Intern. J. Neuroscience, 115:649–667, 2005

ISSN: 0020-7454 / 1543-5245 online
DOI: 10.1080/00207450590524304

SELF-RATED EXECUTIVE FUNCTION: DEVELOPMENT OF THE EXECUTIVE FUNCTION INDEX

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There are several self-rating executive function (SREF) measures in existence that were developed solely in clinical populations or which sample a limited range of executive functions. The Executive Function Index (EFI) was developed here in a normal population with five subscales derived through factor analysis: Motivational Drive, Strategic Planning, Organization, Impulse Control, and Empathy. The content of three second order factors is consistent with the functions mediated by dorsolateral, orbitofrontal, and medial prefrontal circuits. Intrascale reliability and demographic relationships are reported as well as strong correlations with other SREF measures validated in clinical and neuroimaging studies. This brief measure provides a quick and efficient means of collecting data in large samples in order to test hypotheses regarding the role of prefrontal systems in various aspects of behavior and to corroborate findings of other methods, such as objective tests and functional neuroimaging.

Keywords executive, Executive Function Index, prefrontal, psychometric, self-rating

Received 13 July 2004.
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Executive functions are among the most pertinent cognitive abilities for adaptive functioning, allowing for behavior that is more goal-oriented, flexible, and autonomous. As such, the measurement of executive functions is of great interest for both clinical assessment and research into multiple relevant behaviors. Given their importance, both objective and subjective tests have been developed to evaluate them.

Aspects of executive functioning such as planning, flexibility, conceptual reasoning, and set shifting are assessed with tests such as the Wisconsin Card Sorting Test and Tower of London. As objective measures, they are relatively less affected by personal biases. Although factors such as mood and motivation may undermine performance, testing subjects cannot over-represent their own performance when adhering to standardized administration. However, objective neuropsychological tests are designed for use within the constraints of the task performed in a controlled testing environment. As such they are limited in their scope and cannot sample behavior in the widely varying circumstances and conditions of everyday life. Thus, their ecological validity is typically limited.

In contrast, subjective measures of executive function rely entirely on individuals' evaluations of behavior across many different circumstances and over long periods of time. However, personal biases and varying levels of self-awareness are methodological limitations of subjective measures. Individuals with brain injury tend to underestimate their deficits, and self-rated executive function (SREF) measures may have low correlations with objective measures in more severe clinical populations (Bogod et al., 2003). The self-evaluation of behavior required by these measures is itself a form of executive functioning. Many individuals with traumatic brain injury are well known to have reduced self-awareness (Port et al., 2002; Roche et al., 2002). Individuals with severe brain injuries may underestimate their deficits (McKinlay & Brooks, 1984). Functional neuroimaging studies in healthy individuals demonstrate prefrontal activation when they respond to self-rating items requiring knowledge and reflection on their own abilities (Johnson et al., 2002; Kelley et al., 2002; Kircher et al., 2002). Although these represent potential limitations, they do not nullify the utility of subjective measures. Rather, both methodological strengths and limitations should be taken into consideration when using them. Self-awareness is probably not an all-or-none phenomenon, so an empirical approach is useful to determine in which populations and contexts it is appropriate to use them. Further, the utility of SREFs is reinforced when they corroborate the findings of objective methods such as objective tests or neuroimaging.

Several subjective measures of executive function have been developed. These include subjective ratings by the individual and by collaterals such as family members and caretakers. Some instruments, such as the Iowa Collateral Head Injury Inventory, Frontal Behavioral inventory, and Neuropsychiatriic Inventory, rely exclusively on collateral information because this information is often more reliable than self-evaluations in individuals with more severe injury or illness (Martzke et al., 1991; Kertesz et al., 1997; Cummings et al., 1994). Some instruments, such as the Dysexecutive Questionnaire (DEX) and Frontal Systems Behavior Scale (FrSBe), employ both self- and collateral-rating forms, allowing comparison of the individuals' perceptions with others (Grace & Malloy, 2001; Wilson et al., 1996).

