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# Subjective Cognitive Complaints and Neuropsychological Performance in Former Smokers with and without Chronic Obstructive Pulmonary Disease

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## Abstract

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**Objective—**This study examined the association of perceived cognitive difficulties with objective cognitive performance in former smokers. We hypothesized that greater perceived cognitive difficulties would be associated with poorer performance on objective executive and memory tasks.

**Participants and Methods—**95 former smokers recruited from the COPDGene study completed questionnaires (including the Cognitive Difficulties Scale [CDS] and the Hospital Anxiety and Depression Scale [HADS]), neuropsychological assessment, and pulmonary function testing. Pearson correlations and t-tests were conducted to examine the bivariate association of the CDS (total score and subscales for attention/concentration, praxis, delayed recall, orientation for persons, temporal orientation, and prospective memory) with each domain of objective cognitive functioning (memory recall, executive functioning/processing speed, visuospatial processing, and language). Simultaneous multiple linear regression was used to further examine all statistically significant bivariate associations. The following covariates were included in all regression models: age, sex, pack-years, premorbid functioning (WRAT-IV Reading), HADS total score, and COPD status (yes/no based on GOLD criteria).

**Results—**In regression models, greater perceived cognitive difficulties overall (using CDS total score) were associated with poorer performance on executive functioning/processing speed tasks ($b = -0.07$, $SE=0.03$, $p=0.037$). Greater perceived cognitive difficulties on the CDS praxis subscale were associated with poorer performance on executive functioning/processing speed tasks ($b = -3.65$, $SE = 1.25$, $p=0.005$), memory recall tasks ($b = -4.60$, $SE=1.75$, $p = 0.010$), and language tasks ($b = -3.89$, $SE = 1.39$, $p=0.006$).

**Conclusions—**Clinicians should be aware that cognitive complaints may be indicative of problems with executive functioning/processing speed and memory among former smokers with and without COPD.

### Keywords

lung disease; cognition; neuropsychology; Cognitive Difficulties Scale; self-report

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Patients' self-report about cognitive deficits can be used by medical providers to determine whether a referral for neuropsychological assessment is needed. Subjective cognitive complaints play an important role in the overall neuropsychological evaluation and recommendations for the patients. Prior studies suggest differences in the accuracy of patients' perceptions of their cognitive difficulties relative to objective performance, depending in part upon the population being examined. Several primary neurological conditions present with focal brain damage and frank anosognosia, defined as a deficit in self-awareness, and thus self-report of cognition is often inaccurate in these patients. A large portion of clinical neuropsychological referrals are made in the context of cognitive impairment impacted by chronic medical illness (Gasquoine, 2011), a setting in which anosognosia from focal brain damage is not common. Past studies show an inconsistent relationship between self-report of cognition and objective cognition in patients with chronic medical illnesses including cardiovascular disease (Gunstad, Cohen, Tate, Hoth, & Poppas, 2006; Haley et al., 2009; Humphreys, Moser, Hynes, Reese, & Haynes, 2007; Khatri et al., 1999; McKhann et al., 2009; Newman et al., 1989; Vingerhoets, De Soete, & Jannes, 1995), cancer (Bender et al., 2008; Biglia et al., 2012; Shilling & Jenkins, 2007), and human immunodeficiency virus (Hinkin et al., 1996). Some of these studies found a significant association between patients' perception of their cognitive difficulties and objective cognitive performance, while others found no significant association. Researchers have found that depression may negatively affect patients' perception of their own cognition (Derouesné et al., 1999; Humphreys et al., 2007). Questionnaires designed to evaluate subjective cognitive complaints typically focus on specific areas such as memory or "global" cognition, which may not be the most pronounced area of difficulty in chronic medical illness. Thus, it may be important to ask patients about a range of cognitive functions and consider that perceived problems in one area may reflect objective impairment in another.

Chronic obstructive pulmonary disease (COPD (Kochanek, Xu, Murphy, Minino, & Kung, 2011) is a very common medical condition that is often accompanied by cognitive deficits, but no research to date has examined the link between subjective and objective cognitive performance in this population. The disorder is characterized by airflow limitation, shortness of breath, and exercise intolerance ("Global Initiative for Chronic Obstructive Lung Disease," 2016). Smoking is the most common risk factor for developing COPD. Neuropsychological research has documented that smoking can lead to subtle cognitive deficits in executive functioning, processing speed, and memory (Swan & Lessov-Schlagger, 2007). A broader range of cognitive deficits are present among patients with COPD, which are more pronounced than in smokers, with the most consistent in executive functioning (Crews et al., 2001; Dodd, Getov, & Jones, 2010; Kozora et al., 2008; Liesker et al., 2004; Villeneuve et al., 2012), processing speed (Dodd et al., 2010; Kozora et al., 2008), and efficiency of memory retrieval (Crews et al., 2001; Dodd et al., 2010; Kozora et al., 2008; Stuss, Peter, Guzman, Guzman, & Troyer, 1997). These cognitive deficits negatively impact patients' health-related quality of life (Dodd, Charlton, van den Broek, & Jones, 2013) and daily functioning (Özge, Özge, & Ünal, 2006) and increase their risk of hospitalization and death (Chang, Chen, McAvay, & Tinetti, 2012). Patients with COPD are typically treated in primary care settings where a referral for cognitive assessment is needed to connect patients with appropriate services for cognitive impairment. Thus, an accurate understanding of the association between self-reported cognitive complaints and objective performance may facilitate expedited evaluation and treatment.

