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Prospective Memory in People With Chronic Respiratory Diseases

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Abstract

Goal: The efficiency of the respiratory system determines patients' good physical condition and proper functioning of the brain. The failure of this system is associated with the processes of physiological aging or diseases such as chronic obstructive pulmonary disease (COPD). Reducing the transport of oxygen to the brain directly impairs mental performance. Prospective memory (PM) is a set of processes or abilities that enable the formulation, storage and implementation of goals and intentions in the future. It's assumed that the type of disease and the degree of respiratory failure affect mental functions. Therefore the main aim of the study was to determine the general characteristics of PM functioning in people with selected respiratory diseases.

Method: The study involved 116 adults (mean age = 52.4 years; SD = 6.41) diagnosed with asthma (N = 30), COPD (N = 32), controls with allergic rhinitis (N = 27) and healthy controls (N = 27). There were no statistically significant differences in education and age between the groups. The following methods were used: Prospective-Retrospective Memory Questionnaire, Rey-Osterrieth Complex Figure Test, WAIS-R Digit Span, Trail Making Test, Beck Depression Inventory and a clinical task based on The Cambridge Prospective Memory Test (CAMPROMPT).

Results: People with COPD, compared to control groups and patients with asthma, scored lower on tests assessing cognitive functioning, including prospective memory (PM). Respiratory efficiency has been identified as the strongest predictor of PM dysfunction in patients with COPD and asthma.

Conclusion: Respiratory failure poses a risk of serious cognitive disorders associated with respiratory indicators. Patients diagnosed with asthma or COPD are required to actively engage in therapy, including anticipating situations that may lead to exacerbations.

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However, the results suggest that individuals with COPD may struggle to meet the therapeutic demands placed upon them.

Keywords: prospective memory, respiratory failure, COPD, asthma

Prospective memory (PM), or "memory of the future" (Graf & Grondin, 2006), is a specialized type of information processing and refers to the functional, i.e. strategic and organizing aspects of memory (Jodzio, 2008). PM involves not only recalling selected information from the past, but also using it when carrying out a planned activity (Kliegel et al., 2008). When setting goals for future activity and, consequently, realizing intentions and desires, a person uses this type of memory in a controlled and complex way.

Broadly speaking, prospective memory means a set of processes or abilities enabling the formulation of goals and intentions, storing them and implementing them when appropriate conditions occur (a specific time or situation) (Graf & Grondin, 2006; Niedźwieńska, 2008). However, the other definition suggests that PM deals with "storing and sharing the action plan in its permanent form" (Jodzio, 2008, p. 108). In this case PM is simply reminding oneself of the need to perform the intended action at a specific moment in the future (Ellis & Freeman, 2008; Niedźwieńska, 2008).

The mnestic process of PM consists of four phases: 1) creation, 2) storage, 3) initiation, and 4) implementation of the intention. This process begins at the moment of formulating the intention and requires understanding, predicting, and interpreting the future situation to implement the planned action. Phases 1, 3, and 4 are controlled by executive functions (EF), with phases 3 and 4 comprising the prospective component and additionally requiring self-regulation skills (the action must start at the right moment) and cognitive flexibility (e.g., skills for correcting the plan on an ongoing basis) (Witkowska, 2010). Moreover, PM is closely related to working memory, which controls the current processing of information (phases 1 and 4), and long-term memory (LTM), which allows remembering what action was to be taken (phase 2) (Kliegel et al., 2008).

PM is influenced by experience, cognitive processing abilities, and specific situations in which individuals find themselves. Definitions of PM highlight the role of a conscious attitude towards future actions that are to occur at a specific moment or after a specific period (time-based prospective memory) or as a result of a specific event or situation (event-based prospective memory). Tasks with a time context lack external cues signaling the need to recall the intention, thus requiring mental exertion and ongoing control of the passage of time. Conversely, prospective tasks with an event context include an external cue signaling the moment to start implementing the intention (Ellis & Freeman, 2008).

Ellis and Freeman (2008) emphasize the specificity of the techniques individuals use to achieve goals. These techniques constitute a set of essential processes that enable one to lead an independent and fulfilled life. Most PM-related activities manifest in everyday life and directly affect interpersonal relationships and an individual's quality of life (Henry et al., 2007; Kliegel et al., 2006;

Philips et al., 2008; Wilson & Park, 2008). For this reason, PM has high application value and is difficult to discuss in isolation from the context of everyday life. Moreover, the proper functioning of PM results from the integrated cooperation of many brain structures that also regulate processes related to executive functions and other types of memory. The prefrontal cortex (Brodmann's area 10) plays an important role here (Burgess et al., 2008), along with other structures such as the temporal lobes and the posterior part of the parietal cortex (Simons et al., 2006). The ability to use PM is particularly important in difficult situations, such as those caused by chronic disease. Knowledge about the connections between prospective memory and other cognitive functions facilitates the assessment of its dysfunction.

