tested in groups in two laboratory sessions lasting approximately 2 h each. The personality measures were administered in Session 1, and the EF tasks were administered in Session 2. The EF tasks were chosen based on prior work suggesting that these measures index their respective EFs (Miyake et al., 2000). Full task descriptions and references for the EF tasks can be obtained from the first author.

EF Tasks

Operation Span

The participants solved math problems while trying to remember an unrelated set of letters. Participants received three trials of each set-size, with set-sizes ranging from 3–7. Dependent variable (DV) was the number of correct items recalled in the correct position.

Antisaccade

In this task participants were instructed to stare at a fixation point, and then a flashing white equal sign was flashed either to the left or right of fixation followed by the target stimulus (B, P, or R) on the opposite side of the screen. The participants' task was to identify the target letter by pressing a key as quickly and accurately as possible. There were 60 trials. DV = proportion correct.

Arrow Flankers

Participants were presented with a fixation point followed by an arrow directly above the fixation point. The participants' task was to indicate the direction the arrow was pointing (left or right) as quickly and accurately as possible. There were 50 congruent trials (all arrows pointing in the same direction) and 50 incongruent trials (target arrow was flanked by two arrows pointing in the opposite direc-

tion on each side). DV = reaction time (RT) difference between incongruent and congruent trials.

Semantic Fluency

Participants were given 1 min to type as many exemplars from the category of animals as possible. DV = number of unique exemplars.

Letter Fluency

Participants were given 1 min to type as many words that began with the letter F as possible. DV = number of unique exemplars.

Degraded Vigilance

Participants were required to detect the presence of targets (0s) amongst distractors (Ds and backwards Ds) which were visually degraded. Participants received 720 trials broken down into three blocks (240 trials per block) over 12 min. DV = proportion of correct target identifications in the last block of trials.

Psychomotor Vigilance Task (PVT)

Participants were presented with a row of 0s on screen and after a variable amount of time the numbers began to increase. The participants' task was to press the spacebar as quickly as possible once the numbers started counting up. The entire task lasted for 10 min for each individual. DV = RT for minute 10.

gF Tasks

Raven Progressive Matrices

Participants saw a matrix of geometric patterns with the bottom right pattern missing; they were instructed to select among either six or eight alternatives the one that correctly completed the overall pattern. There were 12 test items. DV = number correct.

Number Series (NS)

Participants saw a series of numbers and were required to determine what the next number in the series should be out of five possible numbers. There were 15 test items. DV = number correct.

Personality Measures

NEO Personality Inventory Revised (NEO PI-R)

The NEO PI-R is a 240-item self-report measure of the Five-Factor Model of personality, which includes five broad domains of Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness.

Behavioral Inhibition/Behavioral Activation Systems (BIS/BAS)

The BIS/BAS scales are assessed via 20 self-report questions designed to assess the behavioral inhibition and activation systems (BIS, BAS, respectively). The BIS is assessed using 7 items. Although the BAS items can be scored into three subscales (e.g., BAS-Drive), we have grouped the 13 BAS items into a single score.

Personality Disorder Questionnaire (PDQ-4+)

The PDQ-4+ is 99-item self-report measure of DSM-IV PDs on which items are answered using a Yes/No response format. PD symptom counts are computed by summing the items endorsed for each PD.

Results

Table 1 shows the descriptive statistics and reliability estimates for the measures. The full correlation matrix is available from the first author upon request. Before examining personality–EF relationships, we examined the relationship among the EF measures and the gF measures via CFA. Four EF factors were specified along with one gF factor. All factors were allowed to correlate. The fit of the model was acceptable, $\chi^2(25) = 50.71$, $p < .01$, $\chi^2/df = 2.03$, RMSEA = .08, SRMR = .06, CFI = .92. As shown in Figure 1, all of the measures loaded significantly on their factors, and all of the interfactor correlations were significant.[1] This is consistent with previous research suggesting separable but correlated EFs. Additionally, each of the EFs correlated significantly with gF.

Having established the EF factors, we next examined how these EFs would be related to each of the personality constructs. A CFA combining the correlated EF model with scales from the personality measures was conducted for each of the three personality measures. Note that for these models the loadings of the personality measures onto their latent constructs were set based on their reliabilities. First, we examined the relationship among the EFs and the do-

[1] We intended for WM to be represented by Ospan and N-back. However, the two tasks were not correlated with one another ($r = .08$), and N-back had a low communality estimate when examined with the other EFs ($h^2 = .06$).