The aim of the current study was to determine whether subjective cognitive complaints were associated with objective cognitive performance among former smokers with and without COPD, after adjusting for key demographic and clinical characteristics that could be associated with cognitive impairment. We hypothesized that subjective cognitive complaints would be associated primarily with executive functioning/processing speed and memory, given that these areas of cognition are relatively impaired in former smokers and patients with COPD.

## Methods

The study was approved by the Institutional Review Board at National Jewish Health (NJH) in Denver, CO. All participants provided written documentation of informed consent prior to their participation.

## Participants

One hundred and one former smokers were recruited from the COPDGene study at NJH in Denver, CO (Regan et al., 2010) and completed the current study focused on cognition in former smokers with and without COPD. All participants provided written informed consent after a thorough discussion of the study. Exclusion criteria were as follows: previous diagnosis with a cognitive disorder; neurological disorder (e.g., stroke, movement disorder); traumatic brain injury with loss of consciousness >10 minutes; major psychiatric disorder (e.g., schizophrenia, bipolar disorder, substance use disorder other than tobacco use); change in treatment for depression or anxiety in the previous three months; major medical condition other than COPD or asthma (e.g., renal failure, uncontrolled cancer, previous radiation treatment for cancer); arrhythmia; left sided heart failure; and COPD exacerbation within the past month that required a physician or ER visit and/or treatment with antibiotics or oral corticosteroids. Participant eligibility was determined based on a screening interview with each participant. Six participants were excluded from the current analyses for the following reasons: 2 due to current nicotine use identified via urine cotinine, 3 who endorsed exclusion criteria during study visits not endorsed upon screening (1 active illicit substance use, 2 traumatic brain injury), and 1 participant who did not complete all cognitive measures. The most common staging system for COPD is defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) ("Global Initiative for Chronic Obstructive Lung Disease," 2016) statement (i.e., stage 1–4), which is based largely on airflow limitation measured using spirometry. The current analyses included 95 former smokers: 36 without GOLD defined COPD based on spirometry, 31 with mild-moderate COPD (4 GOLD stage 1, 27 GOLD stage 2), and 28 with severe-very severe COPD (15 GOLD stage 3, 13 GOLD stage 4).

## Procedures and Measures

Participants completed 2 study visits scheduled within 3 weeks of one another (median= 5 days, SD= 7 days) that included: pre- and post-bronchodilator spirometry, urine cotinine testing to confirm smoking abstinence, symptom questionnaires, and neuropsychological testing.

**Pulmonary function testing—**Pre- and post- bronchodilator spirometry were administered to identify the presence of COPD per GOLD criteria ("Global Initiative for Chronic Obstructive Lung Disease," 2016) based on $FEV_1$/FVC and post-bronchodilator $FEV_1$% predicted, which are measures of forced expiratory air flow.

**Hospital Anxiety and Depression Scale (HADS)—**HADS is a 14-item self-report measure of symptoms of anxiety and depression (Zigmond & Snaith, 1983) that is commonly used in patients with chronic medical conditions (Herrmann, 1997), including COPD (Dowson et al., 2001; Engström, Persson, Larsson, Ryden, & Sullivan, 1996). Scores can range between 0–3 for each item and 0–42 overall. The total score was included in the regression models as a measure of psychological distress. The measure had a high level of internal consistency, as determined by a Cronbach's alpha of .84.

**Perceived cognitive difficulties—**The Cognitive Difficulties Scale (CDS) was administered to measure participants' perception of the frequency with which they experienced cognitive difficulties during the past month (McNair & Kahn, 1983). This self-report measure contains 39 Likert scale items on which the respondent is asked how often they experience problems with attention, language, memory, orientation, and motor functioning (Derouesné et al., 1993). Participants rank each item from "not at all" at 0 to "very often" at 4. The total score was calculated based on the sum of all items, and ranged from 0 to 156. Higher scores reflect more perceived cognitive difficulties. The CDS has been used in various populations, including patients with mild cognitive impairment (Bruce et al., 2008), patients with Alzheimer's disease (Derouesné et al., 1999), healthy older adults (Derouesné et al., 1993), and older adults who had coronary artery bypass surgery (Dufouil, Fuhrer, & Alperovitch, 2005) with a 1 month timeframe for reference. Because our inclusion criteria required that participants have no major changes in medical status in the month prior to participation, we believe that the 1 month time frame captured a stable period for the participants to rate. The CDS was administered before objective neuropsychological assessments. The scale had a high level of internal consistency in our study, as determined by a Cronbach's alpha of 0.96. Derouesné and colleagues (1993) completed a factor analysis on the CDS and found six subscales from 26 of the CDS items, which they labeled as follows: attention/concentration, praxis, delayed recall, orientation for persons, temporal orientation, and prospective memory. For example, the attention-concentration subscale includes items such as trouble keeping my mind on a task and losing my train of thought. The praxis subscale includes items such as trouble using tools and trouble sewing. The delayed recall subscale includes items such as forgetting to complete certain tasks or appointments. The orientation for persons subscale includes items such as trouble recalling people's names and recognizing people. The temporal orientation subscale includes items such as forgetting the date or day of the week. The prospective memory subscale includes items such as using a list so they do not forget things or forgetting errands. The full list of items included on each subscale is provided in Derouesné et al. (1993). The score for each subscale was calculated by summing the relevant items for that subscale (Buelow, Tremont, Frakey, Grace, & Ott, 2014; Derouesné et al., 1993). The number of items and range of scores for each subscale are provided in the note of Table 1.