Medical statistics show a rapid increase in the incidence of chronic diseases across all age groups. According to the World Health Organization (WHO, 2020), chronic diseases cause approximately 44–55% of deaths worldwide, with about 15% attributed to pneumological disorders (including COPD). According to the same reports, approximately 100,000 people die each year due to COPD, affecting 3 million patients, making it the third most common cause of death globally. The incidence increases with age – according to the latest update of the Global Initiative for Chronic Obstructive Lung Disease (GOLD[2]) report (Agustí et al., 2023; Mejza, 2023), among people over 40 years of age, the incidence of the disease is approximately 10%. The occurrence of COPD results from complex interactions between environmental factors (active or passive smoking, pollution at work or environmental pollution) and the genome. COPD is diagnosed in approximately 50% of smokers (70% in wealthy countries), while another 50% of cases are caused by other risk factors, particularly air pollution (Agustí et al., 2023; Sin et al., 2023). In the case of smoking, the duration of addiction and the number and quality of cigarettes smoked are important factors (Zielonka, 2005). In Poland, approximately 2 million people suffer from COPD, and 1.5 million adults suffer from bronchial asthma, with 400,000 suffering from advanced forms of these diseases and 75,000 patients (Jassem et al., 2012; Kałucka, 2020). COPD is defined as a heterogeneous and systemic disease with many chronic abnormalities of the respiratory tract (bronchitis and bronchiolitis) or pulmonary alveoli (emphysema) and comorbidities (including pulmonary hypertension and cor pulmonale). It is characterized by irreversible, usually progressive limitation of airflow through the lower respiratory tract (Agustí et al., 2023). Another chronic inflammatory disease of the respiratory tract is bronchial asthma, caused by bronchial hyperresponsiveness. This inflammation results in symptoms of diffuse airway narrowing that are spontaneously reversible or respond well to drugs, accompanied by excessive contractile response of bronchial smooth muscles to various stimuli (Chazan, 2005). One of the basic tests

[2] The 2021 GOLD report focused on the impact of the COVID-19 pandemic on individuals with COPD (Halpin et al., 2021). Initially, it was assumed that these patients would experience increased mortality, a higher risk of hospitalization, and a more severe course of COVID-19 (cf. Alqahtani et al., 2020). However, interestingly, meta-analyses have shown that the incidence of COPD exacerbations decreased by up to 50% during the COVID-19 pandemic (Alqahtani et al., 2021).

used in the diagnosis of pneumological disorders is spirometry, a functional test of the respiratory system. It is used to determine lung vital capacity (VC), FEV_1[3] and the ratio of FEV_1 to forced vital capacity FVC[4] (FEV_1/FVC). The latter, also called the Tiffeau index, is a basic measure of respiratory efficiency.

Respiratory failure, along with inflammatory and vascular processes, results in brain atrophy (Przybylski, 1976), affecting various areas of the CNS involved in cognitive functioning, including prospective memory. Some studies have not shown structural changes in the brains of individuals with stable COPD compared to control groups. However, in clinical patients, numerous ischemic changes in the white matter have been observed (Spilling et al., 2017). Additionally, it has been shown that in COPD patients, the impairment of brain structures – both gray and white matter – is progressive and associated with the progression of pulmonary dysfunction (Yin et al., 2019). MRI results of the CNS in patients with the initial, mild form of the disease do not differ from those without COPD (Yin et al., 2019). In contrast, extensive lesions involving the frontal lobes, hippocampus, corpus callosum, and changes in the white matter are observed in patients with moderate and severe COPD (cf. Wang et al., 2023; Yin et al., 2019).

Regarding cognitive deficits, it is assumed that complex, and less frequently simple, cognitive activities are impaired (Biechowska et al., 2009). The consequences of CNS hypoxia include reduced verbal fluency and verbal memory, generalized attention deficits, increased reaction time, and slower information processing speed (Corsonello et al., 2007; Rzadkiewicz, 2008). These disorders worsen with the progression of lung disease (Zielazny, 2016). However, hypoxia is not the sole cause of potential cognitive dysfunction. Wolska-Bułach et al. (2022) emphasize that cognitive disorders are a consequence not only of disturbed oxygen or hormonal metabolism but also of vitamin deficiencies. This may result from patients' non-compliance with therapeutic recommendations (Yohannes, 2008) or non-participation in rehabilitation programs (Ranzini et al., 2020). Disturbances in the body's homeostasis exacerbate the disease, consequently increasing cognitive disorders. Psychosocial factors, such as lack of social support and depressive and anxiety disorders, also play a significant role (Ranzini et al., 2020).

Much of the existing research concerns the emotional functioning of patients (cf. Corsonello et al., 2007). Rymaszewska and Dudek (2009) state that mental disorders in these patients primarily manifest as neurotic symptoms of an anxiety-depressive nature. Bronchial asthma, classified as a psychosomatic disease, is associated with a significant risk of anxiety disorders, depression, and panic attacks (e.g., Gao et al., 2015). However, most reports regarding the mental condition of COPD patients indicate the co-occurrence of depressive disorders (10–50% of cases) and anxiety disorders (Jaracz, 2007; Ranzini et al., 2020). The disease also negatively affects the quality of life, which in turn reduces the patient's

[3] FEV_1 (forced expiratory volume in one second) is the volume of air expelled from the lungs during the first second of maximum forced exhalation, as determined during spirometry.

