Reduced Attention in Former Smokers with and without COPD

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Abstract

Background Attention difficulties are often reported by patients with chronic obstructive pulmonary disease (COPD); however, limited research exists using objective tests designed specifically to measure attention in this population. This study aimed to (1) identify specific attention deficits in COPD and (2) determine which demographic/clinical characteristics are associated with reduced attention.

Methods Eighty-four former smokers (53 COPD, 31 no COPD) completed questionnaires, pulmonary function testing, and the Conner's Continuous Performance Test II (CPT-II). Participants with and without COPD were compared on CPT-II measures of inattention, impulsivity, and vigilance. CPT-II measures that differed significantly between the two groups were further examined using hierarchical regression modeling. Demographic/clinical characteristics were entered into models with attention as the dependent variable.

Results Participants with COPD performed worse than those without COPD on CPT measures of inattention and impulsivity (i.e., detectability [discrimination of target from non-target stimuli], perseverations [reaction time under 100 ms], omissions [target stimuli response failures], and commissions [responses to non-target stimuli]). More severe COPD (measured by greater airflow limitation) was associated with poorer ability to detect targets vs. foils and perseverative responding after adjusting for age and other covariates in the model.

Conclusion Former smokers with COPD experience problems with attention that go beyond slowed processing speed, including aspects of inattention and impulsivity. Clinicians should be aware that greater airflow limitation and older age are associated with attention difficulties, as this may impact functioning.

Keywords Chronic obstructive pulmonary disease · Attention · Depression · Anxiety · Clinical factors

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Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by airflow limitation that is not fully reversible, as well as sustained inflammation of airways and the lung. COPD is the third leading cause of morbidity and mortality in the USA and the fourth leading cause of death globally [1, 2]. Cigarette smoking is the most common risk factor for developing COPD, though indoor and occupational pollution can also play a role [2]. Researchers have increasingly recognized the prevalence of cognitive impairment among patients with COPD with studies to date invoking hypoxemia, systemic inflammation, and comorbid cardiovascular disease as primary mechanisms. Cognitive difficulties exacerbate the financial and personal burden of COPD [1, 3, 4]. In a recent review of research on cognitive impairment in COPD, attention was cited as one of the cognitive domains most frequently impacted in COPD [5]. Decrements in attention have been linked to diminished daily functioning and quality of life in adults, with implications for occupational and social functioning [6–10]. Additionally, prior research suggests that attention deficits hinder an individual's ability to discontinue tobacco use [11, 12]. Sustained cigarette smoking increases the risk of further airway inflammation and injury in COPD, leading to a worsening of disease-related symptoms [13]. Despite a growing body of literature acknowledging the pervasiveness of attention problems in individuals with COPD, the majority of research in COPD has utilized cognitive measures that are not specific to attention, and which require multiple cognitive functions to complete successfully [14–19]. This limitation in the existing research makes it difficult to differentiate attention deficits from problems with other cognitive domains.

Only one published manuscript addressing cognition in individuals with COPD employed a test designed specifically to measure attention (i.e., the Attention Network Test; 20). The authors found that individuals with COPD performed worse on (1) phasic alertness (decreased speed and accuracy in identifying a target after exposure to an auditory alert), (2) orienting (slower reaction time when a spatial cue is displayed in a central position, versus the same location as the target), and (3) reaction time than age- and gender-matched healthy controls [20]. In addition, age and hypercapnia were associated with slower reaction times [20]. Smoking history was not accounted for in the previous study, making it unclear if the group differences observed were due to disease status rather than the effects of smoking. Furthermore, no published research to date has considered the influence of common psychological comorbidities (i.e., symptoms of depression and anxiety) on attention in individuals with COPD. Depressive and anxious symptoms have been consistently associated with reduced processing speed and attention, and therefore are important to include when examining cognitive dysfunction [21–24].