**Neuropsychological assessment—**A standardized neuropsychological battery was administered to each participant by a trained psychometrician. WRAT-4 Reading Standard Score was used to estimate premorbid intellectual functioning (Wilkinson & Robertson, 2006). The neuropsychological measures were grouped into composite scores of memory recall, executive functioning/processing speed, visual-spatial processing, and language as follows:

**Memory recall:** The Brief Visuospatial Memory Test (BVMT-R) Delayed Recall score (Benedict, 1997) and the California Verbal Learning Test Second Edition (CVLT-II) Long Delay Recall (Delis, Kramer, Kaplan, & Ober, 2000).

**Executive functioning/processing speed:** The Wechsler Adult Intelligence Scale Fourth Edition (WAIS-IV) Coding subtest (Wechsler, 2008), Trail Making Test (Reitan & Wolfson, 1985), and Controlled Word Association Test (COWA) (Benton, Hamsher, & Sivan, 1994).

**Visuospatial processing:** The WAIS-IV Block Design subtest (Wechsler, 2008) and the Hooper Visual Organization Test (Hooper, 1983).

**Language:** Animal Fluency (Borod, Goodglass, & Kaplan, 1980) and the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 2001).

Age corrected T-scores were averaged to create each composite score. The following sources were used to derive these norms: WRAT-4 Manual for WRAT-4 Reading (Wilkinson & Robertson, 2006), the BVMT-R manual for the BVMT-R test (Benedict, 1997), the CVLT-II computerized scoring program for the CVLT-II (Delis et al., 2000), the WAIS-IV manual for the WAIS-IV subtests (Coding and Block Design) (Wechsler, 2008), the HVOT manual for the HVOT (Hooper, 1983), and the Heaton, Waldon Miller, Taylor, and Grant (2004) scoring program for Trail Making Test, Controlled Word Association Test, Animal Fluency, and the Boston Naming Test. The measures were grouped in this manner based on previous research that suggests these or similar measures map onto memory (Hayden et al., 2011; Smith et al., 1992; Smith, Ivnik, Malec, & Tangalos, 1993), executive functioning (Hayden et al., 2011), language (Hayden et al., 2011), and visuospatial functioning (Bowden, Carstairs, & Shores, 1999; Smith et al., 1992; Smith et al., 1993).

## Data Analysis

SPSS Statistics 22.0 (SPSS Inc., Chicago, IL) was used to analyze the data.

**CDS subscale calculation—**Participants rank each item on the CDS from “not at all” (scored as 0) to “very often” (scored as 4). The praxis CDS subscale and the delayed recall CDS subscale were both skewed, with a high percentage of scores (39% and 24% respectively) indicating no reported cognitive difficulty on any of the items. As such, dichotomous variables were created for these subscales. Participants who scored 0 across all subscale items were coded as reporting no cognitive difficulty and participants who scored above 0 for any subscale item were coded as reporting any cognitive difficulty. The remaining CDS subscales and CDS total score were all normally distributed and thus were treated as continuous variables.

**Primary analyses—**Former smokers with COPD were compared to former smokers without COPD using a t-test or $\chi^2$, as appropriate. Pearson correlations and t-tests were conducted to examine the bivariate association of the CDS total score and subscale scores with each domain of objective cognitive functioning. A bivariate association of $p < .05$ was considered to be statistically significant. We did not adjust the alpha level for the bivariate associations because the bivariate analyses were used to determine which variables would be explored using multiple regression, a strategy to reduce the number of regression analyses that would be run. We wanted to be liberal in identifying variables for follow-up with regression. Bivariate associations that were significant were further examined via simultaneous multiple linear regression models. The following variables were included as covariates in all regression models: age, sex, pack-years, premorbid intellectual functioning (WRAT-IV Word Reading), HADS total score, and COPD disease status (yes/no). For all statistical analyses, an $\alpha$ level of less than 0.05 was considered statistically significant.

## Results

### Participant Characteristics

Perceived cognitive difficulties, neuropsychological performance, demographic information, and clinical characteristics are presented in Table 1. The mean of the objective neuropsychological domain scores for both groups fell in the average range relative to appropriate norms, including executive functioning/processing speed, visuospatial functioning, memory, and language.

Differences between former smokers with and without COPD were examined to better characterize the sample (Table 1). There were no significant differences between groups on gender, education, and premorbid IQ. Former smokers with COPD were significantly older ($t= -2.92$, $p=0.004$), had greater pack-years ($t= -3.77$, $p<0.001$), and reported higher levels of psychological distress than former smokers without COPD ($t= -2.09$, $p=0.039$). As expected, former smokers with COPD had significantly lower $FEV_1/FVC$ ($t= 14.46$, $p<0.001$) and post-bronchodilator $FEV_1$% predicted ($t= 10.18$, $p<0.001$) than former smokers without COPD. Patients with COPD performed significantly worse on executive functioning/processing speed than former smokers without COPD ($t= 2.54$, $p=0.013$). There were no significant differences between groups on memory recall, language, and visuospatial functioning. In addition, there were no significant differences between groups on any of the perceived cognition scores.