[4] FVC (forced vital capacity) is the largest volume of air expelled with maximum exhalation effort after the largest possible inhalation.

sense of self-worth and self-efficacy (Yohannes et al., 2008, 2017). Even a mild form of COPD can cause cognitive deficits, such as slowed information processing (Ozge et al., 2006; Yohannes et al., 2017), executive function disorders, attention deficits, and short- and long-term memory problems (Crews et al., 2001), including visuospatial and verbal memory (Borak et al., 1996; Greenlund et al., 2016; Watanabe et al., 2001). Memory efficiency is closely related to respiratory parameters. Moreover, patients in the terminal stage of COPD struggle with tasks assessing executive functions and make more mistakes and perseverations than healthy individuals (Crews et al., 2001). Despite international guidelines recommending the identification of comorbid problems in COPD, the diagnosis of cognitive function is not yet part of routine assessment (Ranzini et al., 2020; Siraj, 2023). Unidentified cognitive deficits in COPD patients can significantly impact clinical management, limiting functional independence, increasing dropout rates from pulmonary rehabilitation programs, and even increasing mortality and disability (Brunette et al., 2021; Siraj, 2023). When assessing the psychological functioning of people with COPD, factors such as age, degree of respiratory failure, smoking rates, and comorbidities should be considered.

In the study, I assumed a mutual relationship between the respiratory system and the central nervous system (Biechowska et al., 2009) and, following Ellis and Freeman (2008), considered the metamemory nature of PM, given its complexity and interaction with other cognitive processes. The aims of our research were: (a) to compare the cognitive functioning, especially PM, of people with COPD and bronchial asthma; (b) to describe the specific functioning of individuals from particular groups in the field of prospective memory; and (c) to estimate the factors determining the functioning of prospective memory in the examined individuals.

Method

Research Procedure

The research was conducted in allergy and pneumonology clinics in the Pomeranian Voivodeship before the COVID-19 pandemic. Prior to commencing the study, consent was obtained from the Ethics Committee for Research Projects. Participants provided written consent for the psychological examination. Spirometry tests were performed on the day of the test measurement. The average duration of each examination was 70–90 minutes.

Subjects

A total of 164 individual tests were performed, but 116 participants, assigned to four groups, were ultimately included in the analyses. Two clinical groups consisted of patients with COPD (Exp1 = 32) and those diagnosed with bronchial asthma (Exp2 = 30). The control groups comprised patients with allergic rhinitis (Ko1 = 27) and healthy individuals (Ko2 = 27). Patients were selected based on information from medical records and spirometry results. Only right-handed individuals were included in the study. None of the participants were receiving psychiatric, oncological, or neurological treatment.

Table 1

Selected Demographic Parameters Characterizing the Respondents

Group Variable	**Exp1** ***n* = 32** ***M* (*SD*)**	**Exp2** ***n* = 30** ***M* (*SD*)**	**Ko1** ***n* = 27** ***M* (*SD*)**	**Ko2** ***n* = 27** ***M* (*SD*)**
Disease duration (years)	8.19 (6.32)	13.47 (5.57)	8.67 (5.47)	–
Age (years)	53.16 (5.55)	51.03 (6.59)	51.85 (7.65)	53.56 (5.76)
Education (years of study)	9.94 (2.99)	11.6 (2.71)	11.52 (3.30)	11.41 (3.00)
Woman/man (number)	8/24	9/21	9/18	10/17
NRS	5.56 (2.14)	1.03 (1.06)	–	–

NRS (Numerical Rating Scale) – a scale for assessing the severity of shortness of breath

The Exp1 group consisted of 32 patients with severe COPD (mean FEV_1/FVC = 35.81%, *SD* = 7.72) (cf. Kałucka, 2020). This disease rarely manifests in an isolated form; therefore, the co-occurring conditions in the study group are listed below (number of patients in brackets): peptic ulcer disease (6), renal dysfunction (3), kidney stones (3), atherosclerosis of blood vessels (3), endocarditis (2), atrial fibrillation (2), low blood pressure (2), varicose veins (4), type 2 diabetes (3), cholecystitis and appendicitis (3 each), and prostatic hypertrophy (4). Additionally, 14 patients reported incidents of loss of consciousness, possibly due to shortness of breath or hypoxia.

The Exp2 group consisted of 30 patients with atopic bronchial asthma. At the time of examination, patients exhibited symptoms of impaired upper respiratory tract function. Patients with overlapping syndrome of bronchial asthma and COPD were excluded from the study.

The Ko1 group included 27 patients with year-round symptoms of moderate allergic rhinitis. At the time of examination, these patients exhibited symptoms that impaired the function of their upper respiratory tract. Patients with a history of bronchial asthma or other somatic diseases were excluded from the study.

The Ko2 group consisted of 27 individuals who periodically consulted allergy clinics only for sporadic allergic reactions that did not impair the function of the upper respiratory tract. Individuals with a history of allergic rhinitis, bronchial asthma, or other somatic diseases were excluded from the study.

The average age of the respondents was 52 years and 4 months (*SD* = 6.41), and the average number of years of education was 11.08 (*SD* = 3.05). There were no statistically significant differences between groups in terms of years of education ($F_{(3,112)} = 2.15$, $p = .1$) and age ($F_{(3,112)} = 0.96$, $p = .41$). Descriptive statistics for each group are presented in Table 1 (p. 162). The predominance of men reflects the distribution of COPD patients in the general population. Differences in gender distribution among the studied groups were statistically insignificant ($\chi^2(3,n = 116) = 1.08$, $p = .78$).

