

NEUROBEHAVIORAL CORRELATES OF IMPULSIVITY: EVIDENCE OF PREFRONTAL INVOLVEMENT

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Impulsivity is associated with the functioning of prefrontal-subcortical circuits particularly, the orbitofrontal circuit, which is shown in neuroimaging studies of neurological and psychological disorders. Objective behavioral measures, such as go/no-go, antisaccades, and delayed alternation, have demonstrated sensitivity to prefrontal function. This study examined the relationship between orbitofrontal-sensitive measures and impulsivity in healthy adults, as measured by the Barratt Impulsiveness Scale-11 (BIS). Go/no-go and antisaccades correlated positively and delayed alternations correlated negatively with BIS subscales, even after controlling for demographic influences. The results add to the validity of the BIS and support a role for prefrontal cortex in impulse control.

Keywords alternation, impulsivity, inhibition, orbitofrontal, prefrontal

Impulsivity involves a lack of control over one's thoughts and behavior, with tendency to act hastily upon urges or environmental demands. Such behavior can be detrimental, because it often achieves immediate objectives at the expense of long-term goals. Impulsivity is increased in many neuropsychiatric conditions, including bipolar disorder, suicide, attention deficit hyperactive disorder (ADHD), borderline personality disorder, antisocial personality disorder, and conduct

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disorder (van Heeringan, 2001; Chretien & Persinger, 2000; American Psychiatric Association, 2000; Swann, Anderson, Dougherty, & Moeller, 2001).

Impulsivity is a wide-ranging personality trait that can potentially impact any area of a person's life. Relevant to education, impulsivity in children is associated with lower academic grades and achievement scores, even when IQ is partialled out (Merrell & Tymms, 1981; Miyakawa, 2001). Recent evidence has related impulsivity to academic achievement in adult college students as well (Spinella & Miley, 2003). Impulsivity has been associated with greater aggression (Hollander et al., 2000), and is associated with greater drug cravings in substance abusers (Zilberman, Tavares, & El-Guebaly, 2003). Thus, measures of impulsivity are of great potential use in clinical and normal populations.

Dysfunction of prefrontal-subcortical circuits, including the striatum and thalamic nuclei, have been associated with impulsivity in various neuropsychiatric disorders (Mega & Cummings, 1994). Functional neuro-imaging studies support a role, particularly, for orbitofrontal cortex in impulsivity. A positron-emission tomography (PET) study of borderline personality disorder, which features pervasive impulsivity, showed diminished responsiveness to serotonergic stimulation in right orbitofrontal and medial prefrontal cortex and the left caudate nucleus (Soloff et al., 2000). Similarly, impulsivity and other symptoms of Tourette's syndrome were associated with activity in the orbitofrontal cortex, inferior insular cortex, and the putamen (Braun, Dougherty, Huang, & Scurlock, 1995). Impulsivity is also a common sequel to traumatic brain injury (TBI), which has a propensity to affect prefrontal structures (McAllister, 1992; Fontaine, Azouvi, Remy, Bussel & Samson, 1999). The neurobehavioral impairments following TBI are particularly associated with orbitofrontal hypometabolism (Varney, Pinkston, & Wu, 2001; Varney, Bushnell, & Nathan, 1995). Impulsivity is a key feature of neurological insults restricted to orbitofrontal cortex and associated subcortical structures (Malloy, Bihrlé, Duffy, & Cimino, 1993; Cardinal, Pennicott, Sugathapala, Robbins, & Everitt, 2001). Thus, many forms of insult to prefrontal cortex, particularly orbitofrontal cortex and associated subcortical structures, are commonly associated with impulsivity.

Several neuropsychological measures have been employed to

assess impulsivity, particularly in ADHD. Motor response inhibition deficits are commonly reported in ADHD, which have been associated with right prefrontal activity (Rubia, Taylor, & Smith, 2001). Other executive tasks, such as the Stroop Test and Porteus Maze Test, involve inhibition of inappropriate responses and differentiate ADHD children from controls, corroborating prefrontal dysfunction (Grodzinsky & Diamond, 1992). However, neuropsychological tests do not seem to differentiate between inattentive and impulsive subtypes of ADHD (Chhabildas, Pennington, & Willcutt, 2001). The bulk of this work has been done in children with ADHD, but far less work has been done on the relationship between prefrontal function and impulsivity in healthy adults (Falkner & Herman, 2001).

Neuropsychological tests do not necessarily localize brain dysfunction, since circuits of multiple brain structures are likely used in any given task. However, showing relationships among several tasks, with demonstrated sensitivity function in a particular brain region, provides convergent evidence of the involvement of those structures. Several neurobehavioral measures are available with demonstrated sensitivity to the function of orbitofrontal circuits: go/no-go, antisaccades, and delayed alternation. Intercorrelations have been found among prefrontal-sensitive measures, supporting at least a partial overlap of their neuroanatomical substrates (Spinella, 2002a). The ecological validity of these measures is supported by correlations with behaviors, such as tobacco use (Spinella, 2002b). Several lines of evidence implicate prefrontal cortex in psychoactive drug use and addiction (Goldstein & Volkow, 2002; Spinella, 2003).