Instruments also vary according to which aspects of executive function they purport to measure. Comprehensive literature reviews commonly identify several broad domains of executive function including control of cognitive processes, verbal and nonverbal reasoning,concentration, motor regulation, emotional regulation, social conduct, self-awareness (Tekin & Cummings, 2002; Stuss & Levine, 2002; Faw, 2003; Miller & Cohen, 2001; Fuster, 2000; Chow, 2000). Cummings and colleagues have delineated functional neuroanatomical substrates of executive functions, involving circuits through prefrontal cortex, the striatum, and thalamus (Cummings, 1993). Different regions of prefrontal cortex and subcortical circuits mediate aspects of executive functioning: medial prefrontal circuits regulate motivational aspects of behavior, such as initiation and persistence, whereas dorsolateral circuits mediate conceptual reasoning, mental flexibility, planning, and working memory (Stuss & Levine, 2002; Tekin & Cummings, 2002). Orbitofrontal circuits mediate self-inhibition, social conduct, empathy, and decision making (Malloy et al., 1993).

The available self-rating instruments attempt to assess several of these aspects of executive function. The Barratt Impulsiveness Scale measures a narrower aspect of executive function, focusing on three aspects of impulsivity: motor, attention, and non-planning (Patton et al., 1995). Several scales are available that assess dysexecutive symptoms used to diagnose attention deficit hyperactive disorder (ADHD), including Conners' Adult ADHD Rating Scales, the Brown Attention-Deficit Disorder Scale for Adults, the Wender Utah Rating Scale, the ADHD Rating Scale (for review see Murphy & Adler, 2004). The FrSBe has three subscales: Apathy, Disinhibition, and Executive Dysfunction (Grace & Malloy, 2001). Others focus on more circumscribed aspects of executive function such as the Situational Self-Awareness Scale (Govern & Marsch, 2001) and the Interpersonal Reactivity Index (IRI), which assesses executive aspects of social functioning such as perspective taking and empathy (Davis, 1980).

Given the potential for bias in self-evaluation on self-rating scales of executive function, empirical support for their validity is of high importance. The SREF measures discussed here have demonstrated their validity through various methods. The BIS, IRI, FrSBe, and DEX have demonstrated construct validity through factor analysis, showing that the items organize logically according to their content and theoretical models. In a large mixed clinical sample of people with prefrontal system illnesses, the FrSBe items organized into scales that correspond to behavioral syndromes associated with medial, dorsolateral, and orbital prefrontal systems, respectively (Grace & Malloy, 2001). A small clinical sample of normal elderly adults showed a comparable 5-factor structure in the DEX (Amieva et al., 2003). BIS items have factored into three higher-order factors in normal individuals (Patton et al., 1995).

SREF measures have also been validated in clinical populations. The BIS has been validated in several clinical populations, including bulimia, bipolar disorder, and borderline personality disorder (Paul et al., 2002; Swann et al., 2001; Dougherty et al., 1999). The FrSBe differentiates people with frontal lesions from those with nonfrontal lesions (Grace et al., 1999). Sensitivity of the FrSBe has also been demonstrated in other illnesses with known prefrontal system dysfunction including neurodegenerative dementias (Paulsen et al., 1996; Cahn-Weiner et al., 2001) and psychiatric illnesses such as bipolar disorder and schizophrenia (Grace & Malloy, 2001; Velligan et al., 2002). FrSBe scores have been associated with psychoactive drug use and impulse-control aspects of eating in healthy individuals (Spinella, 2003; Spinella & Lyke, 2004). BIS scores have similarly related to eating in healthy individuals and cravings in substance abuse (Lyke & Spinella, 2004; Zilberman et al., 2003). Similarly, an apathy scale was validated by Starkstein and colleagues (1992) in a sample of individuals with Parkinson's Disease. Brooks & McKinlay (1983) developed a questionnaire of personality adjectives that they showed differ in individuals with closed head injury.