Measuring Tools

To verify the identified variables, a set of psychological tests was selected. The main examination was preceded by an analysis of the medical history and a subjective interview, during which basic demographic data were collected (age, number of years of education, cigarette smoking data[5]) and a subjective assessment of shortness of breath using the Numerical Rating Scale (NRS[6]) (Jassem et al., 2012). The methods were administered in a fixed order: Rey-Osterrieth Complex Figure Test (CFT) – copy (Strupczewska, 1990), WAIS-R Digit Span (Brzeziński et al., 2011), CFT – reproduction from memory (Strupczewska, 1990), Trail Making Test (TMT) from the Halstead-Reitan Test Battery (Kądzielawa, 1990), and the Beck Depression Inventory (BDI) (Czapiński, 1992; Parnowski & Jernajczyk, 1977) to subjectively assess the severity of depressive symptoms. Finally, to assess prospective memory, two methods were used that did not have Polish standardization at the time of the study: the Prospective-Retrospective Memory Questionnaire (PRMQ) (Smith et al., 2000) and an experimental-clinical task[7] modeled on The Cambridge Prospective Memory Test (CAMPROMPT) (Wilson et al., 2005).

The PRMQ (Smith et al., 2000) is a self-report measure used to subjectively assess the functioning of both prospective and retrospective aspects of PM. The test consists of 16 questions about minor memory errors that occur in everyday life situations. Respondents indicate how often such mistakes happen on a 5-point Likert scale. Higher scores indicate lower self-assessment of prospective memory, with a minimum score of 16 and a maximum of 80.

The adaptation of the questionnaire was carried out in several stages, using various methods to ensure a reliable, culturally adequate questionnaire that

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[5] Based on the data collected during the interview, the “pack years of smoking” index was calculated by multiplying the number of packs of cigarettes smoked per day by the number of years of smoking. This conventional method is used in medicine to assess the risk of developing diseases related to tobacco smoke.

[6] The NRS (Numerical Rating Scale) is an 11-point scale commonly used by healthcare workers to measure the severity of shortness of breath, ranging from 0 to 10 (Jassem et al., 2012).

[7] This study follows the clinical-experimental approach of Kurt Goldstein (cf. Jodzio, 2011).

examines the same properties as the original tool (Brzeziński, 2000; Drwal, 1995). The following elements were considered to guarantee the equivalence of the questionnaires (see Drwal, 1995, p. 20): translation fidelity, psychometric, and functional equivalence.

CAMPROMPT (Wilson et al., 2005) is a standardized method for examining both types of prospective memory, combining ecological and laboratory approaches. During the 25-minute task, the subject solves various puzzles while remembering to perform several other tasks. The puzzles serve as distractors from the actual memory test, which checks whether the subject completes six tasks at the right time or in response to an event specified in the instructions. The subject's behavior is assessed using a 6-factor scale, with a maximum score of 36 points (18 in the time cue subtest and 18 in the event cue subtest). If there is no response or an incorrect task is performed, verbal instructions are provided.

For this study, the CAMPROMPT questionnaire was translated, and an experimental and clinical task was constructed based on it, closely resembling the original task. A set of puzzles of varying difficulty was selected. Subjects performed six tasks, including three with a time context (e.g., "Change the puzzle in 2 minutes," "Remind me to call the office at 2 p.m.") and three with an event context (e.g., "When you get to question 5, give me the envelope"). They could receive up to 6 points for correctly completing each task.

Non-verbal immediate memory, long-term memory, and eye-hand coordination were tested using the Rey-Osterrieth Complex Figure Test (Strupczewska, 1990) (copy and reproduction from memory after a delay). The test material is a figure with a complex form and structure, where the presence and arrangement of individual elements are justified. Each of the 18 elements can be reproduced in isolation, but assembling these parts into a coherent whole is challenging. Correctly drawing the figure requires analytical and organized action. The placement of individual elements in relation to the entire pattern and the accuracy of the drawing are assessed. Each attempt is scored from 0 to 36 points, with higher scores indicating more accurate drawings. This method is often used for scientific research purposes (Lezak et al., 2004, p. 537).

Digit Span is a subtest the Wechsler Intelligence Scale for Adults, consisting of two trials: the examinee repeats increasingly longer sequences of digits – directly in the first trial and backward in the second. This method assesses short-term memory and simple attention, with the backward task also involving executive functions. For each correctly repeated set of numbers, the examinee receives one point. The task is stopped after two incorrectly repeated digit sequences of the same length (Brzeziński et al., 2011).

The Trail Making Test (Kądzielawa, 1990) was also used, assessing the ability to maintain the mental set to perform a selected action and executive control, including inhibitory control. The solution requires constant concentration and cognitive flexibility, including the ability to switch attention smoothly between various aspects of the task.

The test consists of two separately assessed parts – A and B. In both parts, there are 25 circles on white sheets of paper. In part A, the circles are numbered from 1 to 25, while in part B, they are marked with numbers from 1 to 13 and letters from A to L. The subject's task is to connect the circles with a pencil as quickly as possible, without lifting the pencil from the paper. In part A, the circles are connected in numerical order, while in part B, the circles are connected alternately between numbers and letters in ascending order to create a sequence: 1 – A – 2 – B – 3 – C, etc. The raw result is the time taken (in seconds) to complete each part. During the task, the patient's work should be observed, noting any mistakes (e.g., connecting the dots in the wrong order) (Jodzio, 2008).