The goal of the current study was to determine the effect of COPD on attention above and beyond other factors that are likely to influence attention. This was accomplished by (1) examining components of inattention, impulsivity, and vigilance in former smokers with COPD as compared to former smokers without COPD using the Conner's Continuous Performance Test II, a commonly used attention measure, and (2) testing whether clinical and demographic factors (including age, smoking history, symptoms of anxiety and depression, and comorbid sleep apnea) and disease severity (estimated using airflow limitation) are associated with attention. We hypothesized that former smokers with COPD would perform worse on measures of inattention, impulsivity, and vigilance than former smokers without COPD. We expected that greater COPD severity (as measured by spirometry) and elevated symptoms of depression and anxiety would be associated with worse CPT-II performance after adjusting for the effects of age, smoking history, obstructive sleep apnea status, and premorbid IQ.

Materials and Methods

Participants

Participants were 84 former smokers, 53 of whom met traditional GOLD criteria for COPD based on airflow limitation measured via spirometry, and 31 that did not have significant airflow limitation [2]. Participants were recruited from the COPDGene cohort [2, 25] at National Jewish Health in Denver, CO to participate in a separate study of factors that are associated with cognitive impairment in former smokers (NIH K23 HL095658). Inclusion criteria for the current study were former smoker, minimum of an 8th grade education, fluency (at the level of a native speaker) in the English language, and normal corrected hearing and vision. Criteria for exclusion were previous diagnosis of a learning, cognitive or neurological disorder, traumatic brain injury with loss of consciousness > 10 min, current illicit drug use, major psychiatric disorder, alteration in depression or anxiety treatment within 3 months prior to enrolment, major medical condition apart from COPD or asthma, arrhythmia, left-sided heart failure, a COPD exacerbation a month before enrolment which required consultation with or treatment by a physician, or performance suggestive of poor test engagement on the CPT-II using cutoffs published in the manual [26].

Informed consent was obtained from all individual participants included in the study.

All study procedures were approved through the Institutional Review Board at National Jewish Health. Participants completed two study visits for the ancillary study that were separate from COPDGene. All measures included in the current analysis were collected during the same study visit.

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Measures

Attention Measure

The Conner's Continuous Performance Test II (CPT-II) is a commonly used assessment tool for detecting and diagnosing disorders of attention. The CPT-II is a computerized attention task that takes approximately 15 min to complete. Participants are instructed to press the space bar as quickly as possible when they see any letter other than "X" appear on the computer screen [26]. The test measures response accuracy (omissions, commissions, and detectability), response time (overall hit reaction time, reaction time by inter-stimulus interval, hit reaction time by block, and perseverations), and consistency of response time (standard error, variability of standard error, and standard error by block). The CPT-II yields 12 subscales that are organized into three domains: (1) inattention, which refers to failure to attend to or focus on a task, and is measured via slower reaction time, inconsistency in response speed across the task, and decreased accuracy; (2) impulsivity, which refers to inability to appropriately regulate one's behavior or responsiveness, and is measured by a greater number of responses to non-target stimuli and decreased reaction time; and (3) vigilance, which refers to sustained attention, and is measured by a higher degree of consistency in response time throughout the test [26]. The Conner's Continuous Performance Test-II computer software was used for scoring, which calculates T-scores based upon age-corrected normative data from a mixed clinical/non-clinical sample of 2521 individuals [26]. T-scores (mean = 50, SD = 10) for the CPT measures were re-calculated for the current analysis so that higher scores were indicative of better performance for all subscales. As recommended in the test's user manual, individuals who obtained T-scores greater than 100 (or re-calculated T-scores less than 0) on perseverations (responses occurring less than 100 ms after stimulus presentation) or omissions (failures to respond to target stimuli) were considered to have had poor test engagement and were thus excluded from further analyses [26].

Symptoms of Depression and Anxiety

Severity of depressive and anxious symptoms were evaluated using the Hospital Anxiety and Depression Scale (HADS; 27). The HADS includes 14 items, 7 of which assess depressive symptoms and 7 of which assess symptoms of anxiety [27]. This measure has been used frequently in research involving patients with COPD [28–30]. The total score can range from 0 to 42, with a higher score indicating a more symptoms of anxiety and depression.