SREF measures have also shown validity against objective measures of prefrontal system function, both behavioral and neuroimaging. BIS scores correlate with the performance of healthy individuals on behavioral measures of impulsivity and prefrontal function, including go/no-go, antisaccades, and delayed alternation, tasks with demonstrated sensitivity to prefrontal function (Spinella, 2004; Carrillo-de-la-Pena et al., 1993). BIS scores also correlated with the micro structure of white matter in inferior right frontal lobe in a sample of people with schizophrenia (Hoptman et al., 2002), and with activation of prefrontal cortex in healthy individuals performing a response inhibition task (Horn et al., 2003). FrSBe scores have correlated with objective measures of executive dysfunction in schizophrenic and multiple sclerosis patients (Chiaravalloti & DeLuca, 2003; Velligan et al., 2002). Individuals with posttraumatic anosmia and elevated scores on the Iowa Collateral Head injury Interview showed orbitofrontal hypoperfusion using SPECT (Varney & Bushnell, 1998).

There are normal variations in the cognitive functions measured by SREF scales, although these have been little studied in healthy individuals. However, many of the existing scales have some methodological limitations in this population because they have only been developed in clinical populations. It is unknown whether their factor structure applies to healthy individuals. Further, many contain items regarding behaviors that are too extreme or pathological to apply to most normal adults (e.g., utilization behavior, lack of concern over incontinence, or alien hand syndrome). Other SREF measures were created to assess a specific aspect of executive functioning and do not sample a wider range of behaviors that apply to this rubric. This study was undertaken to develop a SREF measure in a sample of healthy individuals that samples a wide array of executive function.

METHODS

Participants

Participants were 188 adults (81 male, 107 female), aged 17 to 60 years (M = 26.6, SD = 10.2) who had completed between 11 and 18 years of formal education (M= 14.5, SD = 1.4). Participants were recruited via word-of-mouth from the college campus and local community by research assistants. They were given no specific criteria for selection other than to find noninstitutionalized, community-dwelling adults. The study was approved by an institutional review board and all participants agreed to a consent form in accordance with the ethical principles of the American Psychological Association and the Declaration of Helsinki. To maintain anonymity and encourage honest responding, participants were asked to seal their completed questionnaires in an envelope that was provided to them before returning them to the research assistant. No financial compensation was given for participation.

Measures

Executive Function Index (EFI). Initial were generated based on recent, comprehensive literature reviews (Tekin & Cummings, 2002; Stuss & Levine, 2002; Faw, 2003; Miller & Cohen, 2001; Fuster, 2000; Chow, 2000). A total of 41 items were generated that covered several content areas ascribed to executive functions: motivation (e.g., activity level, drive), impulse control (e.g., risk taking, substance abuse, excessive spending), empathy (e.g., concern for others, aggressive social stance, prosocial behaviors), planning (e.g., anticipation of consequences, use of strategies, saving money), and social conduct (e.g., socially inappropriate behaviors, conversational conduct, sexual impropriety). Items were rated on a 5-point Likert-type scale (1 = Not at all, 5 = Very much). Twenty-six of the 41 items were inverted to control for acquiescent responding. The responses for these items were inverted so that scores uniformly reflect executive function.

Frontal Systems Behavior Scale (FrSBe). The self-rating form of the FrSBe was used for this study. It consists of 46 items, which yields scores for three non-overlapping scales of dysfunction: Apathy, Disinhibition, and Executive dysfunction (E). An adaptation of the FrSBe was needed to measure prefrontal-associated traits in this study: whereas the original version was designed for clinical populations and asks for pre- and post-injury/illness ratings for each item, participants in this study were only asked for one global self-rating per item. Reliability studies of the FrSBe have shown high intrascale reliability in normal and clinical samples (Grace & Malloy, 2001).

Barratt Impulsiveness Scale—Version 11 (BIS). The BIS is a 30-item, self-rating scale. The items form three non-overlapping scales that show good reliability: non-planning (BISnp), motor impulsivity (BISm), and attentional impulsivity (BISa) (Patton et al., 1995).

Interpersonal Reactivity Index (IRI). The IRI is a 28-item self-report scale designed to measure both cognitive and emotional components of empathy (Davis, 1980). Two subscales of the EU were employed for this study: Perspective Taking (IRIpt) and Empathic concern (IRIec), because these relate closest to functions with demonstrated relationship to prefrontal system function. Items of the IRIptscale address one's tendency to take another's point-of-view, akin to the "theory of mind," whereas IRIec items relate to feelings of empathy toward others. The IRI has demonstrated good intrascale and test–retest reliability, and convergent validity is indicated by correlations with other established empathy scales (Davis, 1980). Validity of the IRI has been established in comparing healthy controls to child abusers and violent sex offenders (PerezAlbeniz & de Paul, 2003; Curwen, 2003). IRIpt scores also predicted volunteerism in healthy adults (Oswald, 2003).