A particularly sensitive indicator of executive dysfunction is the result in part B. Patients with brain damage typically take approximately three times longer to complete part B than part A. Therefore, researchers emphasize the diagnostic value of the B/A ratio (the proportion of time needed to solve part B to part A, expressed in raw form). A high value of this indicator (>3) suggests serious difficulties in maintaining the mental set for the selected action in working memory, a symptom typical in individuals with executive dysfunction syndrome (cf. Jodzio, 2008).

The subjective severity of depressive symptoms was measured using the Beck Depression Inventory (BDI) (Czapiński, 1992). The scale is completed by the patient and takes about 20 minutes. The test describes the 21 most frequently observed symptoms of depression. The subject answers each question in a way that best describes their condition during the indicated period. Responses are assessed on a 4-point scale (0–3 points).

Data Analysis Methods

The first stage of statistical analyzes focused on assessing intergroup differences in cognitive functions. For this purpose, the means obtained in individual test tasks (PRMQ, TMT, CFT, Digit Span) by patients with Exp1 and Exp2 and people from the control groups were compared. One-way analysis of variance (ANOVA) with post hoc comparison by Tukey's test was used (see Table 2, p. 167). The dependent variables were raw test scores. The independent variable was defined as belonging to a specific group of respondents (Exp1, Exp2, Ko1, Ko2). The mean results along with the F statistic are presented in Table 2.

Subsequently, to assess differences in participants' prospective memory (PM) functioning and detect possible intra-group effects, the results were subjected to a repeated measures ANOVA in a mixed model. The within-group factor was the type of prospective task (time context subtest vs. CAMPROMPT event context subtest), and the between-group factor was group membership (Exp1, Exp2, Ko1, Ko2). The dependent variable was the test score. After determining the significance of the interaction, an analysis of simple effects was performed, incorporating Sidak's correction for multiple comparisons. The results are presented in Tables 3 (p. 167) and 4 (p. 168) and illustrated in Figure 1 (p. 168).

It is hypothesized that prospective memory functioning is influenced by several factors, including respiratory efficiency, smoking, and depression severity. To predict PM functioning in the Exp1 and Exp2 clinical groups (dependent variable), multiple regression analysis was conducted. Initially, the same explanatory variables were entered into the regression equations and then gradually eliminated based on their significance levels. The analyses revealed that PM functioning in individual clinical groups depends on different factors; therefore, only the predictors ultimately included in the regression equations are presented below. For the COPD group, explanatory variables included the level of respiratory efficiency (FEV_1/FVC index value) and the discrepancy in completion times for parts B and A of the TMT. For the bronchial asthma group (Exp2), the regression equation included the Tiffeau index (level of respiratory efficiency) and the number of cigarettes smoked per day. The results are presented in Table 5 (p. 169).

Results

The data in Table 2 (p .167) show that individuals with COPD, compared to the control groups and patients with bronchial asthma, achieved lower scores in CFT-copy and CFT-reproduction. These patients also required more time to complete TMT – part A and TMT – part B, resulting in a greater disproportion in the time taken to complete part B relative to part A. This result may indicate limited executive abilities, as the average value of the disproportion index B/A is greater than 3. No intergroup differences were found in the WAIS-R Digit Span.

In terms of prospective memory functioning (CAMPROMPT score), a strong main effect of group was demonstrated, indicating overall significantly higher scores in both control groups ($p < .001$) than in the experimental groups ($p < .001$), with no differences between the two control groups ($p = .98$). There was also a weak main effect of task, suggesting that all subjects, regardless of group membership, achieved higher results in the task with an event context than a time context CAMPROMPT ($p < .05$) (see Tables 3, p. 167 and 4, p. 168).

Moreover, in relation to the CAMPROMPT subtests, a weak group x prospective task interaction effect was demonstrated (see Table 3 and Figure 1, p. 168). This means that the level of performance on prospective tasks depends both on the type of context and on the health status of the subjects (group membership). In the CAMPROMPT time and event context subtests, both control groups achieved significantly higher results than the clinical groups (Exp1 vs Ko1, $p < .001$; Exp1 vs Ko2, $p < .001$; Exp2 vs Ko1, $p < .001$; Exp2 vs Ko2, $p < .05$). This indicates that control group participants coped significantly better with prospective tasks in both time and event contexts than the experimental groups. The analysis of simple effects in the experimental groups revealed that patients with asthma (Exp2) performed significantly better on the time context task than patients with COPD (Exp1) ($p < .001$). At the same time, the performance of the CAMPROMPT event context subtest by Exp1 was similar to that of individuals with bronchial asthma (Exp2) ($p = .414$). The analysis of simple within-group effects showed significant differences in results between the two CAMPROMPT tasks only in Exp1 ($p < .01$), with COPD patients performing significantly worse on tasks with a time context than with an event context. Detailed results (*M* and *SD*) are given in Table 4 (p. 168).