### Association between Perceived and Objective Cognition

The bivariate association of the CDS total score with executive functioning/processing speed ($r= -.24$, $p=0.020$) and language ($r= -.24$, $p=0.022$) was statistically significant (Table 2). The bivariate association of the CDS attention/concentration subscale with executive functioning/processing speed ($r= -0.23$, $p=0.030$) and language ($r= -0.27$, $p=0.011$) was statistically significant (Table 2). In addition, the CDS praxis subscale was associated with executive functioning/processing speed ($t=3.57$, $p=0.001$), memory recall ($t=3.39$, $p=0.001$), and language ($t=3.35$, $p=0.001$), as shown in Table 3. The remaining CDS subscales did not have a statistically significant bivariate association with objective measures of cognition.

A regression model was calculated to further examine each statistically significant bivariate association for a total of seven regression models. Each model examined whether perceived cognition was associated with the objective measure of cognition while adjusting for age, gender, pack-years, WRAT-IV Word Reading standard score, HADS, and COPD disease status (COPD diagnosis or no COPD diagnosis).

Greater perceived cognitive difficulties (i.e., higher CDS total score) was associated with poorer executive functioning/processing speed after adjusting for the other covariates in the model ($b= -0.07$, $SE=0.03$, semi-partial correlation = $-.187$, $p=0.037$; Table 4). On average, for every one unit increase in perceived cognitive difficulites, there was a 0.07 decrease in executive functioning/processing speed T-score after adjusting for the other predictors in the model. In this model, a diagnosis of COPD was associated with lower performance on executive functioning (p=0.014). The CDS total score was not significantly associated with objective performance in the language domain after adjusting for the other covariates in the model (p=0.079).

With regard to the CDS subscales, praxis was associated with objective performance in the executive functioning/processing speed domain, the language domain, and the memory recall domain after adjusting for the other covariates in the model. Greater perceived praxis difficulties were associated with poorer executive functioning/processing speed (b= −3.65, SE= 1.25, semi-partial correlation = −.259, p=0.005; Table 5). Individuals who reported any praxis difficulty had executive functioning/processing speed T-scores that were 3.65 lower than individuals who reported no praxis difficulties after adjusting for the other predictors in the model. Greater perceived praxis difficulties were associated with poorer memory recall (b= −4.60, SE=1.75, semi-partial correlation = −.256, p=0.010; Table 6). Individuals who reported any praxis difficulty had memory recall T-scores that were 4.60 lower than individuals who reported no praxis difficulties after adjusting for the other predictors in the model. Greater perceived praxis difficulties were also associated with poorer language performance (b= −3.89, SE= 1.39, semi-partial correlation = −.263, p=0.006; Table 7). Individuals who reported any praxis difficulty had language T-scores that were 3.89 lower than individuals who reported no praxis difficulties after adjusting for the other predictors in the model.

The remaining CDS subscales were not associated with objective measures of cognitive functioning after adjusting for the covariates in the regression models.

## Discussion

The current study examined whether perceived cognitive difficulties accurately reflect objective neuropsychological performance among former smokers with and without COPD. Participants spanned a broad range with regard to severity of airflow limitation (i.e., no COPD to very severe COPD), making it possible to examine COPD disease status as a correlate of neuropsychological performance. Indeed, the presence of COPD was associated with reduced executive functioning/processing speed. This finding is consistent with prior research (Crews et al., 2001; Dodd et al., 2010; Kozora et al., 2008; Liesker et al., 2004; Villeneuve et al., 2012).

Perceived cognitive difficulties, specifically self-reported problems on the CDS total scale and praxis subscale, were associated with reduced performance on objective measures of cognition after adjusting for key demographic characteristics, symptoms of depression and anxiety, and COPD disease status (COPD diagnosis or no COPD diagnosis). In the bivariate associations, we found that those with self-reported difficulties in the praxis domain scored *on average* about a half a standard deviation below those without praxis complaints on executive functioning/processing speed, memory, and language, suggesting that a subset of these individuals may indeed show at least mild impairment if seen in the context of neuropsychological assessment.

The fact that participants showed mild, relatively specific areas of cognitive weakness may be expected given the study design to exclude smokers with previously identified cognitive disorders. Our results suggest that perceived cognitive difficulties may reflect mild executive and processing speed dysfunction, the cognitive skills that are most often affected early among smokers who develop obstructive lung disease. Patients with more advanced COPD have dysfunction in a broader range of cognitive domains, including memory (Crews et al., 2001; Dodd et al., 2010; Kozora et al., 2008; Stuss et al., 1997). Thus, the fact that we observed an association between perceived cognitive difficulties and objective cognitive performance in patients with mild cognitive weaknesses suggests that association would be even more pronounced if patients with more severe and broad cognitive impairments were included.