RESULTS

Scale Construction and Factor Analyses

Corrected item-total correlations revealed 3 items with correlations below .2, which were dropped from the analyses. Exploratory factor analysis was done on the remaining items using principal components analysis with varimax rotation. The number of factors to be extracted was determined by interpretability and parallel analysis. Parallel analysis indicated a 5-factor structure, which also yielded logically interpretable factors (Zwick & Velicer, 1986). The five factors had 9, 7, 13, 5, and 4 items, respectively. Eigenvalues for these 5 factors were 4.0, 4.0, 4.0, 3.2, and 2.1, which accounted for 9.8%, 9.7%, 9.6%, 7.7%, and 5.1% of the variance, respectively. Collectively these 5 components accounted for 42.0% of the total variance. To refine and shorten the scales, up to 6 items with the highest loadings were chosen from each factor. This yielded 5 factors with a total of 27 items (6, 5, 6, 6, and 4 items per factor), which were again subjected to principal components analysis. Eigenvalues for these 5 factors were 3.1, 2.8, 2.8, 2.5, and 2.2, accounting for 11.5%, 10.4%, 10.2%, 9.4%, and 8.2% of the variance, respectively. Collectively these 5 components accounted for 49.7% of the total variance. Highest item loadings for each item was identical in both factor analyses (41 item and 27 item versions).

These factors were named Empathy (EM), Strategic Planning (SP), Organization (ORG), Impulse Control (IC), and Motivational Drive (MD) (Table 1). Ratings from items were summed to create additive scales. Values for negatively valenced items inverted so that scores on all scales and the total score represent better executive functioning. Cronbach's alpha was acceptable for the subscales: .76, .70, .75, .69, and .70, respectively, and .82 for the total score. Total scores for the EFI were normally .distributed (Kolmogorov-Smirnov $Z = .88$, $p = .42$).

A second-order factor analysis was done with the 5 scales using principal components analysis with varimax rotation. A three-factor solution was specified a priori to determine whether the scales organized according to the three principal regions of prefrontal systems identified by Cummings (1993).

Table 1. Factor analysis of the Executive Function Index (*N* = 188)

1	2	3	4	5	Item
.78	.17	–.10	.11	.00	Concern for others
.69	.21	–.17	–.07	.21	Help others in need
.68	.19	–.04	.01	.10	Takes others' feelings into account
.67	–.10	.31	–.08	.19	Protective towards a friends
.61	–.01	.00	.18	.08	Dislikes actions or words hurting others
.51	–.11	.13	.33	.00	Socially aggressive stance (INV)
.00	**.66**	.25	.09	.01	Organized person
–.03	**.62**	.11	–.08	–.07	Save money regularly
.16	**.59**	.07	.08	.15	Self-monitor for mistakes
.04	**.58**	.03	.16	.21	Plan for the future
.15	**.58**	–.02	.05	.21	Use of memory strategies
.15	**.51**	.18	.21	.03	Anticipate consequences of actions
–.11	**.46**	.18	.36	.02	Learn from mistakes
–.01	.15	**.74**	.01	.06	Trouble summing information for decisions (INV)
–.04	.08	**.71**	.11	.14	Distractibility (INV)
–.21	.24	**.67**	.19	–.15	Lost track of what I'm doing (INV)
.09	.05	**.64**	.12	–.06	Mix up the sequences of actions (INV)
.11	.16	**.64**	.10	.20	Trouble doing two things at once (INV)
.24	.18	**.09**	**.71**	.08	Socially embarrassing behavior (INV)
–.03	.05	.15	**.69**	.01	Inappropriate sexual behavior (INV)
.09	.17	–.03	**.65**	.02	Use obscenities (INV)
.01	–.05	.24	**.51**	–.48	Maladaptive risk taking (INV)
.18	.18	.18	**.41**	–.05	Lose my temper when upset (INV)
.22	.13	.12	.00	**.73**	Interested in new things
.16	.23	.05	–.15	**.67**	Energetic person
.34	.24	.12	.10	**.59**	Have enthusiasm
–.15	–.15	.05	.46	**.59**	Inactivity (INV)

Values for inverted items (INV) were inverted prior to the factor analysis.
Bold signifies faster loadings (7.40).