Table 2

Descriptive Statistics and Group Comparisons in Memory and Attention Tests

Group / Variable	Exp1 $n = 32$ M (SD)	Exp2 $n = 30$ M (SD)	Ko1 $n = 27$ M (SD)	Ko2 $n = 27$ M (SD)	$F_{df=3.112}$	*eta*-squared
PRMQ	32.44 (10.28) a	34.87 (7.70) a	25.04 (7.89) b	24.07 (5.54) b	12.42***	0.25
– PRMQ-Pro	17.16 (5.83) ac	18.8 (5.29) a	13.37 (4.17) b	14.00 (4.74) bc	7.36**	0.18
– PRMQ-Retro	15.28 (4.98) a	16.07 (2.82) a	11.67 (4.05) b	10.07 (2.13) b	17.1***	0.32
TMT-A (time/sec)	66.5 (22.88) a	44.47 (9.59) b	42.11 (6.82) b	46.41 (6.65) b	19.85***	0.38
TMT-B (time/sec)	198.39 (131.17) a	101.00 (24.07) b	83.63 (17.26) b	101.33 (19.88) b	16.43***	0.32
TMT-B/A	3.07 (0.98) a	2.28 (0.37) b	1.99 (0. 31) b	2.18 (0. 27) b	19.33***	0.38
TFZ-K	28.29 (5.16) a	32.06 (2.61) b	33.51 (2.10) b	32.09 (2.46) b	13.12***	0.29
TFZ-R	12.51 (4.34) a	17.40 (4.93) b	20.53 (4.84) b	19.33 (4.10) b	17.99***	0.33
Digit Span	9.41 (2.43) a	9.87 (1.63) a	10.74 (2.52) a	10.22 (2.04) a	1.95; (ni)	0.04

** Intergroup differences at $p \leq .01$;
*** Intergroup differences at $p < .001$. Means marked with the same letter (a, b or c) do not differ statistically significantly between groups at the .05 level (Tukey's post hoc comparison method).
PRMQ – overall score on the Prospective-Retrospective Memory Questionnaire; Pro – prospective aspect; Retro – retrospective aspect.

Table 3

Repeated Measures ANOVA Results for the CAMPROMPT Test

Variable	F	p	ηp^2
group	61.75	.001	0.45
Task type (CAMPROMPT-time, CAMPROMPT-event)	4.37	.05	0.02
group x task type	2.72	.05	0.035

ηp^2 – partial eta squared

Table 4

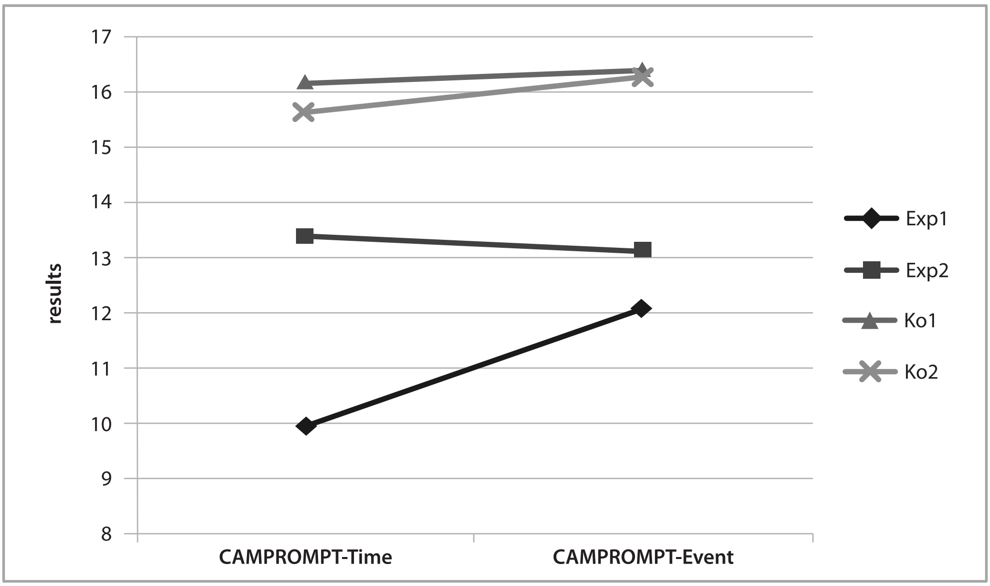
Descriptive Statistics for Two Subscales of the CAMPROMPT Test

Group	CAMPROMPT-Time *M* (*SD*)	CAMPROMPT-Event *M* (*SD*)
Exp1 (df = 31)	9.94 (2.95)	12.03 (3.26)
Exp2 (df = 29)	13.37 (2.5)	13.10 (2.31)
Ko1 (df = 26)	16.15 (2.08)	16.37 (1.71)
Ko2 (df = 26)	15.63 (2.2)	16.26 (1.7)

Additionally, COPD patients completed the PRMQ questionnaire (general measure and subscales assessing the prospective and retrospective aspects) similarly to patients with bronchial asthma. Interestingly, COPD patients (Exp1) rated the prospective aspect of the PRMQ similarly to healthy individuals (Ko2). However, the group with bronchial asthma (Exp2) differed significantly from both control groups (Ko1 and Ko2) in all measures of the test. The average results indicate that people with asthma (Exp2) evaluate both the prospective and retrospective aspects of their own memory worse than control individuals (Ko1 and Ko2) (see Table 2, p. 167).