Table 1. Descriptive statistics and reliability estimates for all measures

Measure	*M*	*SD*	Range	Skew	Kurtosis	α
Ospan	59.41	12.22	4–75	–1.56	3.85	.78
Semantic fluency	16.14	5.98	4–28	–1.07	1.49	NA
Letter fluency	18.28	4.44	4–28	–.57	2.51	NA
Antisaccade	.58	.17	.24–.95	.05	–.74	.84
Flanker	116	70	–65–616	3.05	18.24	NA
Degraded vigilance	.51	.25	0–1.0	–.13	–.92	.93
PVT	363	34	290–447	–.05	–.32	.95
Raven	9.24	1.64	4–12	–.84	1.04	.72
NS	9.52	2.19	3–14	–.25	–.05	.70
Neuroticism	2.90	.37	1.81–3.85	.23	–.07	.90
Extraversion	3.66	.43	2.19–4.69	–.29	.55	.92
Openness	3.51	.44	2.12–4.44	–.26	–.01	.90
Agreeableness	3.43	.38	2.19–4.44	–.31	.58	.89
Conscientiousness	3.39	.45	2.33–4.40	–.08	–.51	.92
BIS	20.14	3.13	10–28	.07	.64	.82
BAS	28.90	6.25	13–52	–.54	3.22	.86
Paranoid	2.24	1.67	0–7	.58	–.40	.59
Schizoid	.91	1.09	0–6	1.44	2.84	.51
Schizotypal	2.20	1.69	0–7	.52	–.41	.56
Antisocial	1.29	1.21	0–5	.71	–.25	.50
Borderline	2.27	1.60	0–7	.57	–.12	.57
Histrionic	2.48	1.58	0–7	.41	–.13	.47
Narcissistic	2.43	1.79	0–8	.53	.03	.50
Avoidant	2.05	1.77	0–7	.78	–.01	.70
Dependent	1.59	1.55	0–7	.91	.45	.64
OC	3.57	1.64	0–8	.14	–.48	.43

Note. Ospan = operation span; Degraded vig = degraded vigilance; PVT = psychomotor vigilance; NS = number series; BIS = Behavioral Inhibition system; BAS = Behavioral Activation System; OC = obsessive compulsive.

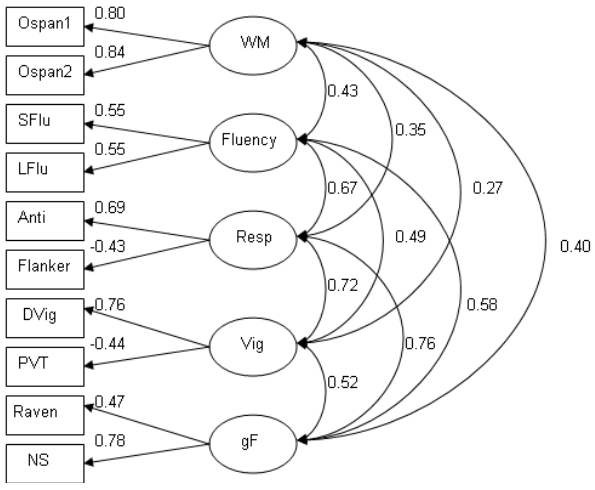

Figure 1. Confirmatory factor analysis for executive functions and fluid intelligence measures. WM = working memory; Resp = response inhibition; Vig = vigilance; Ospan1 = first half of operation span; Ospan2 = second half of Ospan; SFlu = semantic fluency; LFlu = letter fluency; Anti = antisaccade; DVig = degraded vigilance; PVT = Psychomotor vigilance; NS = number series.

mains from the NEO PI-R. Here, a model was specified with the four EF factors and the gF factor from the previous model along with the FFM domains. All of the factors were allowed to correlate. The fit of the model was acceptable, $\chi^2(50) = 74.73$, $p < .01$, $\chi^2/df = 1.49$, RMSEA = .06, SRMR = .06, CFI = .93. Table 2 shows the correlations for each of the FFM domains with each of the EF factors and the gF factor.

Neuroticism was weakly and negatively related to gF, which is consistent with previous research suggesting a link between the two, which may be mediated by test anxiety effects (Moutafi, Furnham, & Tsaousis, 2005). Follow-up analyses suggested that this correlation was driven by significant relationships between gF and the facets of anxiety and vulnerability. None of the other gF to Neuroticism facets were significant. Extraversion was negatively related to Vigilance, which is also consistent with previous research (Rose, Murphy, Byard, & Nikzad, 2002). Follow-up analyses suggested that Vigilance was related to all of the Extraversion facets except for excitement-seeking. Openness was moderately positively related to Fluency, which is consistent with previous research

Table 2. Latent correlations of personality measures with executive functions and fluid intelligence

	Latent factor				
Measure	WM	Fluency	Resp	Vig	gF
NEO PI-R					
Neuroticism	.00	–.18	–.05	.09	–.22*
Extraversion	–.19	.16	–.11	–.34*	–.07
Openness	–.04	.32*	.06	.03	.04
Agreeableness	–.18	–.06	.00	.00	.02
Conscientiousness	–.16	–.06	–.16	–.13	.02
BIS/BAS					
BIS	–.15	–.18	–.11	.01	–.24*
BAS	.04	.11	.01	–.01	.03

Note. *$p < .05$ based on parameter estimates and standard errors from the CFAs.