Pulmonary Function

Pulmonary function was assessed via pre- and post- bronchodilator spirometry. The EasyOne spirometer (ndd, Medical Technologies Inc., Andover, MA) was utilized in agreement with the American Thoracic Society guidelines [31]. After baseline FVC testing, two puffs of albuterol (180 μg) were administered from a metered dose inhaler with a spacer. After 20 min, participants were prompted to perform three additional acceptable FVC maneuvers. Post bronchodilator FEV1% predicted, a continuous spirometric measure of airflow limitation, was selected as the primary variable to be entered into regression analysis. Classification of disease severity (mild to moderate airflow limitation [GOLD stages 1–2] vs. severe to very airflow limitation [GOLD stages 3–4]) was additionally calculated using two estimates of airflow limitation (FEV1/FVC ratio and post bronchodilator FEV1% predicted) as described in the Global Initiative for Chronic Obstructive Lung Disease (GOLD) statement of strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease and was used in supplemental exploratory analyses [31]. For three participants, past spirometry results were used due to the suboptimal quality of their present pulmonary function outcomes.

Demographic Characteristics

Participants completed self-report forms inquiring about gender, age, years of education, and smoking history (amount and number of years smoked and years since smoking cessation) and whether or not they had a diagnosis of obstructive sleep apnea. Additionally, the WRAT 4 Word Reading subtest was administered in order to obtain an estimate of premorbid IQ.

Statistical Analysis

Former smokers with and without GOLD-defined COPD were compared on each of the 11 subscales of the CPT-II, using t tests for subscales that were normally distributed and Mann-Whitney U tests for subscales that were not normally distributed, as determined via the Shapiro-Wilk test. Several CPT-II subscale measures (i.e., perseverations, omissions, and commissions) typically yield non-normal distributions, as most individuals make few, if any, of these types of errors [26]. CPT-II subscales that differed significantly between participants with and without COPD were examined further via hierarchical multiple linear regression models for subscales that were normally distributed and hierarchical logistic regression models for subscales that were not normally distributed. An alpha level of 0.05 was selected across analyses, reducing type II error, while accepting some elevation in type I error. This approach maximizes the number of variables chosen to be examined further via regression. In the logistic regression

models, the T-scores of non-normally distributed variables were dichotomized by assigning a value of 1 to scores that fell above 40 and 0 to scores that were 40 or less (at least one standard deviation below the mean, indicating clinically meaningful impairment). The goals of the regression models were to identify demographic and clinical characteristics that are associated with decreased attention and also to determine the effect of COPD, as assessed using a spirometry measure of airflow limitation (post bronchodilator FEV1% predicted), above and beyond the demographic and clinical characteristics that were included in these models. All models included the following predictors: age, pack-years, sleep apnea status, estimated premorbid intellectual functioning, depressive/anxious symptoms, and post bronchodilator FEV1% predicted. In the first step of the regression, post bronchodilator FEV1% predicted was entered as the sole the predictor, with this variable, along with the remaining predictors, entered in the second step. This approach was employed to examine the extent to which the shared variance between FEV1% predicted and covariates might explain the relationship with attention function. Statistical analyses were two-tailed. Data analysis was conducted with Statistical Product and Service Solutions software (SPSS) Version 23, with a two-sided significance level of 0.05.

Results

Demographic Characteristics of Participants

Participants with COPD did not differ significantly from individuals without COPD in estimated premorbid IQ (WRAT 4 Word Reading standard score; 101.7 ± 5.4 vs. 99.9 ± 9.3; t $(82) = -1.05$, $p = .30$). Participants with COPD had a more extensive smoking history (61.2 ± 36.4 vs. 37.7 ± 22.3 pack years; $t (82) = -3.66$, $p < .001$), more recent smoking history (14.0 ± 10.9 vs. 22.9 ± 13.7 years since smoking cessation; t $(82) = 3.30$, $p < .01$), and higher mean age (70.3 ± 6.5 vs. 66.1 ± 6.6; $t (82) = -2.81$, $p < .01$) than former smokers without COPD. Individuals with COPD also reported more depressive and anxious symptoms, as measured via the HADS (7.3 ± 5.4 vs. 5.0 ± 3.4; $t (82) = -2.42$, $p < .05$). See Table 1 for further information regarding the demographic and clinical characteristics of the sample.