Figure 1

Group Interaction of Time- and Event-Based Tasks in a Clinical-Experimental Setting of the CAMPROMPT Test



The consideration of PM condition in clinical groups was supplemented by the results of regression analysis. Both the model for patients with COPD ($R^2 = .70$; $F_{(1,30)} = 19.87$, $p < .001$) and for patients with asthma ($R^2 = .77$; $F_{(2,27)} = 44.32$, $p < .001$) were a good fit to the data, explaining at least 70% of the variability of the results. In Exp1, greater respiratory efficiency (Tiffeau index), smaller TMT-B/A disproportion, and lower severity of depressive symptoms were associated with better prospective memory functioning. In Exp2, greater respiratory efficiency and fewer cigarettes smoked were associated with better prospective memory functioning. Table 5 includes only statistically significant explanatory variables.

Table 5

Regression Analysis of Prospective Memory Functioning in Patients With COPD and Bronchial Asthma

Group	Explained variables	Explanatory variables	B	Beta	*t*	*p*
Exp1	CAMPROMPT	FEV_1/FVC	0.48	0.60	4.67	.001
		TMT-B/A	–1.64	–0.31	–2.37	.05
		BDI	–0.3	–0.29	–1.74	.05
Exp2		FEV_1/FVC	0.33	0.84	8.98	.001
		Number of cigarettes smoked per day	–0.1	–0.20	–2.15	.05

Discussion

This study aimed to characterize the cognitive functioning of patients with COPD and bronchial asthma, with a particular emphasis on prospective memory (PM). I sought to identify hypothetical predictors of PM disorders in these lung diseases.

The collected data indicate that respiratory failure poses a significant risk for serious cognitive disorders. In the presented studies, all COPD patients exhibited various types of cognitive dysfunctions. Prospective memory was particularly impaired, but disturbances in non-verbal permanent memory, attention, and executive functions were also observed.

In patients with bronchial asthma, the problems were almost exclusively limited to PM. As Goldberg (2009) notes, one of the first symptoms of dementia is subtle impairments in planning and anticipating future events. Our analyses showed that the reduction in PM abilities is influenced by the severity of respiratory failure and, in patients with asthma, the number of cigarettes smoked per day. In patients with COPD, PM impairments were also influenced by the severity of mood disorders and limited executive abilities.

Analyzing the obtained results in detail, it should be noted that symptoms of dysfunction in people with COPD, compared to control groups, were observed in tasks involving various types of material (prospective, digits, non-verbal material) and in tasks requiring attention, executive functions, and eye-hand coordination. Similar results were presented by Prigatano et al. (1983), who emphasized that cognitive disorders become more profound in the more severe stages of the disease. Ozge et al. (2006) also noted that over 72% of patients with severe COPD, compared to healthy individuals, showed impairments in tests examining recent memory, attention, and visuospatial orientation, reflecting a progressive dementia process. According to Yohannes et al. (2017), one in four COPD patients meets the criteria for mild cognitive impairment. Lower abilities particularly affect measures of memory, attention, and eye-hand coordination (Borak et al., 1996), as well as tasks that contain a time component, where correct execution depends on the rate of information processing (e.g., TMT) (Park & Larson, 2015).

In this study, reduced results in part A of the TMT in people with COPD reflect a slow pace of work. Patients reported difficulty concentrating and often made mistakes in tasks requiring cognitive flexibility and attention switching, which is especially reflected in part B of the TMT. This is likely due to the low tolerance for exercise in COPD patients, including mental exertion, which in some cases exacerbates respiratory failure (Jassem et al., 2012). Consequently, this leads to slower information processing (Samajdar et al., 2022), especially since attempts to correct errors are tedious and long-lasting, further increasing breathing difficulties and, in extreme cases, making task completion impossible. Significant fatigue was observed in the studied patients while performing cognitive tasks. Subjects with Exp1 often needed breaks, answered questions with effort, and reported feelings of shortness of breath (see Table 1, p. 162, NRS result).

Prospective memory (PM) is also disorganized in pulmonary diseases. Disturbances have already been observed in patients with bronchial asthma, whose cognitive problems were primarily limited to this type of memory. As Panaszek (2008) notes, asthma in the elderly does not follow a specific pattern of cognitive impairment, so isolated PM dysfunctions are likely the only neuropsychological issues distinguishing these patients from healthy individuals of the same age. However, in people with COPD, a significant reduction in PM indicators is associated with generally low performance in tasks measuring other cognitive functions. Profound disorders in prospective, visuospatial, short-term memory, and information processing speed were also confirmed by Cleutjens et al. (2014). In this research, patients with COPD encountered significant difficulties in time-based prospective tasks. In these tasks, subjects must remember how many minutes or hours have passed since the start of the task, without any external indication of when to initiate the plan. Such tasks, requiring substantial self-initiated resources, are challenging even for healthy individuals (Einstein & McDaniel, 1990), and particularly problematic for older adults (Einstein et al., 1995). Another probable cause of performance difficulties in time-context tasks may be the depressed mood of the COPD patients. Depressive symptoms often co-occur with COPD and are a negative prognostic indicator of PM functioning disorders in both sick (Ranzini et al., 2020) and healthy individuals (cf. Altgassen et al., 2011). Additionally, the disproportion between the performance of parts B and A of the TMT, as shown in the regression equation for COPD patients, suggests that limited executive abilities contribute to PM dysfunction. The TMT-B/A measure highlights issues with switching attention, acting under time pressure, and maintaining task focus, while somewhat bypassing (but not excluding) the depressive factor and its associated slowing effects. This result indicates that the mechanisms underlying PM problems in patients with respiratory failure are multidimensional.