Eigenvalues for these 5 factors were 1.6, 1.2, and 1.1, which accounted for 31.6%, 23.8%, and 21.8% of the variance, and collectively accounted for 77.2% of the total variance (Table 2).

Demographics Influences

Linear regression was performed to determine the contributions of demographic variables to EEI total scores, which was significant, $F(3,187) = 10.6$, $p < .001$ (Table 3). The model accounted for 14.8% of the variance (Adjusted

Table 2. Second order factor analysis of the Executive Function Index subscales (*N* = 188)

	1	2	3
ORG	**.84**	–.07	.09
SP	**.70**	.17	.31
EM	–.08	**.85**	.35
IC	**.57**	**.65**	–.28
MD	.21	.15	**.88**

Values for inverted items (INV) were inverted prior to the factor analysis. Abbreviations: EM = empathy, SP = strategic planning, ORG = organization, IC = impulse control, and MD = motivational drive.

R^2 = .0134). Females scored higher than males, and scores increased with age and educational level. Analyses of variance of subscales showed sex differences to be significant for IC and EM scales, with medium effect sizes as indicated by Cohen's *d* (Table 4).

Validity

Pearson correlations coefficients were obtained between scales of the EFI, FrSBe, BIS, and IRI (Table 5). Inverse correlations occurred between scales of the all scales of the EFI with the all scales of the FrSBe. Inverse correlations also occurred between the all BIS scales and MD, IC, ORG, and SP, whereas only BISnp correlated with EM. Both IRI scales correlated positively with MD, IC, and EM, whereas only IRIpt correlated positively with SP. Partial correlations were performed to control for the influences of age,

Table 3. Linear regression of demographic variables predicting total scores of the Executive Function Index

	B	SE	Beta	Partial	Part
Age	.28	.08	.24**	.25	.24
Sex	–3.99	1.67	–.16*	–.17	–.16
Education	1.54	.41	.26**	.27	.26

**p* = .018, ***p* <= .00l.

Table 4. Descriptive statistics for EFI scores

	Overall		Males		Females			
	M	*SD*	*M*	*SD*	*M*	*SD*	*p*	*d*
MD	14.6	3.0	14.8	2.6	14.5	3.2	.499	
IC	16.4	4.0	15.4	3.7	17.2	4.0	.002	0.5
EM	22.8	4.1	21.5	4.1	23.8	3.7	.000	0.6
ORG	18.3	3.7	18.2	3.5	18.4	3.9	.777	
SP	23.7	4.4	23.4	4.5	23.9	.4.3	.442	

Abbreviations: EM = empathy, SP = strategic planning, ORG = organization, IC = impulse control, and MD = motivational drive.

Table 5. Correlations between subscales of the Executive Function Index subscales (EFI)

	Bivariate					Partial				
	MD	IC	EM	ORG	SP	MD	IC	EM	ORG	SP
A	–.60†	–.23**	–.23†	_.54†	–.37†	–.59†	–.17*	–.17*	–.54†	–.34†
D	–.19**	–.77†	–.38†	–.41†	–.39†	–.17*	–.73†	–.28†	–.42†	–.28†
E	–.34†	–.26†	–.20**	–.58†	–.47†	–.30†	–.25†	–.15*	–.58†	–.43†
BISnp	–.27†	–.26†	–.15*	–.43†	–.69†	–.21**	–.29†	–.14	–.43†	–.67†
BISm	–.17*	–.51†	–.12	–.44†	–.36†	–.12	–.53†	–.08	–.43†	–.32†
BISa	–.18*	–.39†	–.04	–.43†	–.50†	–.12	–.42†	–.03	–.42†	–.49†
IRIpt	.18*	.22**	.58†	.02	.22*	.16*	.16*	.54†	.00	.18*
IRIec	.19*	.22**	.67†	.03	.08	.21*	.13	.63†	.01	.05