Aim 1: Attention in Former Smokers with Versus Without COPD

Bivariate analyses were used in aim 1 to identify specific attention deficits in COPD. Because the Shapiro-Wilk tests for normality of CPT measures revealed that errors of omission, errors of commission, hit reaction time standard error variability, perseverations, and hit reaction time block change

were not normally distributed Mann-Whitney U tests were conducted to compare performance between groups on these attention measures. As shown in Table 2, former smokers with COPD performed significantly worse than those without COPD on detectability ($t (82) = 2.51$, $p < .05$). Participants with COPD also made significantly more perseverative errors (response reaction time less than 100 ms; $U = 521$, $p < .01$), errors of commission (responses to non-target stimuli; $U = 577$, $p < .05$), and errors of omission (failures to respond to target stimuli; $U = 565.5$, $p < .05$) than those without COPD.

Aim 2: Demographic and Clinical Characteristics Associated with Attention

Four regression models were generated based on the CPT-II measures that differed significantly between participant groups (i.e., detectability, perseverations, errors of omission, and errors of commission). Two of the four regression models (i.e., detectability and perseverations) had an overall level of statistical significance that was < 0.05 when entered alongside covariates.

For detectability, the hierarchical regression model was statistically significant at stage 1 ($F (1, 82) = 11.29$, $p < 01$) and did not account for a significantly greater proportion of the variance at stage 2 ($F (5, 77) = 1.61$, $p = .17$). Detectability measures the ability to identify target stimuli and ignore non-target stimuli. Decreased FEV1% predicted (indicating greater COPD severity) was associated with poorer performance on detectability after adjusting for the other covariates in the model ($b = .09$, $p < .05$). As shown in Table 3, lower FEV1% predicted continued to be significantly associated with worse performance on detectability after controlling for age, smoking history, obstructive sleep apnea status, estimated premorbid IQ, as well as depressive and anxious symptoms.

For perseverations, a hierarchical logistic regression was used due to the non-normal distribution of data for that variable. T-scores 40 or less (at least one standard deviation below the mean) were coded as 0, and T-scores over 40 were coded as 1 (within one standard deviation below the mean and above) in order to dichotomize perseverations. The overall hierarchical regression demonstrated a statistically significant R^2 change at stage 2 ($Chi-square$ [5] $= 13.83$, $p < .05$). Increased FEV1% predicted (less disease severity) was associated with increased odds of performing within the average range (T-score > 40) on the perseveration subscale by 3% ($OR = 1.03$, $p < .05$) after adjusting for the other covariates in the model. Additionally, older age was also associated with decreased odds of average performance on perseverations ($OR = .87$, $p < .05$) after adjusting for the other covariates in the model. This indicates that greater COPD severity and age are related to the propensity to respond before a target stimulus is presented. As shown in Table 4, disease severity was significantly associated with performance on perseverations after

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Table 1 Demographic and clinical characteristics of the sample

Demographics	No COPD ($n = 31$)		COPD ($n = 53$)		Test statistic t or X^2 (p value)
	Mean (SD)	N (%)	Mean (SD)	N (%)	
Age (years)	66.1 (6.6)		70.3 (6.5)		$t = -2.81$ (0.007)
Sex (female)		14 (45.2)		22 (41.5)	$X^2 = 0.11$ (0.744)
Years of education	14.5 (2.2)		13.8 (2.2)		$t = 1.34$ (0.183)
Estimated premorbid IQ (WRAT 4 Standard Score)[a]	99.9 (9.3)		101.7 (5.4)		$t = -1.05$ (0.297)
MMSE II Raw Score	28.5 (1.6)		27.8 (1.5)		$t = 1.98$ (0.051)
MMSE II Raw Score $\leq$ 23		1 (3.2)		1 (1.9)	
Smoking history (pack-years)	37.7 (22.3)		61.2 (36.4)		$t = -3.66$ (<.001)
Years since smoking cessation	22.9 (13.7)		14.0 (10.9)		$t = 3.30$ (0.001)
Obstructive sleep apnea (yes)		12 (38.7)		12 (22.6)	$X^2 = 2.47$ (0.116)
Depression and anxiety (**HADS score**)[b]	5.0 (3.4)		7.3 (5.4)		$t = -2.42$ (0.018)
Post-bronchodilator spirometry					
FEV1/FVC (%)[c]	77.9 (5.4)		51.3 (13.0)		$t = 13.13$ (<.001)
FEV1% predicted[d]	91.8 (18.1)		51.0 (19.3)		$t = 9.55$ (<.001)
Severity of airflow limitation					
No COPD (GOLD 0)[e]	–		–		
Mild to moderate COPD (GOLD 1–2)	–		29 (54.7)		
Severe to very severe COPD (GOLD 3–4)	–		24 (45.3)		