Table 3. Latent correlations of personality disorder measures with executive functions and fluid intelligence

	Latent factor				
Measure	WM	Fluency	Resp	Vig	gF
PDQ-4					
Paranoid	.11	–.02	.11	.10	–.08
Schizoid	.14	–.20	–.11	–.12	–.21
Schizotypal	.02	–.41*	–.29*	–.17	–.34*
Antisocial	–.08	.14	–.22	–.40*	–.34*
Borderline	.19	–.09	–.29*	–.08	–.11
Histrionic	.14	.18	–.02	–.12	–.04
Narcissistic	.24*	.05	.07	–.02	.13
Avoidant	.21	–.25*	–.05	–.07	–.11
Dependent	.07	–.01	–.20	.07	–.18
OC	–.03	–.41*	–.02	–.08	.01

Note. *$p < .05$ based on parameter estimates and standard errors from the CFAs.

suggesting a link between Openness and creative aspects of EF (DeYoung et al., 2005). Follow-up analyses suggested that this relationship was due to the Ideas and Values facets. Interestingly, Openness was not related to gF, which adds to inconclusive nature of the extant literature, where effect sizes for this relationship vary (Moutafi et al., 2006). Neither Agreeableness nor Conscientiousness was significantly related to any of the EFs or with gF. Overall, these results suggest that most of the five factors of personality were differentially related to the EFs and gF. That is, not only were there relationships between personality and EFs, but each of the EFs were differentially related to the personality constructs.

Next, we examined the relationship among the EFs and the BIS/BAS with a similar analytic model. Specifically, a model was specified with the four EF factors and the gF factor from the previous model along with both BIS and BAS latent factors. All factors were allowed to correlate. The fit of the model was acceptable, $\chi^2(35) = 57.52$, $p < .01$, $\chi^2/df = 1.64$, RMSEA = .07, SRMR = .06, CFI = .93. As shown in Table 2, BIS correlated weakly and negatively with gF and at a similar magnitude as the same correlation with Neuroticism, which is consistent with the notion the Neuroticism and the BIS are similar in that both index negative emotional sensitivity (Smits & Boeck, 2006). In fact, in the current study BIS and Neuroticism were strongly correlated ($r = .64$). Inconsistent with prior work (Gray & Braver, 2002), BAS was not related to any of the EFs or with gF. This may be due to the fact that only the Ospan task was used in these analyses. Further work is needed to better clarify the nature of the relationship between BAS and WM.

The final analyses examined the relationship among the EFs and the 10 DSM-IV PDs. Three separate models were run for each of the clusters from the DSM-IV. The first model examined the relationship among the EFs and Cluster A PDs (Paranoid, Schizoid, and Schizotypal). Again, a model was specified with the four EF factors and the gF factor from the previous models along with latent factors representing the three PDs from Cluster A. The fit of the model was acceptable, $\chi^2(40) = 68.17$, $p < .01$, $\chi^2/df = 1.70$, RMSEA = .07, SRMR = .06, CFI = .92. As shown in Table 3, neither Paranoid PD nor Schizoid PD was significantly related to any of the EFs or with gF. Most interesting is the finding that Schizotypal PD was moderately negatively related to Fluency, Response Inhibition, and gF, which is consistent with previous work suggesting a link between Schizotypal PD and cognitive disturbances in EFs (Matheson & Langdon, 2008). The second model examined the relationship among the EFs and Cluster B PDs (Antisocial, Borderline, Histrionic, and Narcissistic). A similar model as the Cluster A model was specified. The fit of the model was acceptable, $\chi^2(45) = 75.10$, $p < .01$, $\chi^2/df = 1.67$, RMSEA = .07, SRMR = .06, CFI = .92. As shown in Table 3, Antisocial PD was moderately negatively related to Vigilance and gF, and weakly negatively related to Response Inhibition. This suggests that individuals prone to antisocial tendencies are less able to sustain attention on relatively monotonous tasks, which may hinder their scores on measures of gF. Indeed, the correlation between antisocial tendencies and gF dropped substantially once Vigilance was partialled out ($pr = –.16$). Also shown in Table 3, Borderline PD was moderately negatively related to Response Inhibition, which is consistent with current work suggesting that individuals with BPD symptoms have problems resolving conflict (Posner et al., 2002). Histrionic PD was not significantly related to any of the EFs or to gF. Finally, Narcissistic PD was only positively related to WM, which is consistent with prior work suggesting that this PD is related to some adaptive features (Ruocco & Swirsky-Sachetti, 2007). The final model examined the relationship among the EFs and Cluster C PDs (Avoidant, Dependent, and Obsessive-Compulsive)