Previous research has examined the relationship between perceived and objective cognition in other populations using the CDS, including older adults (Derouesné et al., 1993), patients with neurological conditions (Buelow et al., 2014; Gass & Apple, 1997; Spitznagel & Tremont, 2005), and in other chronic medical conditions (Haley et al., 2009; Humphreys et al., 2007). The results of these studies are variable regarding the relationship between subjective and objective cognition. Many measured cognition using brief global cognitive screening measures or included only a few cognitive domains. Consistent with our results, one previous study found a relationship between the CDS and objective performance on executive functioning tasks in healthy older adults (Buelow et al., 2014). Previous research has also found a relationship between the CDS praxis subscale and objective performance on memory measures in healthy older adults (Derouesné et al., 1993) and patients with closed head injury (Gass & Apple, 1997). Our study expanded upon previous research by examining patients with COPD and by including a broad range of objective cognitive domains with multiple assessments within each domain.

While previous authors named the CDS factor they identified in their analysis as “praxis” (Derouesné et al., 1993), the items that are included may require several domains of cognition to successfully complete beyond solely motor planning and sequencing. Thus, individuals might identify problems on items included on the “praxis” subscale for reasons other than apraxia. To provide more insight, we conducted follow-up analyses on the items on the praxis scale by examining the relationship between each item and executive functioning/processing speed, memory, and language using t-tests. We found that trouble using tools was significantly associated with executive functioning/processing speed, memory, and language. Trouble using tools may require higher cognitive functioning beyond motor sequencing. For example, this item may measure the ability to complete a multiple-step task and process information quickly, which could be influenced by executive functioning or processing speed abilities that are affected in patients with COPD. Furthermore, performance on praxis tasks may be impacted by fatigue, which also occurs in former smokers and patients with COPD. Thus, it is important to assess multiple domains of cognition in former smokers and patients with COPD.

As expected, patients who endorsed more perceived cognitive difficulties showed evidence of worse performance on measures of executive functioning/processing speed and memory recall. It is notable that this association was observed among a sample of patients who had not been previously clinically identified as having cognitive problems. These findings support our hypothesis that there is an association of perceived cognitive difficulties with objective executive functioning/processing speed and memory recall. The association of perceived cognitive difficulties with worse objective performance on the language domain was not expected. It is possible that the language domain in our sample was influenced by slowed processing speed because one subtest in the language domain (i.e. Animal Naming) was a timed language task. This is supported by previous research that suggests that verbal fluency is influenced by processing speed (Bryan, Luszcz, & Crawford, 1997). However, this is speculative because the visuospatial processing domain also had a timed task (i.e., Block Design).

Another variable that is important to consider carefully in our results is sex. We found a significant effect of sex in the regression analyses. This finding reflects that in our sample, women performed better than men overall in the executive functioning/processing speed domain. Women have not consistently performed better than men on measures of executive-functioning and processing speed in previous research in patients with COPD (Villeneuve et al., 2012) or healthy elderly (Kennedy & Raz, 2009; Van Hooren et al., 2007). We cannot definitely explain the sex difference in our sample. However, a recent review suggests that sex may influence how nicotine influences neuronal and cognitive functioning (Cross, Linker, & Leslie, 2017), which is relevant because smoking is a main risk factor for COPD. Future research should explore whether sex influences executive functioning/processing speed in patients with COPD.

The frequency of asthma is higher in former smokers with COPD than those without COPD. We chose not include asthma in the regression analyses given evidence that asthma and COPD overlap in the aging population (Gibson & Simpson, 2009; Hardin et al., 2014; Papaiwannou et al., 2014; Postma & Rabe, 2015; Zeki, Schivo, Chan, Albertson, & Louie, 2011), a concept termed “asthma-COPD overlap syndrome.” Including asthma as a covariate could remove important variance associated with a COPD diagnosis and decrease the generalizability of our sample.

Overall, findings suggest that providers should understand that cognitive complaints are likely to reflect an actual reduction in cognition, but that patients may not provide accurate detail about the type of cognitive functions that are reduced. Results further suggest that evaluating multiple domains (especially executive functioning/processing speed, memory, and language) should be considered in patients with COPD and former smokers despite the possibility that patients describe cognitive complaints in either one focal area such as memory, or other domains of cognition.

This study is the first to examine perceived cognitive impairment in older adults with a history of chronic smoking, a common risk factor for cognitive decline. The older adult population is continuing to increase (Ortman, Velkoff, & Hogan, 2014), which will result in more older adults presenting with COPD and cognitive dysfunction. A strength of the study was that the cognitive battery included measures across multiple domains of objective cognition. The most frequently used screening measures in clinical settings, such as the Mini Mental State Exam, do not capture executive or processing speed dysfunction. Patients’ early perception of cognitive deficits (in the absence of overt/previously clinically identified impairment) appear to be most elevated regarding executive functioning and processing speed in this population. Measures should be used that capture perceived impairments in various domains, such as the Cognitive Difficulties Scale.

The findings have implications for how clinicians approach their assessment of patients with COPD who have not been diagnosed with a cognitive disorder, but express concerns about their cognitive functioning. It can be challenging to determine whether or not comprehensive neuropsychological assessment is warranted when a patient does not have obvious cognitive impairment. Our findings indicate that patients' report of cognitive difficulties are likely to reflect objective weaknesses on neuropsychological tests and that a referral for neuropsychological evaluation is prudent when patients express cognitive concerns.