[a] WRAT-4: Wide Range Achievement Test–Fourth Edition

[b] HADS: Hospital Anxiety and Depression Scale

[c] FEV1/FVC: forced expiratory volume in 1 s (FEV1) over forced vital capacity (FVC)

[d] FEV1% predicted: forced expiratory volume in 1 s divided by the predicted value times 100

[e] GOLD: Global Initiative for Chronic Obstructive Lung Disease

controlling for age, smoking history, obstructive sleep apnea status, estimated premorbid IQ, as well as depressive and anxious symptoms.

Discussion

Overall, the results of the current analysis suggest that former smokers with COPD have greater difficulties with inattention and impulsivity than former smokers without COPD and that greater airflow limitation may contribute to these issues. Participants with COPD did not have significant difficulties in the domain of vigilance (i.e., ability to maintain responding over time), but tended to have more inconsistent reaction times than participants without COPD. Additional research is needed to determine the extent to which these attention problems impair daily functioning and influence quality of life.

The present study examined whether former smokers with COPD differ from former smokers without COPD on specific aspects of attention. Indeed, individuals with COPD performed worse than comparison participants on detectability, perseverations, commissions, and omissions on the CPT-II, a more targeted measure of attention than has been used in the

past literature. Greater disease severity (as assessed via airflow limitation) was associated with poorer performance on both detectability and perseverations after adjusting for key demographic and clinical covariates known to have implications for attention including age, estimated premorbid intellectual functioning, and obstructive sleep apnea [32, 33]. Further, airflow limitation was the strongest predictor of detectability, uniquely explaining 12% of the variance in performance on this measure. Also, addition of the aforementioned covariates as a second step in a hierarchical regression model failed to significantly improve upon the first model, in which airflow limitation was the sole independent predictor. In addition to worse airflow limitation, older age was also associated with poorer performance on perseverations independent of other covariates, which may be expected given the well-documented relationship between age and impulsivity [34].

Several weaknesses should also be acknowledged. We failed to observe an association between more severe depressive and anxious symptoms and poorer attention. The overall symptoms of depression and anxiety were low in the sample, as measured by the HADS, which hinders the ability to understand the role of depression and anxiety in decreased attention performance in COPD. Secondly, sample size was also a limitation and likely resulted in reduced power to detect

Table 2 Conner's Continuous Performance Test-II Performance by participant group

CPT domain	No COPD (n = 31) Mean (SD)	COPD (n = 53) Mean (SD)	Test statistic t or U (p value)
Inattention			
Omissions	*52.8 (8.4)*	*46.7 (13.8)*	*U = 565.50 (0.017)*
Commissions	*55.5 (6.1)*	*51.4 (8.6)*	*U = 577.00 (0.023)*
Hit RT[a]	46.4 (10.5)	49.2 (15.4)	t = − 0.91 (0.368)
Hit RT Std. error	45.1 (8.3)	43.5 (9.5)	U = 722.00 (0.356)
Variability	50.7 (10.3)	46.5 (9.7)	t = 1.85 (0.068)
Detectability	*55.8 (8.0)*	*51.0 (8.8)*	t = 2.51 (0.014)
Hit RT ISI change[b]	45.1 (11.3)	48.3 (11.4)	t = − 1.25 (0.214)
Hit RT SE ISI change[c]	43.9 (14.4)	47.3 (12.1)	t = − 1.16 (0.250)
Impulsivity			
Commissions	*55.5 (6.1)*	*51.4 (10.6)*	*U = 577.00 (0.023)*
Hit RT[a]	46.4 (10.5)	49.2 (15.4)	t = − 1.00 (0.368)
Perseverations	*52.3 (12.1)*	*45.8 (14.8)*	*U = 521.00 (0.004)*
Vigilance			
Hit RT block change[d]	52.6 (9.8)	51.2 (10.6)	U = 688.00 (0.216)
Hit SE block change[e]	47.7 (8.0)	46.5 (8.0)	t = 0.70 (0.487)

