Decline of Executive Function in a Clinical Population: Age, Psychopathology, and Test Performance on the Cambridge Neuropsychological Test Automated Battery (CANTAB)

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Decline of Executive Function in a Clinical Population: Age, Psychopathology, and Test Performance on the Cambridge Neuropsychological Test Automated Battery (CANTAB)

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This study presents a cross-sectional examination of the age-related executive changes in a sample of adults with a history of psychiatric illness using the Cambridge Neuropsychological Test Automated Battery. A total of 406 patients, aged 18 to 72 years old, completed executive function tests of working memory, strategic planning, and set shifting. Using current Diagnostic and Statistical Manual for Mental Disorders - Fourth Edition criteria, patients were diagnosed with: (a) affective disorders (N = 153), (b) substance-related disorders (N = 112), (c) personality disorders (N = 82), or (d) pervasive developmental disorders (N = 59). Test performances were compared to those of 52 healthy adults. Similar rates of age-related executive decline were found for patients and healthy participants. However, as adults with a history of psychiatric illness started out with significantly lower baseline levels of executive functioning, they may require less time before reaching a critical threshold where functional deficits emerge. Limitations as well as implications for future research were discussed.

Key words: aging, psychopathology, tests

As people grow older, cognitive changes become apparent. Common problems may include increased forgetfulness, slowed speed of processing, and difficulties in learning new tasks. This decreased cognitive ability may lead to reduced activation and less engagement in daily life, which underscores the importance of a better understanding of these age-related cognitive changes (Drag & Bieliauskas, 2010; Salthouse, 2005; Salthouse, Atkinson, & Berish, 2003).

Several models have been proposed to explain the cognitive difficulties people experience when they grow older. An often-cited model has been the frontal-lobe
The hypothesis of aging (West, 1996). Here, it is proposed that the prefrontal areas of the brain are particularly sensitive to the aging process and may form a key contributor to the age-related changes in cognitive performances and behavioral characteristics. Evidence can be found in the poorer performances of older adults on neuropsychological tasks that are highly dependent on executive functioning (EF) and linked with the frontal areas of the brain (Phillips & Henry, 2008). Studies have demonstrated that normal aging is accompanied by decreasing performances on EF tests, tapping inhibitory processes (Lowe & Rabbitt, 1997; Rabbitt, Lowe, & Shilling, 2001), mental flexibility (Salthouse, Fristoe, McGuthry, & Hambrick, 1998; Verhaegen & Cerella, 2002), and planning skills (Gilhooly, Phillips, Wynn, Logie, & Della Salla, 1999; Robbins et al., 1998).

Executive decline in the elderly may further be influenced by comorbid factors such as lifestyle, health behavior, and socioeconomic background. One important risk factor that may have an effect on the severity and course of EF difficulties may be a history of psychiatric illness. While impairments of EF are often associated with different psychiatric disorders, severely invalidating one's occupational, social, and/or emotional functioning (Burgess, Veitch, Costello, & Shallice, 2000; Vaughan & Giovanello, 2010), the relationship between psychiatric conditions and age-related executive decline has not been well documented.

In a longitudinal study exploring the relationship between early-life characteristics, such as psychiatric history and later-life cognition, Brown (2010) applied hierarchical growth curve models to compare cognition scores (memory and executive function) of individuals with and without a reported history of psychiatric illness. Results suggested that those participants with a history of psychiatric illness not only performed significantly poorer on cognitive measures as they grew older but also showed sharper rates of cognitive decline. It was concluded that these individual differences appear to "reflect the cumulative disadvantages by experiences in early life" (p. 654), with one important factor being a history of psychiatric illness. In contrast, Harvey, Reichenberg, and Bowie (2006) argued that in both depression and schizophrenia, the age-related cognitive changes, albeit at a greater level of severity, followed similar pathways as is seen in the typical (i.e., healthy) aging process. In a recent review of the literature on the developmental course of EF in schizophrenia, however, Freedman and Brown (2011) pointed out that based on their analysis of a selection of cross-sectional studies, decline of EF in patients with schizophrenia does surpass the normal age-related changes seen in healthy adults.