A limitation of our study includes subject selection. There is evidence that patients with chronic medical illness who are experiencing significant psychological distress tend to perceive that they have greater cognitive dysfunction (Derouesné et al., 1999; Humphreys et al., 2007). The current study did not directly explore the relationship between perceived cognition and psychological distress. The inclusion and exclusion criteria led to a sample that had relatively mild symptoms of depression and anxiety. Future studies that include an unselected sample of former smokers, including patients with severe psychological distress, are needed to examine the potential effect of depression and anxiety on self-reported cognition. While the limited range of reported cognitive difficulties limits the conclusions that can be drawn regarding patients with severe cognitive impairment, we believe the findings are interesting because a significant relationship between perceived and objective cognition was found even in patients who do not have any previously clinically identified cognitive impairments. This suggests that perceived cognitive difficulties in response to specific questioning may have relevance even among those who would not typically rise to clinical attention. Another limitation of the study is that it is unclear if and how medications impacted cognitive performance. We did not control for multiple comparisons in our bivariate analyses. Previous research in neuropsychology has examined bivariate associations to reduce the number of regression models to be run (Seelye et al., 2015), and we believe that this is a reasonable approach as a first step in our analyses. A limitation of the study is that the bivariate analyses could inflate Type I error. Future studies using larger samples will be important to replicate. In addition, the current study was cross-sectional. Future research would benefit from a longitudinal design to evaluate if perception of cognitive abilities predicts future cognitive decline in patients with smoking-related lung disease, as shown in patients with cardiovascular disease (Haley et al., 2009).

Since there is evidence of a relationship between perceived and objective cognition, future research should consider mechanisms associated with correspondence between self-report and objective cognition, such as willingness to report cognitive difficulties, depression, anxiety, and insight. We considered depression in our study, but our sample had a restricted range of depressive symptoms. Additional clinical features of cognitive deficits (subjective and objective) in relation to neurological disease and treatment would also be of interest. For example, previous research suggests that perceived cognitive difficulties may be related to white matter hyperintensities in patients with cardiovascular disease even prior to developing clinically significant cognitive impairment (Haley et al., 2009). Continued investigations regarding white matter abnormalities in COPD and its relationship to cognitive dysfunction may be useful in both diagnostic and treatment areas.

In older adults with a history of chronic smoking, self-reported cognitive difficulties are associated with objectively measured cognitive performance. Cognitive complaints reflect underlying variability in executive functioning/processing speed even in a sample of patients without previously identified cognitive impairment. Thus, it is important to pay attention to patients' reports about their cognition even if they do not show clinically obvious evidence of cognitive impairment. These findings may help guide improved evaluation and treatment of cognitive dysfunction in this population.

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**Table 1**

*Perceived Cognitive Difficulties, Neuropsychological Performance, Demographic Information, and Clinical Characteristics.*

| | All Participants n=95 | | Former Smokers Without COPD n=36 | | Former Smokers With COPD n=59 | | Effect size (Cohen's D or phi) |
|---|---|---|---|---|---|---|---|
| **Demographic and Clinical Variables** | **Mean (SD)** | **(n) %** | **Mean (SD)** | **(n) %** | **Mean (SD)** | **(n) %** | |
| Age | 68.7 (7.0) | | 66.1 (6.6) ** | | 70.3 (6.8) ** | | 0.63 |
| Sex (n/% female) | | (40) 42.1 | | (16) 44.4 | | (24) 40.7 | 0.04 |
| Education | 14.2 (2.2) | | 14.6 (2.2) | | 13.9 (2.2) | | 0.32 |
| Estimated Premorbid IQ (WRAT-IV) | 101.0 (7.8) | | 99.4 (9.1) | | 101.9 (6.8) | | 0.31 |
| Smoking history (pack-years) | 51.3 (33.1) | | 37.4 (22.3) *** | | 59.8 (35.8) *** | | 0.75 |
| Depression and Anxiety (HADS) | 6.6 (5.0) | | 5.3 (3.8) * | | 7.4 (5.5) * | | 0.44 |
| Post-Bronchodilator Spirometry | | | | | | | |
| FEV1/FVC(%) | | | | | | | |
| FEV1 % Predicted | 61.4 (17.0) | | 78.3 (5.3) *** | | 51.1 (12.8) *** | | 2.78 |
| Asthma | 66.6 (28.2) | | 92.7 (17.8) *** | | 50.7 (20.4) *** | | 2.19 |
| Diabetes Mellitus Type 2 | | (24) 25.3 | | (4) 11.1 * | | (20) 33.9 * | 0.25 |
| Sleep Apnea | | (11) 11.6 | | (5) 13.9 | | (6) 10.2 | 0.06 |
| Hypertension | | (25) 26.3 | | (13) 36.1 | | (12) 20.3 | 0.17 |
| Hypercholesterolemia | | (4) 4.2 | | (3) 8.3 | | (1) 1.7 | 0.16 |
| | | (54) 56.8 | | (20) 55.6 | | (34) 57.6 | 0.02 |
| **Neuropsychological Test Performance** | | | | | | | |
| Memory Recall (T-score) | 49.1 (8.5) | | 51.0 (8.9) | | 47.9 (8.1) | | 0.36 |
| Executive functioning/ | 48.7 (6.5) | | 50.8 (6.4) * | | 47.4 (6.3) * | | 0.54 |
| Processing-speed (T-score) | | | | | | | |
| Language (T-score) | 52.2 (7.0) | | 53.6 (7.6) | | 51.3 (6.6) | | 0.32 |
| Visuospatial Functioning (T-score) | 52.0 (6.2) | | 51.6 (6.9) | | 52.2 (5.7) | | 0.09 |
| **Cognitive Difficulties Scale (CDS)** | | | | | | | |
| CDS Total Score | 36.5 (18.0) | | 35.9 (17.3) | | 36.9 (18.5) | | 0.06 |
| CDS Attention/Concentration | 11.6 (6.3) | | 11.4 (6.1) | | 11.7 (6.4) | | 0.05 |