Frontal Systems Behavior Scale (FrSBe), Barratt Impulsiveness Scale (BIS), and Interpersonal Reactivity Index (IRI) (*df*= 186; **p* = 05, ***p* <= .01, †*p* < .001). Partial correlations are controlling for age, sex, and education (*df*= 183). Abbreviations: EFI: EM = empathy, SP = strategic planning, ORG = organization, IC = impulse control, and MD = motivational drive; FrsBe: A = apathy, D = disinhibition, and E = executive dysfunction; BIS: BISnp = nonplanning, BISm = motor impulsivity, BISa = attention impulsivity; IRI: IRIpt = perspective taking, IRIec = empathic concern.

sex, and education. Small reductions in the magnitude occurred in the correlation coefficients, while the overall pattern of relationships remained and was significant for the majority of correlations.

DISCUSSION

The EFI was created as a brief, self-rated measure of executive functioning in normal individuals. The items were derived from reviews of clinical and experimental studies of executive functions in order to reflect the activity of prefrontal-subcortical systems. This instrument has the advantage of having been developed in a community sample, demonstrating the viability of such an instrument in normal individuals whereas many in the past had been created for clinical purposes. Factor analysis showed that the items organized into 5 factors whose content relates to recognized domains of executive functioning. The relationship of the content of these scales to prefrontal system function is evident in clinical and neuroimaging studies.

Items of the EM scale reflect a concern for the well-being of others, prosocial behaviors, and a cooperative attitude. Functional neuroimaging studies have shown activation in superior frontal and orbitofrontal cortex during empathy judgments (Farrow et al., 2001; Decety & Caminade, 2003). Activation in the prefrontal-subcortical circuits (orbitofrontal and anterior cingulate cortex, nucleus accumbens, and caudate nucleus) was demonstrated in subjects engaging in social cooperation during the Prisoner's Dilemma Game (Rilling et al., 2002). Both neuroimaging and lesion studies suggest a role for orbitofrontal and medial prefrontal cortex in theory of mind ability, or the ability to take another's point of view (Goel et al., 1995; Stone et al., 1998). Accordingly, individuals with prefrontal insults exhibit reduced empathy (Eslinger, 1998).

SP items address tendencies to think ahead, plan, and use strategies. Several studies have demonstrated prefrontal system activity during an objective measure of planning, the Tower of London. Van den Heuvel and colleagues (2003) showed activation of dorsolateral prefrontal cortex, striatum, premotor cortex, supplementary motor area, and visuospatial system (precuneus and inferior parietal cortex) during performance of the task. Newman and colleagues (2003) showed that right prefrontal areas may be more involved in plan generation, whereas left prefrontal areas may be more involved in plan execution. Beauchamp and colleagues (2003) showed that medial orbitofrontal and frontopolar activity related to indices of learning across trials. Dorsolateral prefrontal activation was evident in a study by

Fincham and colleagues (2002) using the analogous Tower of Hanoi planning task. Individuals with prefrontal and striatal injury show deficits in diverse tasks of planning (Colvin et al., 2001; Mendez et al., 1989).

ORG items address the ability to carry organized goal-directed behavior through functions like multitasking, sequencing, and holding information in mind in order to make decisions. Dorsolateral prefrontal circuits mediate working memory, a function necessary to handle multiple demands simultaneously (Courtney et al., 1998). Individuals with lesions of dorsolateral, frontopolar, and left anterior cingulate show deficits in multitasking (Burgess et al., 2000). Prefrontal systems are also active during use of mnemonic strategies (Speer et al., 2003). Items of the IC scale address self-inhibition, risk taking, and social conduct. Individuals with orbitofrontal injuries show deficiencies in these areas (Malloy et al., 1993). Performance on the Iowa Gambling Task, a measure of risk taking and decision making, causes activation of orbitofrontal and other prefrontal structures (e.g., Bolla et al., 2003). MD items address behavioral drive, activity level, and interest in novelty. Individuals with medial prefrontal circuit dysfunction show apathy, reduced drive, and abulia (Teckin & Cummings, 2003; Sarazin et al., 2003; Matsumoto & Tanaka, 2004).