Go/no-go tasks involve regulation and inhibition of motor responses. Lesion and electrophysiology studies in humans suggest prefrontal involvement in go/no-go tasks (Drewe, 1975; Ikeda et al., 1996; Malloy, Rasmussen, Braden, & Haier, 1989; Falkner & Herman, 2001). Functional neuro-imaging studies also demonstrate orbitofrontal activation during go/no-go tasks (Liddle, Kiehl, & Smith, 2001; Tamm, Menon, & Reiss, 2002). Antisaccades, or inhibition of saccades toward a visual target, are an oculomotor equivalent of go/no-go tasks. Antisaccades correlate positively (e.g., $r = .47, p < .01$) with go/no-go tasks (Spinella, 2002a), and lesion studies indicate that orbitofrontal cortex is necessary for saccade inhibition (Hodgson et al., 2002).

Alternation tests require a subject to make alternating responses, each one the opposite of a previously rewarded response. Both animals and humans with orbitofrontal lesions have impairments on alternation tasks (Freedman et al., 1998). Also, performance on alternation tasks is also impaired in obsessive-compulsive disorder, which is associated with orbitofrontal dysfunction (Zohar, Hermesh, Weizman, Voet, & Gross-Isseroff, 1999; Gross-Isseroff et al., 1996). Functional neuro-imaging studies have demonstrated alternation tasks to activate the prefrontal cortex (Gold, Berman, Randolph, Goldberg, & Weinberger, 1996; Zald, Curtis, Folley, & Pardo, 2002).

Several self-report measures of impulsivity scales have been developed, measuring various aspects of impulsivity. Harmstead and Lester (2000) combined the items of nine impulsivity scales, yielding a total of 95 items, and found eight factors: concentration, decision-making, thinking, money, excitement, temper, future orientation, and complexity. The Barratt Impulsiveness Scale (BIS) is a psychometrically well-developed scale that has been validated with clinical populations and experimental measures (e.g., Patton, Stanford, & Barratt, 1995; Dougherty, Bjork, Huckabee, Moeller, & Swann, 1999; Bjork, Dougherty, Huang, & Scurlock, 1998). The BIS also correlates with tobacco use (Spinella, 2002b). A recent neuro-imaging study also related BIS scores to right frontal white matter structure in schizophrenic patients (Hoptman et al., 2002).

Given the evidence for prefrontal involvement in impulse control, this study was undertaken to explore the relationship between impulsivity and prefrontal-sensitive measures in a sample of normal, healthy adults.

METHODS

Participants

Participants were a convenience sample of 45 (23 female, 22 male) healthy, community-dwelling individuals recruited by research assistants and who did not receive any financial compensation for participating. A proportion ($n = 27$) were students enrolled in an undergraduate course in physiological psychology, who received a

small amount of course credit for their participation. However, course credit was not contingent upon their performance, and they were free to partake in an alternate task or decline participation entirely without penalty. The study was approved by an institutional review board; all participants read and signed an appropriate informed consent, in accordance with the Declaration of Helsinki and the ethical principles of the American Psychological Association. Participants ranged in age from 19 to 89 years (mean 31.6 ± 15.8 years), and had completed between 8 and 16 years of education (mean 13.6 ± 1.9 years).

Measures

Go/No-Go

An imitation set (20 trials) was performed where the subject imitated a standardized sequence of taps, either 1 or 2 taps, performed by the examiner. The conflict tapping set (GNGc) involved 30 trials of the subject performing the opposite of the examiner (one tap for two, and vice versa). An inhibition tapping set (GNGi) involved the subject tapping once when the examiner tapped once, but not tapping at all when the examiner tapped twice. All taps by the examiner were done at 1 s intervals. An incorrect response or a response delayed by more than 1 s was counted as an error. More errors indicate greater dysfunction.

Antisaccades

The procedure and norms were defined by Currie and colleagues (1991). A prosaccade set (10 trials) required the subject to make saccades left or right toward a visual target, presented in random, but standardized, sequence. An antisaccade set (AS, 25 trials) required the subject to look in the direction opposite of the visual target, presented in random but standardized sequence. More errors indicate greater dysfunction.

Delayed Alternation

A delayed spatial alternation test was used, adapted from Gross-Isseroff and colleagues (1996). The subject is shown two opaque

cups and told that a penny is underneath one of them. A movable screen prevented the subject from seeing the placement of the penny, and a felt-covered board underneath minimized extraneous auditory cues. Both cups were baited with pennies for the first trial, and on every successive trial the cup opposite the subject's last choice was baited. The task involves 25 trials with 24 possible alternations. The subject must correctly remember the placement of the penny on the last trial and alternate his or her response on successive trials. The number of alternations made was recorded (DAL). Fewer alternations indicates greater dysfunction.