| | All Participants n=95 | | Former Smokers Without COPD n=36 | | Former Smokers With COPD n=59 | | Effect size (Cohen's D or phi) |
|---|---|---|---|---|---|---|---|
| **Demographic and Clinical Variables** | **Mean (SD)** | **(n) %** | **Mean (SD)** | **(n) %** | **Mean (SD)** | **(n) %** | |
| CDS Praxis (n/% with no reported impairment)┼ | | (37) 38.9 | | (17) 47.2 | | (20) 33.9 | 0.34 |
| CDS Delayed Recall (n/% with no reported impairment)┼ | | (23) 24.2 | | (6) 16.7 | | (17) 28.8 | 0.23 |
| CDS Orientation for Persons | 5.2 (2.5) | | 4.9 (3.0) | | 5.4 (2.2) | | 0.19 |
| CDS Temporal Orientation | 2.1 (1.5) | | 2.1 (1.4) | | 2.1 (1.6) | | 0.00 |
| CDS Prospective Memory | 3.0 (1.5) | | 3.2 (1.3) | | 2.9 (1.5) | | 0.21 |
| **Medications** | | | | | | | |
| Inhaled Corticosteroid | | (42) 44.2 | | (4) 11.1*** | | (38) 64.4*** | 0.52 |
| Inhaled Short Acting Beta Agonist | | (29) 30.5 | | (3) 8.3** | | (26) 44.1** | 0.38 |
| Long Acting Beta Agonist | | (33) 34.7 | | (1) 2.8*** | | (32) 54.2*** | 0.52 |
| Statin | | (48) 50.5 | | (16) 44.4 | | (32) 54.2 | 0.10 |
| Antidepressant | | (19) 20.0 | | (7) 19.4 | | (12) 20.3 | 0.08 |
| ACE Inhibitor | | (22) 23.2 | | (6) 16.7 | | (16) 27.1 | 0.13 |
| Beta Blocker | | (18) 18.9 | | (6) 16.7 | | (12) 20.3 | 0.05 |
| Hormone-Replacement Therapy | | (11) 11.6 | | (5) 14.0 | | (6) 10.2 | 0.24 |

* p<.05,

** p<.01,

*** p<.001;

┼ CDS Praxis and Delayed Recall Scales were considered dichotomously in all analyses due to skewed distributions

*Note:* T-Scores for each cognitive domain are age-corrected average values for the tests in that domain. T-scores have a mean of 50 and a standard deviation of 10. The CDS scores have the following items and ranges: Total Score (39 items): 0–156; Attention/Concentration (11 items): 0–44; Praxis (4 items): 0–16; Delayed Recall (3 items): 0–12; Orientation for Persons (4 items): 0–16; Temporal Orientation (2 items): 0–8; CDS Prospective Memory (2 items): 0–8. Regarding effect sizes, Cohen's D was used for continuous variables and phi was used for dichotomous variables.

**Table 2**

Bivariate correlations between the continuous CDS subscales and age-adjusted cognitive domain T-scores

| CDS Scale | Executive functioning/ processing speed | Memory Recall | Language | Visuospatial Function |
|---|---|---|---|---|
| | **r (p)** | **r (p)** | **r (p)** | **r (p)** |
| **Total Score** | **−0.24 (0.020)** | −0.16 (0.126) | **−0.24 (0.022)** | 0.08 (0.434) |
| **Attention/Concentration** | **−0.23 (0.030)** | −0.17 (0.107) | **−0.27 (0.011)** | 0.06 (0.563) |
| **Orientation for Persons** | −0.10 (0.333) | −0.00 (0.970) | −0.07 (0.485) | 0.11 (0.300) |
| **Temporal Orientation** | −0.19 (0.066) | −0.12 (0.267) | −0.17 (0.103) | 0.08 (0.466) |
| **Prospective Memory** | 0.01 (0.907) | −0.13 (0.221) | 0.02 (0.831) | 0.07 (0.503) |

*Note:* The variables are bolded if they were significant (p<.05).

## Table 3

T tests between the dichotomous CDS subscales and age-adjusted cognitive domain T scores

| CDS Subscale | Executive functioning/ processing speed | | | Memory Recall | | | Language | | | Visuospatial Function | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean (SD)** | **t** | **p** | **Mean (SD)** | **t** | **p** | **Mean (SD)** | **t** | **p** | **Mean (SD)** | **t** | **p** |
| **Praxis** | | **3.57** | **0.001** | | **3.39** | **0.001** | | **3.35** | **0.001** | | −1.13 | 0.261 |
| **No Impairment** | 51.6 (6.7) | | | 52.5 (6.4) | | | 55.0 (6.1) | | | 51.2 (6.4) | | |
| **Yes Impairment** | 46.8 (5.9) | | | 46.7 (9.0) | | | 50.2 (7.0) | | | 52.7 (6.1) | | |
| **Delayed Recall** | | 1.53 | 0.130 | | 1.24 | 0.219 | | 1.27 | 0.211 | | −0.48 | 0.632 |
| **No Impairment** | 50.5 (6.7) | | | 51.0 (8.2) | | | 53.5 (4.8) | | | 51.5 (6.1) | | |
| **Yes Impairment** | 48.1 (6.4) | | | 48.5 (8.5) | | | 51.8 (7.6) | | | 52.2 (6.2) | | |

*Note:* The variables are bolded if they were significant ($p<.05$).