Assessment of EF is confronted with several methodological problems paralleling the diffuse characterization of the behaviors that make up EF (see Chan, Shum, Toulopoulou, & Chen, 2008). One approach to overcome these difficulties has been the introduction of computerized test batteries. Coverage of a wide range of skills as well as a precise and detailed recording of accuracy and response latencies may make computerized test administration better-suited for the early detection of cognitive changes (Browndyke & Schatz, 2005; Levaux et al., 2007; Wild, Howieson, Webbe, Seelye, & Kaye, 2008).

The Cambridge Neuropsychological Test Automated Battery (CANTAB) is an example of such a psychometrically solid battery that adapts standard cognitive tests for computerized administration and scoring. It consists of 19 different subtests assessing visual memory, executive function, attention, verbal memory, and (emotional) decision making. The CANTAB has been extensively used to compare the performances of normal controls to a range of neurological and psychiatric disorders, including Parkinson’s disease, Alzheimer’s disease, schizophrenia, autism, attention-deficit hyperactivity disorder, Wynn, Logie, & Della Salla, and depression (e.g., Fray, Robbins, & Sahakian, 1996; Heinrichs & Zakwanis, 1998; Hill, 2004; Ozonoff et al., 2004; Robbins et al., 1994; Summers & Saunders, 2012). Furthermore, research has demonstrated its sensitivity of detecting age-related decline of EF performances in healthy adults (see, e.g., De Luca & Leventer, 2008; De Luca et al., 2003; Robbins et al., 1998). Its frequent use in clinical practice has contributed to the construct validity of its separate subtests (Owen, Roberts, Polkey, Sahakian, & Robbins, 1991; Robbins et al., 1998). Moderate correlations (ranging from .17 to .28, p-values below .05) have been found between subtests of the CANTAB and more traditional clinical neuropsychological tests of EF, including the Stroop Test (Golden, 1978; Stroop, 1935), the Trail-Making Test (Reitan, 1979), and several subtests of the Wechsler Adult Intelligence Scale-Third Edition (Wechsler, 1997), supporting the criterion validity of the CANTAB (Smit, Need, Cirulli, Chiba-Falek, & Attix, 2013; Torgerson, Flaatten, Engelsen, & Gramstad, 2012). Test–retest reliability scores have been shown to differ substantially, ranging from only .26 to .94 (see Lowe & Rabbitt, 1998; Shur-Fen Gau & Shang, 2010).

The current study examines the cross-sectional relationship of age and psychopathology on strategic planning, set-shifting, and working-memory skills using the CANTAB. In particular, we were interested to see whether the executive changes in aging clinical populations would exceed the age-related changes seen in healthy adults. For this reason, we compared test performances of individuals with varying psychiatric conditions to the performances of healthy controls. All participants were aged 18 to 29 years old (young
adulthood), 30 to 49 years old (middle adulthood), and 50 to 65 years or older (late adulthood).

METHOD

Participants

Participants included a total of 406 patients and 50 healthy adults aged 18 to 72 years old (M = 40.90, SD = 14.92). Of the sample, 138 participants (30.3%) were younger than 30 years old, 158 participants (34.6%) were aged 30 to 49 years old, and 160 participants (35.1%) were older than 50 years old. The numbers of men and women were evenly distributed in each group (58.4% men). In accordance with current Diagnostic and Statistical Manual for Mental Disorders-Fourth Edition (DSM-IV) criteria, patients were classified into one of the following main diagnostic groups: (a) affective disorders (N = 159), (b) substance-related disorders (N = 109), (c) personality disorders (N = 79), or (d) developmental disorders (N = 59). For participants’ demographics, see Table 1.