similar to previous models. The fit of the model was acceptable, $\chi^2(45) = 60.07$, $p < .05$, $\chi^2/df = 1.50$, RMSE = .06, SRMR = .05, CFI = .94. As shown in Table 3, Avoidant PD was negatively related to Fluency, whereas Dependent PD was unrelated to the EFs or gF. Finally, Obsessive-Compulsive PD was moderately negatively related to Fluency, suggesting that individuals high in Obsessive-Compulsive PD may have trouble using controlled retrieval abilities to generate unique exemplars and prevent repetitions.

Discussion

The current study examined the relationship among various EFs, gF, and aspects of personality. Consistent with previous research it was found that the EFs were best considered as separate yet related functions, each of which was related to gF. In terms of the personality constructs, the results were largely consistent with previous research that have demonstrated several relationships between EFs and personality. Importantly, however, the current study examined these relationships at a latent level while simultaneously examining multiple EFs as well as fluid intelligence. The current study goes beyond previous work by demonstrating that many of these EFs–personality relationships can be found at the latent level and are specific to certain EFs. By simultaneously examining separate yet correlated EFs, the current study provides important evidence for divergent links between specific EFs and personality and supports the need for more fine-tuned testing and parsing of these important relationships.

Additionally, the correlations between the EFs and the PDs suggest a number of findings, some of which have been suggested previously and others which have not been studied extensively. The majority of the significant findings between the EFs and PDs occurred for Schizotypal and Antisocial PDs, which is consistent with previous work. These two PDs are thought to have quite significant heritable components and substantially impaired functioning (Kendler, Myers, Torgersen, Neale, & Reichborn-Kjennerud, 2007). Given the heritability of EFs (Friedman et al., 2008) and PDs, it is possible that there is some overlap in what is inherited across these two sets of individual differences (Coolidge, Thede, & Jang, 2004), and that deficits in EF may explain some of the impairment associated with these pathological traits. This may be due to variation in frontal lobe functioning associated with both (Ruocco & Swirsky-Sachetti, 2007) in which deficits in EFs and PD symptomatology co-occur because of the reliance on common frontal systems. Indeed, prior work has suggested that each of the PDs that evinced relationships with EFs have been associated with frontal deficits (Dolan & Park, 2002; Ruocco & Swirsky-Sachetti, 2007). Importantly, however, the current study demonstrated that these relationships were specific to certain EFs. That is, certain PDs were related to deficits in response inhibition, deficits in sustained attention, or deficits in controlled retrieval rather than deficits in global executive functioning. It appears that problems with executive functioning may be more relevant to maladaptive patterns of behavior, cognition, and emotion in which specific deficits in executive functioning can manifest themselves as PDs (Coolidge et al., 2004).

The current results also suggest both convergent and discriminant validity for EFs with personality. Specifically, although there were several correlations between the EFs and personality, the majority of the correlations were not significant and were close to zero. Thus, the EFs demonstrated convergent validity by being related to one another and to gF, but they also demonstrated discriminant validity by not being strongly or uniformly related to the personality variables. The same was true for the personality variables, with many of them being related to one another and less related to the EFs. Indeed the FFM accounted for 17–45% of the overall variance in the 10 PDs. Despite this overall pattern, several of the correlations between the personality measures and EFs were of the same magnitude or higher than the relationships between the EFs. For instance, Vigilance was more highly correlated with Antisocial PD ($r = -.40$) than with WM ($r = .27$). Thus, these correlations are not trivial and suggest that aspects of personality are systematically related to EFs in a number of ways and that more work is needed to better understand these relationships.

There are a number of limitations to the current study including the use of a college sample, self-reports of general and pathological personality, poor internal consistency of some of pathological personality scales, and few significant correlations. Future studies could improve upon this study by testing these relationships in community or clinical samples using interview, informant, and self-reported personality data, and creating broader latent EF factors. Additionally, it would be interesting to test the relationships between the EFs and trait models of personality pathology rather than using the current DSM-IV PD constructs, which are thought to be highly problematic and are at risk for replacement in DSM-V.

Despite these limitations, we believe that the current study provides a rich unique dataset used to examine the interrelationship among aspects of EF, gF, and a variety of conceptualizations of personality. As suggested by Cattell (1971) these results suggest the need for a more unified field of individual differences, where cognitive abilities are examined simultaneously with personality differences to get a better sense of when these individual differences variables are related and when they are not. Combining these two disparate fields should provide us with a better understanding of how people differ on constructs that may be important foundations of human behavior.

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