The functioning of prospective memory (PM) in patients with respiratory failure is related to cigarette smoking. In the study sample, 97% of COPD patients and 50% of bronchial asthma patients smoked cigarettes. Smoking, especially chronic smoking, has a negative impact on memory (Heffernan et al., 2005, 2010; Hill et al., 2003), including PM (Heffernan et al., 2010). Smokers tend to need more time for memory tasks and make more mistakes, although they assess their PM status similarly to non-smokers (Rash, 2007, as cited in Heffernan et al., 2010). Chronic smoking, even in small amounts (Kalmijn et al., 2002), hinders lung regeneration and negatively affects brain functions, accelerating cerebral cortex degeneration (Nooyens et al., 2008). Additionally, heavy metal particles in cigarette smoke may have a direct neurotoxic effect on the CNS, increasing the risk of Alzheimer's disease and cerebral atherosclerosis (Anstey et al., 2004). However, the precise mechanisms underlying the observed PM deficits are not fully understood. Meta-analyses on structural changes in the CNS of COPD patients show generalized changes in brain macrostructure, affecting the frontal lobes, hippocampus, right temporal lobe, and motor cortex bilaterally, clinically manifesting as dementia disorders distinct from Alzheimer's disease (Wang et al., 2023).

It also seems logical to believe that people with COPD and bronchial asthma are aware of their PM deficits, as these deficits impact their daily lives, including social, personal, and professional spheres. Although COPD patients critically assessed their PM functioning, the differences compared to control groups mainly concerned its retrospective aspect. Interestingly, healthy individuals assessed the prospective aspect of PM similarly to COPD patients. The subjectively high assessment of the prospective aspect of PM is not confirmed by objective memory tasks. Moreover, among COPD patients, the subjective assessment of PM is not related to other cognitive functions (Rönnlund, 2011), and these patients, like heavy smokers, demonstrate reduced self-awareness of their disorders (Heffernan et al., 2011). In contrast, abovementioned research on asthma patients showed that they assessed both aspects of their PM functioning more accurately.

It is important to consider the multifactorial determinants of the cognitive condition in people with COPD. The key pathomechanism of dysfunction is neuronal damage resulting from hypoxia. The relationship between FEV_1 and reaction time, as well as information processing speed, has been demonstrated even in healthy individuals over 50 years of age (Anstey et al., 2004). Moreover, memory disorders in COPD are more closely related to respiratory indicators than to the physiological aging processes of the body (Fioravanti et al., 1995). Some researchers also suggest the possibility of disruption in the function of oxygen-dependent enzymes involved in neurotransmitter synthesis (Heaton et al., 1983).

Another important issue is the number of psychosocial factors affecting the daily lives of these patients and their ability to adhere to treatment recommendations (Ranzini et al., 2020). The severity of depressive symptoms, which negatively impact PM, is also significant (Da Silva Coelho et al., 2023). In the discussed studies on COPD patients, the level of respiratory failure, limited executive abilities, and the severity of depressive symptoms explained 70% of the variance in the results obtained in prospective tasks.

When comparing the study groups in terms of respiratory efficiency, it is evident that people with asthma (moderate respiratory failure) fall between the control groups (full respiratory efficiency) and patients with COPD (severe respiratory failure). This suggests that worsening respiratory disorders are a negative prognostic indicator for the development of profound PM disorders.

Conclusions

An important conclusion is that respiratory failure carries a significant risk of cognitive impairment. In light of the presented results, PM disorders constitute a major clinical problem that requires detailed neuropsychological diagnosis and adaptation of the therapeutic process to address the specific disorders in this group of patients. However, restoring memory abilities depends on the proper transfer of memory strategies (Jodzio & Wieczorek, 1996). This can be achieved by incorporating neuropsychological rehabilitation into the treatment program, including PM, especially since the cognitive deficits of COPD patients impair their independence and may lead to the abandonment of pulmonary rehabilitation programs, thereby increasing mortality among patients (Siraj, 2023). Therefore, properly conducted training that supports, among other things, prospective memory would positively impact the regularity of therapy (Zogg et al., 2012), contributing to the overall improvement of both the physical and mental functioning of the patient.

Summary

In summary, prospective memory deficits complicate the independent resolution of everyday problems, not only due to forgetting important tasks but also by limiting the ability to strategically adapt to these dysfunctions. Therefore, understanding the ecological dimension of prospective memory functioning in these patients is crucial. This requires the collaborative efforts of neuropsychologists, MDs, other healthcare professionals, social and community workers, and the patient's family. Unfortunately, most activities offered to patients with respiratory failure in health centers focus solely on symptomatic treatment and respiratory rehabilitation. Only in a few cases is there integrated, multi-specialty collaboration involving the entire treatment team.

Limitations

The limited size of the study sample results from the strict inclusion and exclusion criteria adopted for patients with COPD and asthma. Only right-handed patients with severe COPD and isolated atopic bronchial asthma without overlap syndrome were included in the study. The patients were not undergoing oncological, neurological, or psychiatric treatment. Additionally, the study groups did not differ in terms of age and education level. In a population-based study without these criteria, patients' cognitive functioning would be influenced by other, difficult-to-control factors, which this study aimed to minimize.

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