Patient records were drawn from a large electronic database containing test results of clinical inpatients and outpatients attending several departments of a psychiatric hospital in The Netherlands from June 2009 to March 2012. Data were obtained as part of the regular administration of a neuropsychological assessment battery. The majority of inpatients and outpatients received medical treatment to relieve symptoms of mental illness. Exclusion criteria were: (a) a primary diagnosis other than an affective, substance-related, developmental, or personality disorder, (b) intellectual disability, (c) age younger than 18 years old, and (d) poor understanding of the Dutch language. In addition, healthy volunteers were recruited from outside the mental health care services, and similar exclusion criteria were applied in addition to excluding individuals with a previous diagnosis of mental or neurological illness and evidence of current or past drug or alcohol abuse.

Measures

Cambridge Neuropsychological Test Automated Battery. The CANTAB consists of a computer-administered set of (nonverbal) neuropsychological tests developed to examine specific components of cognition. The CANTAB has been widely used in academic research and in clinical trials, and tests hold acceptable levels of concurrent validity and test–retest reliability (Lowe & Rabbitt, 1998). Subtests are graded in difficulty, minimizing floor and ceiling effects, and allow for use in a wide variety of ages and conditions. Participants are given multiple training trials to learn the requirements of each task, and detailed recording of responses is made possible by using a touch-sensitive screen.

Intradimensional/Extradimensional Set Shifting. The Intradimensional/Extradimensional Set Shifting (IED) is a computerized analogue of the Wisconsin Card-Sorting Task (Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) and features set formation (rule acquisition and maintenance), shifting, and attentional flexibility. Participants are presented with stimuli that are made up of color-filled shapes, white lines (simple stimuli), or both (compound stimuli). Feedback teaches participants to select the correct stimuli out of two. After six correct responses, rules and stimuli are changed. The test terminates if a participant fails to reach the criterion. Shifts are either intradimensional (Stage 1 to 5; variation within the selected dimension, e.g., shape) or extradimensional (Stage 6 to 9; relevant dimension varies from shape to white lines). The total number of errors adjusted to the amount of categories achieved, calculated by the CANTAB program was used as a measure of one’s mental flexibility.

Stockings of Cambridge. The Stockings of Cambridge (SOC) was designed to be similar to the tower tasks (e.g., Tower of London; Shallice, 1982) and is thought to be a measure of spatial planning, working memory, and inhibition. The task consists of

<table>
<thead>
<tr>
<th>Group/Variable</th>
<th>Healthy Controls</th>
<th>Affective Disorder</th>
<th>Substance-Related Disorder</th>
<th>Pervasive Developmental Disorder</th>
<th>Personality Disorder</th>
<th>Total*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age in years (SD)</td>
<td>39.30 (16.32)</td>
<td>42.93 (14.70)</td>
<td>44.69 (15.18)</td>
<td>34.71 (13.09)</td>
<td>36.86 (13.24)</td>
<td>40.90 (14.92)</td>
</tr>
<tr>
<td>Male (%)</td>
<td>46.0</td>
<td>53.5</td>
<td>72.4</td>
<td>88.1</td>
<td>31.6</td>
<td>58.4</td>
</tr>
<tr>
<td>N Total</td>
<td>50</td>
<td>159</td>
<td>109</td>
<td>59</td>
<td>79</td>
<td>456</td>
</tr>
<tr>
<td>N Age group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–29 years</td>
<td>19</td>
<td>43</td>
<td>24</td>
<td>27</td>
<td>25</td>
<td>138</td>
</tr>
<tr>
<td>30–49 years</td>
<td>13</td>
<td>51</td>
<td>33</td>
<td>22</td>
<td>39</td>
<td>158</td>
</tr>
<tr>
<td>&gt;50 years</td>
<td>18</td>
<td>65</td>
<td>52</td>
<td>10</td>
<td>15</td>
<td>160</td>
</tr>
</tbody>
</table>

*Diagnoses based on DSM-IV criteria were provided by the treating psychiatrist.
two displays, each containing a set of colored balls, which are held in stockings or socks suspended from a beam. Participants are asked to copy the pattern shown in the upper display by moving the colored balls in the lower display. For present purposes, the amount of problems solved in the minimum number of moves was taken as a measure of one’s planning ability.