In addition to items factoring logically according to abilities mediated by prefrontal systems, a second-order, 3-factor model of these subscales showed that ORG and SP form one factor, EM and IC form a second, and MD forms a third. These fit what would be anticipated from Cummings (1993) identification of dorsolateral, orbitofrontal, and medial prefrontal circuits, respectively. The factor organization of the scales parallels the functional organization of prefrontal circuits.

Regression analysis showed that the EFI total score increases with age and education, and that females score higher than males. This pattern of demographic influences matches those of some other executive measures, such as the FrSBe and Wisconsin Card Sorting Test (Grace & Malloy, 2001; Heaton et al., 1993; Boone et al., 1993). Age-related differences in executive function have been documented and corroborated by neuroimaging studies of prefrontal system activity (Luna et al., 2001). This has particularly been evidenced in response inhibition tasks (Tannin et al., 2002; Booth et al., 2003; Rubiya et al., 2000). There are several possible neurobiological underpinnings for this maturation, including increases in frontal myelination, which can persist into the fifth decade of life (Sowell et al., 2003; Bartzokis et al., 2001).

The sex differences shown here on the IC and EM scales are supported by other studies. Females tend to perform better on measures of response inhibition (Klinteberg et al., 1987), a finding that is not limited to humans (Jentsch & Taylor, 2003). Females, on average, also tend to exhibit higher degrees of empathy (Mehrabian & Epstein, 1972). One possible underpinning for these differences is greater volume of orbitofrontal cortex in females compared to males (Gur et al., 2002). Also of interest in this study was the lack of sex differences in dorsolateral prefrontal cortex. The pattern of results reported here fits these neuroanatomical findings: no sex differences in dorsolateral-associated function (SP and ORG), and lower scores in males on orbitofrontal-associated function (IC and EM).

Executive function correlated positively with educational level. Aspects of education have also been associated with executive functions. In children, impulsivity is consistently associated with lower grades and achievement scores, even when IQ is partialled out (Meade, 1981; Miyakawa, 2001). Grades in an undergraduate college course were also found to be inversely related to impulsivity (measured by the Barratt Impulsiveness Scale), independent of age, sex, or years of school completed (Spinella & Miley, 2003). Orbitofrontal-sensitive measures (go/no-go, delayed alternation, and smell identification) were also related to years of educational attainment, independent of age or sex (Spinella & Miley, 2005a). Overall college GPA was inversely related to FrSBe E scores, even after controlling for hours worked and studying per week (Spinella & Miley, 2005b). Hours studying per week relate inversely to the FrSBe A scale, even after controlling for hours worked per week.

The EFI shows consistent correlations with other SREF measures. Correlations are inverse with the FrSBe and BIS and positive with the IRI because the EFI and IRI items are inverted to reflect good executive functioning, whereas the opposite is true for the others. These correlations are independent of age, sex, or education. In addition to the directionality of the correlations, the pattern is also relevant. Correlations are highest between EFI measures that correspond most closely to their FrSBe, BIS, and IRI equivalents. For example, MD correlates the most with the FrSBe A scale, while IC and EM correlate the most with FrSBe D, and SP and ORG correlate highest with FrSBe E. The EFI SP scale correlates strongest with BISnp, and IC correlates strongest with BISm. The EFI scale that correlates strongest with IRI scales is EM. Thus the EFI strongly correlates with other SREF measures that have been validated with thorough clinical, experimental, and neuroimaging studies.

A limitation of the EFI remains in its self-rating methodology. Although SREF measures may correlate with objective neuropsychological and physiological measures, one could not immediately make conclusions about brain structure from a self-rating measure, particularly in individual cases. As with all subjective data, corroborating evidence from other objective sources is desirable. Scores on SREF measures could he influenced by temporary conditions or by individual biases. Epistemologically, one is limited to conclude that the patterns of responses observed are consistent with prefrontal system function.

However, insofar as SREF measures do correlate with objective measures of brain structure and function, they are useful research instruments. This is especially the case because they can be quick and efficient means to gather data in large samples, affording statistical power and control of covariates. Results from SREF research can be used to corroborate and also to elaborate upon findings from more objective measures like functional neuroimaging. Given the low cost of administering SREF measures, they can also be used to test new hypotheses regarding executive function, which could then be followed by objective methods.

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