## Table 4

Simultaneous Multiple Linear Regression Model: Prediction of Executive Functioning/Processing Speed from CDS Total Score

Overall Model: Adjusted $R^2$=.271; F=5.935 (p<.001)

| Independent Variable | Unstandardized b | SE | Semi-partial Correlation | p |
|---|---|---|---|---|
| Age | −0.120 | 0.094 | −.113 | 0.204 |
| **Sex** | | | | |
| **Male** | **Reference** | | | |
| **Female** | **4.805** | **1.208** | **.352** | **<0.001** |
| Pack-years | 0.011 | 0.019 | .050 | 0.575 |
| **Estimated Premorbid IQ (WRAT-IV)** | **0.305** | **0.080** | **.338** | **<0.001** |
| Depression and Anxiety (HADS) | −0.129 | 0.130 | −.088 | 0.324 |
| **COPD Diagnosis** | | | | |
| **No COPD** | **Reference** | | | |
| **COPD** | **−3.337** | **1.326** | **−.223** | **0.014** |
| **CDS Total Score** | **−0.072** | **0.034** | **−.187** | **0.037** |

*Note:* The variables are bolded if they were significant (p<.05).

## Table 5

Simultaneous Multiple Linear Regression Model: Prediction of Executive Functioning/Processing Speed from CDS Praxis

Overall Model: Adjusted $R^2$=.302, F=6.447 (p<.001)

| Independent Variable | Unstandardized b | SE | Semi-partial Correlation | p |
|---|---|---|---|---|
| Age | −0.138 | 0.094 | −.130 | 0.147 |
| **Sex** | | | | |
| **Male** | **Reference** | | | |
| **Female** | **4.573** | **1.224** | **.333** | **<0.001** |
| Pack-years | 0.009 | 0.019 | .040 | 0.654 |
| **Estimated Premorbid IQ (WRAT-IV)** | **0.305** | **0.081** | **.334** | **<0.001** |
| Depression and Anxiety (HADS) | −0.148 | 0.138 | −.096 | 0.286 |
| COPD Diagnosis | | | | |
| No COPD | Reference | | | |
| COPD | −2.666 | 1.349 | −.176 | 0.051 |
| **CDS Praxis Subscale** | | | | |
| **No Impairment** | **Reference** | | | |
| **Yes Impairment** | **−3.646** | **1.253** | **−.259** | **0.005** |

*Note:* The variables are bolded if they were significant (p<.05).

## Table 6

Simultaneous Multiple Linear Regression Model: Prediction of Memory Recall from CDS Praxis

Overall Model: Adjusted $R^2$= .161, F=3.415 (p=.003)

| Independent Variable | Unstandardized b | SE | Semi-partial Correlation | p |
|---|---|---|---|---|
| Age | −0.218 | 0.132 | −.162 | 0.102 |
| Sex | | | | |
| Male | Reference | | | |
| Female | −0.031 | 1.711 | −.002 | 0.986 |
| Pack-years | 0.010 | 0.027 | .037 | 0.709 |
| **Estimated Premorbid IQ (WRAT-IV)** | **0.297** | **0.114** | **.255** | **0.011** |
| Depression and Anxiety (HADS) | −0.335 | 0.193 | −.170 | 0.085 |
| COPD Diagnosis | | | | |
| No COPD | Reference | | | |
| COPD | −1.646 | 1.885 | −.085 | 0.385 |
| **CDS Praxis** | | | | |
| **No Impairment** | **Reference** | | | |
| **Yes Impairment** | **−4.598** | **1.751** | **−.256** | **0.010** |

*Note:* The variables are bolded if they were significant (p<.05).

## Table 7

Simultaneous Multiple Linear Regression Model: Prediction of Language from CDS Praxis

Overall Model: Adjusted $R^2$= .223, F=4.614 (p<.001)

| Independent Variable | Unstandardized b | SE | Semi-partial Correlation | p |
|---|---|---|---|---|
| Age | −0.206 | 0.105 | −.185 | 0.053 |
| Sex | | | | |
| Male | Reference | | | |
| Female | −0.598 | 1.358 | −.041 | 0.661 |
| Pack-years | 0.041 | 0.021 | .180 | 0.058 |
| **Estimated Premorbid IQ (WRAT-IV)** | **0.313** | **0.090** | **.326** | **0.001** |
| Depression and Anxiety (HADS) | −0.241 | 0.153 | −.148 | 0.119 |
| COPD Diagnosis | | | | |
| No COPD | Reference | | | |
| COPD | −1.862 | 1.496 | −.117 | 0.217 |
| **CDS Praxis Subscale** | | | | |
| **No Impairment** | **Reference** | | | |
| **Yes Impairment** | **−3.890** | **1.390** | **−.263** | **0.006** |

*Note:* The variables are bolded if they were significant (p<.05)