**Spatial Working Memory.** The Spatial Working Memory (SWM) assesses a participant’s ability to retain and manipulate spatial information in working memory and the ability to use an effective strategy to do so. Participants are presented with a number of colored squares or boxes. By using the process of elimination, they are asked to find blue “tokens.” In each trial, there are as many tokens as there are boxes; however, a box contains a token only once per trial, and the next token occurs only after the previous one has been found. The number of boxes is gradually increased to a maximum of eight boxes. The number of between-search errors (i.e., revisiting an already emptied box during a trial) was used as an indicator of one’s working memory.

Data Preparation and Statistical Analyses

Normality could not be guaranteed for all variables; therefore, outlier correction was applied. Only values within the range of 3 standard deviations were included in analyses. Also, values with a Cook’s distance > 1 were excluded from analyses. As a result, 15 cases with outliers were removed and assumptions concerning normality were met for the SOC. Homogeneity of variance in SWM scores could only be guaranteed between age groups but not between the different diagnostic groups; therefore, differences in working memory between diagnosis groups were examined using the nonparametric Kruskal-Wallis Test. The same was done for IED scores for both diagnostic groups and age groups. Participants were classified into three age groups (i.e., 18 to 29 years old, 30 to 49 years old, 50 years old and older), which allowed a detailed look at age-related changes in EF during young, middle, and late adulthood.

Data were analyzed using a univariate analysis of variance with diagnostic group (healthy controls vs. patients with affective disorder, substance-related disorder, personality disorder, or pervasive developmental disorder) and age group (i.e., 18 to 29 years old, 30 to 49 years old, 50 years old and older) as independent variables and individual test scores on the SOC as a dependent variable. As for the SWM, only age group was included as an independent variable, concerning the heterogeneity of variance in the different diagnostic groups (see previous paragraph). The SWM and SOC were not combined into a multivariate analysis of covariance because this would have a negative effect on sample size (assessment of the SWM was not executed for a large part of participants with a pervasive developmental disorder, including all participants of 50 years old or older with this disorder).

Planned (repeated) contrasts were executed for the age groups because we expected EF to decline during aging. To examine differences between the several diagnosis groups, pairwise comparisons (based on estimated marginal means using Sidak correction for multiple comparisons) were applied. To explore the so-called cumulative disadvantage hypothesis (Brown, 2010), interaction effects between age group and diagnostic group were examined for the SOC. All analyses were performed using the Statistical Package for the Social Sciences Version 19.

**RESULTS**

Performances on the IED (total number of errors), SOC (problems solved in the minimum number of moves), and SWM (between-search errors), organized by diagnostic group and age group, are presented in Table 2 and Table 3. When nonparametric tests were used, medians and minimum and maximum scores were reported.

**Table 2**

<table>
<thead>
<tr>
<th>Diagnosis Group</th>
<th>Age Group</th>
<th>SOC</th>
<th>IED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18- to 29-year-olds</td>
<td>30- to 49-year-olds</td>
<td>50-year-olds and older</td>
</tr>
<tr>
<td>Healthy controls</td>
<td>1.026</td>
<td>1.45</td>
<td>10</td>
</tr>
<tr>
<td>Affective disorder</td>
<td>8.66</td>
<td>1.96</td>
<td>14</td>
</tr>
<tr>
<td>Personality disorder</td>
<td>7.99</td>
<td>1.78</td>
<td>19</td>
</tr>
<tr>
<td>Developmental disorder</td>
<td>8.40</td>
<td>1.83</td>
<td>12.5</td>
</tr>
<tr>
<td>Substance-related disorder</td>
<td>7.72</td>
<td>2.21</td>
<td>22.5</td>
</tr>
<tr>
<td>Total</td>
<td>8.32</td>
<td>2.03</td>
<td>16</td>
</tr>
</tbody>
</table>
Overall, a significant effect of diagnostic group (i.e., healthy controls vs. affective, substance-related, pervasive developmental, and personality disorders) was found for the SOC, $F(4, 413) = 4.76$, $p = .001$, $\eta^2 = .044$, the SWM, $H(4) = 31.70$, $p < .001$, and the IED, $H(4) = 20.17$, $p < .001$, indicating that healthy participants performed significantly stronger than did patients on CANTAB tests of working-memory, set-shifting, and planning skills.