Impulsivity

The Barratt Impulsiveness Scale—Version 11 (BIS-11) was used in this study. Subjects completed the 30 item, self-rating scale, which measures 3 factors: non-planning (orientation toward the present rather than the future, BISnp), motor impulsivity (or acting without thinking, BISm), and attention impulsivity (trouble concentrating/paying attention, BISa), in addition to a total score (BIS_t) (Patton et al., 1995).

TABLE 1. Partial correlations between behavioral measures and BIS-11 scores (controlling for age, sex, and education, $n = 43$, $df = 38$, two-tailed significance)

	<i>BISnp</i>	<i>BISm</i>	<i>BISa</i>	<i>BIS_t</i>
GNGc				
<i>r</i>	0.26	0.27	0.45	0.39
<i>p</i>	0.104	0.093	0.004	0.014
GNGi				
<i>r</i>	0.21	0.35	0.26	0.33
<i>p</i>	0.193	0.028	0.106	0.039
AS				
<i>r</i>	0.26	0.50	0.43	0.48
<i>p</i>	0.109	0.001	0.006	0.002
DAL				
<i>r</i>	-0.26	-0.33	-0.22	-0.33
<i>p</i>	0.104	0.036	0.167	0.039

GNGc = Go/No-Go conflict, GNGi = Go/No-Go inhibition, AS = antisaccades, DAL = delayed alternation, BISnp = non-planning, BISm = motor impulsivity, BISa = attention impulsivity, BIS_t = total impulsivity. Significant results are in boldface.

RESULTS

Partial correlations were performed between the BIS subscales and behavioral measures to control for the influences of age, sex, and years of education (see Table 1). GNGc correlated with attention impulsivity (BISa; $r = .45, p = .004$) and total impulsivity (BIS_t; $r = .39, p = .014$). GNGi correlated with motor impulsivity (BISm; $r = .35, p = .028$) and total impulsivity (BIS_t; $r = .33, p = .039$). As shown in Figure 1, AS correlated with motor ($r = .50, p = .001$), attention ($r = .43, p = .006$), and total impulsivity ($r = .48, p = .002$). DAL correlated with motor impulsivity (BISm; $r = -.33, p = .036$) and total impulsivity (BIS_t; $r = -.33, p = .039$).

DISCUSSION

This study demonstrates relationships between objective prefrontal measures sensitive to prefrontal function and a subjective, self-rating

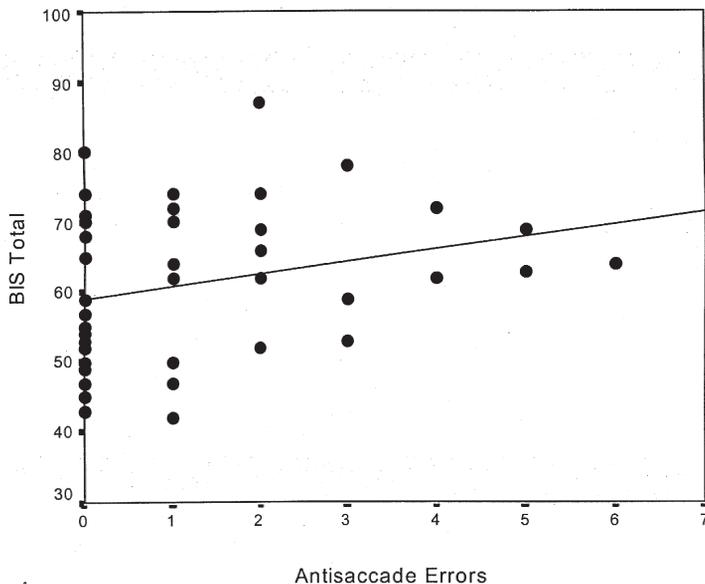


FIGURE 1. Relationship between antisaccade errors (AS) and total impulsivity (BIS_t).

impulsivity scale, even after controlling for the demographic influences of age, sex, and education. Relationships were demonstrated for GNG, AS, and DAL. While the correlations for DAL did not reach any significance after using stringent adjusted alpha levels, they were uniformly in the predicted direction. Also noteworthy is that the observed relationships were consistently in the predicted direction, where error scores on GNGc and AS correlated positively with impulsivity and DAL (correct responses) related inversely. Thus, better performance on all measures relates to lesser self-ratings of impulsivity.

The validity of these behavioral measures, demonstrated in lesion and neuro-imaging studies, affirms the role of the prefrontal cortex and the associated subcortical structures in impulsivity. Further, it adds to the validity of the BIS and its ability to detect variations in behavioral correlates of prefrontal functioning. Thus, combined use of these prefrontal-sensitive measures, as well as the BIS in clinical and experimental paradigms, may be of interest. For example, these behavioral measures have been shown to relate to tobacco use (Spinella, 2002b), and may be applied to other populations where impulsivity is a prominent feature, such as bulimia, kleptomania, drug addiction, and borderline personality disorder. Ideally, the study of impulsivity in both clinical and normal populations should utilize multiple methods available: self-rating scales, behavioral measures, neuro-imaging, and lesion analysis. Ultimately, the use of multiple measures provides greater convergent evidence and suggests future avenues for research.

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