Italicized values indicate significantly different mean values for former smokers with and without COPD, as determined via *t* test or Mann-Whitney *U* test, with greater values indicating better performance

[a] Hit reaction time

[b] Hit reaction time inter stimulus interval change

[c] Hit reaction time standard error inter stimulus interval change

[d] Hit reaction time block change

[e] Hit standard error block change

effects when conducting certain statistical tests (i.e., regression). In future research with larger sample sizes, it may be interesting to include interaction testing in addition to examining regression models. Further, we did not examine all possible demographic and clinical characteristics that may influence attention. For example, there may be additional comorbid medical conditions that affect attention. We also acknowledge that use of the MMSE II, which produces a restricted range of scores, is likely inadequate for us to dismiss a potential association between general cognition and attention in our

sample. Additionally, this study did not gather data on day-to-day functional implications of attention deficits in individuals with COPD. Future researchers may choose to include self-report questions to better understand practical implications of reduced attention. Finally, airflow limitation is likely not the only aspect of COPD that influences attention in individuals with COPD. A more comprehensive study of physiological mechanisms involved in COPD, in relation to attention functions, would help elucidate why these decrements are observed in this population.

Table 3 Hierarchical linear regression for detectability

Predictor variable	Step 1				Step 2			
	Unstandardized b	β	SE	p	Unstandardized b	B	SE	p
FEV1% predicted	*0.11*	*0.35*	*0.03*	*0.001*	*0.09*	*0.27*	*0.04*	*0.015*
Age	–	–	–	–	− 0.19	− 0.14	0.15	0.222
Pack-years	–	–	–	–	− 0.04	− 0.14	0.03	0.201
Sleep apnea status	–	–	–	–	− 0.98	− 0.05	2.10	0.641
WRAT 4	–	–	–	–	0.22	0.19	0.13	0.099
HADS	–	–	–	–	− 0.34	− 0.19	0.20	0.095
R²	*0.12*			*0.001*	0.20			0.167
R² change					0.08			0.167

Table 4 Hierarchical logistic regression for perseverations

Predictor variable	Step 1				Step 2			
	β	Odds ratio	SE	p	β	Odds ratio	SE	p
FEV1% predicted	0.02	1.02	0.01	0.075	0.02	1.03	0.01	0.045
Age	–		–	–	− 0.14	.87	0.06	0.016
Pack-years	–		–	–	< 0.01	1.00	0.01	0.725
Sleep apnea status	–		–	–	− 1.10	.33	0.80	0.169
WRAT 4	–		–	–	− 0.04	.96	0.05	0.417
HADS	–		–	–	0.10	1.11	0.08	0.213
Nagelkerke R^2	0.06				0.29			
R^2 change					0.23			

Though the presence of attention deficits in COPD is widely recognized in the literature, few studies have employed attention-specific measures in research with this group. The primary strength of the current study is the use of an attention-specific assessment, which has been repeatedly employed in the detection of ADHD and other disorders of attention but not previously in COPD. Interestingly, asthma and respiratory symptoms in children and adolescents have been linked to greater risk of having attention deficit hyperactivity disorder (ADHD) in several published studies [35–39]. Although research on specific attention decrements in adult populations with respiratory illness is extremely limited, it is reasonable to suspect similar types of attention impairment to manifest due to the brain changes associated with COPD-related pathophysiology including hypoxemia and cardiovascular disease [40]. Attention problems in adults in general are associated with reduced quality of life and functional impairments, which can manifest as an increased incidence of traffic accidents and greater occupational and relationship difficulties [6–10, 41]. There is also evidence demonstrating that individuals with attention deficits tend to have greater difficulty maintaining smoking cessation [11, 12]. Smoking cessation has important implications for the outlook of COPD, as continued cigarette smoking increases the risk of inflammation and disease-related symptoms [13]. Thus, it is important to establish a better understanding of the types of attention problems associated with COPD and the extent to which they impact the daily functioning of these individuals, already burdened with managing a chronic illness.

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