Pairwise comparisons of the SOC scores revealed significant differences between controls and patients diagnosed with a substance-related disorder ($p = .011$) or a personality disorder ($p = .006$). Controls and patients diagnosed with pervasive developmental disorders or affective disorders scored within a similar range on the SOC. Furthermore, patients with a personality disorder scored significantly lower than did patients with a pervasive developmental disorder ($p = .045$).

Pairwise comparisons of SWM scores revealed a stronger performance of controls compared with patients diagnosed with affective disorders ($p < .001$), substance-related disorders ($p < .001$) and personality disorders ($p = .018$), but not compared with patients with pervasive developmental disorders. No differences in performance were found between all patient groups. IED performances showed a significantly stronger performance of controls compared with participants diagnosed with personality disorders ($p = .044$) and substance-related disorders ($p = .001$), but not compared with those with pervasive developmental disorders and affective disorders. Furthermore, patients with pervasive developmental disorders obtained significantly higher scores than did patients with substance-related disorders ($p = .015$). See Figures 1, 2, and 3.

Results also revealed that aging had a significantly negative effect on SOC performance, $F(2, 413) = 11.73$, $p < .001$, $\eta^2 = .054$, and SWM, $F(2, 306) = 29.08$, $p < .001$, $\eta^2 = .160$, confirming the decline of planning

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**TABLE 3**

Median, Minimum, and Maximum Scores of Diagnosis Groups and Means and Standard Deviations of Age Groups on the SWM (Between-Search Errors)

<table>
<thead>
<tr>
<th>Diagnosis Group</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy controls</td>
<td>15</td>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td>Affective disorder</td>
<td>38</td>
<td>0</td>
<td>91</td>
</tr>
<tr>
<td>Substance-related disorder</td>
<td>38.5</td>
<td>0</td>
<td>92</td>
</tr>
<tr>
<td>Personality disorder</td>
<td>37.5</td>
<td>3</td>
<td>83</td>
</tr>
<tr>
<td>Developmental disorder</td>
<td>17</td>
<td>4</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>0</td>
<td>92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>18- to 29-year-olds</td>
<td>23.38</td>
<td>18.78</td>
</tr>
<tr>
<td>30- to 49-year-olds</td>
<td>29.34</td>
<td>22.19</td>
</tr>
<tr>
<td>50-year-olds and older</td>
<td>45.05</td>
<td>21.04</td>
</tr>
<tr>
<td>Total</td>
<td>34.19</td>
<td>22.79</td>
</tr>
</tbody>
</table>

---

**FIGURE 1** Participants’ mean performances on the SWM (between-search errors).
skills and working memory as a function of age. Similarly, a main effect of age group was found for the IED, $H(2) = 26.01, p < .001$, indicating that set-shifting performances weaken as participants grow older. Results indicated a significant decrease in planning abilities (SOC) around middle adulthood; significant differences were found for the young (18 to 29 years old) and middle (30 to 49 years old) age groups ($p = .021$).
A further decline was found after the age of 50 years; middle-aged adults scored significantly higher on the SOC than did older (older than 50 years old) participants ($p = .008$).

Additionally, adults aged older than 50 years old performed significantly poorer ($p < .001$) on a test of working memory (SWM) compared with middle-aged adults (i.e., 30 to 49 years old). The younger and middle-aged adults scored within a similar range. Performances on the IED showed a similar trend. Again, a significant decline in performance was found between the middle-aged and older adults ($p < .001$), but not for the younger and middle-aged adults.

Finally, a significant interaction effect (i.e., between age group and diagnostic group) was found for SOC performances, $F(8, 413) = 2.21$, $p = .026$, $\eta^2 = .041$, indicating that groups based on current DSM-IV diagnosis were affected differently by age. Univariate analyses examining the course of aging per diagnosis group revealed that age had a significant effect on EF decline in the healthy control group, $F(2, 46) = 10.76$, $p < .001$, $\eta^2 = .319$, those with affective disorders, $F(2, 140) = 3.13$, $p = .047$, $\eta^2 = .043$, and those with substance-related disorders, $F(2, 96) = 13.13$, $p < .001$, $\eta^2 = .215$. Due to non-normality and heterogeneity of variance (and therefore the use of nonparametric Kruskal-Wallis Tests), no interaction effect could be examined for the SWM and IED.

**DISCUSSION**

The present research indicates that the decline of executive skills in populations with psychiatric conditions does not exceed the anticipated age-related executive changes seen in healthy aging adults. However, lower baseline levels, together with the decrease in executive capacity around middle adulthood, may have important implications for those groups of people already living with a disadvantage. That is, they may require less time before reaching a critical threshold where functional deficits emerge, even with a comparable rate of cognitive decline (see also Drag & Bieliauskas, 2010).

Overall, healthy participants performed significantly stronger than did patients on tests of working memory, strategic planning, and set shifting. Examination of the patient samples revealed significantly weaker performance on all tests of EF in adults diagnosed with either a substance-related disorder or a personality disorder when compared with a sample of healthy aging adults. Although patients diagnosed with affective disorders performed significantly poorer on a test of working memory, no differences were found between their performances on tests of set shifting and strategic planning when compared with the performances of healthy controls. Apart from patients diagnosed with a developmental disorder, differences between patient samples were not significant, suggesting that the executive profiles of adults with substance-related disorders, affective disorders, and personality disorders in this study exhibited few differences.

The poorest performances were found for those participants diagnosed with a substance-related disorder, which is consistent with literature concerning the long-lasting effects of drug abuse on cognitive functioning (see, e.g., Lundqvist, 2010; Van Holst & Schilt, 2011). Contrary to expectations, performances of patients with a pervasive developmental disorder were similar to those of the healthy aging adults. Although small sample sizes may have influenced the results, it can be suggested that as they grow older, adults with pervasive developmental disorders develop some compensatory strategies to account for their weaker skills (Hill, 2004). Future research may extend on the present findings by including specified samples of psychiatric patients, different levels of symptom severity, and different medication regimens.

Executive functions were seen to decline earlier than expected, with significant decrements in skills appearing from as young as 30 to 49 years of age. In contrast, healthy aging literature suggests a sharp decline in function around the age of 65 years (see, e.g., De Luca & Leventer, 2008; Salthouse et al., 2003). Using more sensitive EF measures like the CANTAB, De Luca and colleagues (2003) suggested that the changes in executive skills may even start at an earlier age than once thought, with a reported decline in performance of healthy aging adults aged 50 to 64 years old. Our data suggest a comparable reduction in working-memory, strategic planning, and set-shifting skills well before the benchmark age of 65 years old, and these data are consistent with findings of neural degeneration (see, e.g., Bishop, Lu, & Yankner, 2010).

Additionally, aging appeared to influence subfunctions differently, thereby supporting the consideration of different types of executive function independently. While poorest set-shifting and working-memory skills were reported for our oldest participants (late adulthood), planning functions were found to decline at an even earlier stage of the aging process (i.e., middle adulthood). Successful performance on tower tasks such as the SOC typically involve a sequence of cognitive processes to formulate, retain, and implement plans, as well as revise them “online.” As such, there are multiple possible reasons for low scores on complex tower tasks, and it can be argued that complex tasks placing high demands on several cognitive components simultaneously (i.e., “dual-task effect”; see Miyake et al., 2000) are more strongly affected by increasing age. For example, Brennan, Welsh, and Fisher (1997) already demonstrated that when compared with younger adults,
middle-aged adults are less capable of creating and ordering an effective plan, leading to disorganized behavior and failure to complete complex tasks. However, literature has failed to offer consistent results, and future research investigating the specific contribution of EF domains on aging processes is needed. Finally, our data suggested a steeper decline of planning skills in relation to age for patients diagnosed with substance-related disorders and affective disorders; this effect was also demonstrated in our sample of healthy controls. Unfortunately, our data did not permit for comparison of the relation between age and the IED and SWM scores.

To summarize, we did not find strong evidence for the so-called cumulative disadvantage hypothesis (Brown, 2010). Findings showed that the trajectories of change in those participants with a psychiatric condition followed similar patterns of executive decline compared with healthy aging adults and that aging affected the subcomponents of EF not unitarily.

A number of issues remain open for debate. First, although there are several advantages of computerized batteries over table-top measurement of EF, caution needs to be taken in the application of computers in clinical settings. Psychometrically, they do not all meet the criteria of the American Psychological Association for neuropsychological instruments concerning their reliability, validity, and normative data. Also, different familiarity of patients with computerized instruments and alterations in the nature of tests when adapting table-top tasks to computerized versions may alter a person’s perception to those tests that can affect one’s response style (i.e., data obtained from table-top measurements are not necessarily interchangeable with scores obtained from automated test batteries; see Crook, Kay, & Larrabee, 2009; De Luca et al., 2003).

Second, although the current patient sample possessed notable strengths, its composition might also be considered a limitation. It targeted only four broadly defined, diagnostic categories with selection criteria based on one’s primary diagnosis, thereby not specifying for either different subgroups with different etiologies or accounting for high levels of comorbid prevalence. Also, the selected patients were diagnosed and tested by different clinicians, and no validation check of these diagnoses has been done.

Third, the current study relied entirely on cross-sectional data leading to some important methodological limitations regarding the distillation of cause-and-effect relationships. Individual differences in education, socioeconomic background, marital status, or gender may make it hard to separate the actual determinants that account for the age-related changes in executive function. Examining the predictive validity in longitudinal studies will provide an important step in evaluating the clinical usefulness and manner in which interpersonal traits and environmental variables interact with EF, age, and pathology.

A final remark concerning the large variability of our data is necessary. Though the tendency of test scores to spread out from the mean may, in part, be the result of measurement error, the diffuse distribution of test scores is more likely related to the heterogeneity among individuals and is lacking precision of used instruments. The latter is a known artifact of commonly used (neuro-) cognitive tasks, and may be especially true for tests assessing complex human skills (see, e.g., Barkley, 2011; Chan et al., 2008). Because of their multicomponent nature, EF measures may have odd distributions that do not conform clearly to specific diagnostic profiles or to common cognitive styles. Ardila (2007) already reported that tasks assessing complex skills such EF had greater variability than did those assessing lower-level cognitive functions (e.g., visuo-construcive abilities). Regardless of the magnitude of differences, it remains difficult to interpret mean tests scores, and further development of the conceptual models that define the actual processes involved in the acquisition of EF skills over time may be appropriate.

Despite the aforementioned limitations, appreciation of the effects of (normal) aging in (non-) clinical and healthy populations may contribute to a better understanding of EF, and the use of automated test batteries like the CANTAB may provide a step forward in detecting age-related differences in these populations. As even subtle impairments in EF may be responsible for adverse effects on complex tasks of everyday social and occupational functioning, a thorough analysis of age-related cognitive deficits in populations with psychiatric illness may have substantial implications for treatment. Especially for those who are persistently ill, mental health care services are challenged to match their environment with individuals’ weaknesses and strengths. Understanding aging and its interaction with variables that influence cognition in later life might, therefore, serve as a potential means to address these issues.

REFERENCES


