Original Research Article

Smoking And Neuropsychological Functions

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ABSTRACT

Background: Smoking remains a significant public health concern, contributing to mortality and morbidity rates while also impacting neuropsychological function, particularly in young adults. This study aimed to comprehensively assess the cognitive functioning of smoking and non-smoking individuals, focusing on domains such as mental speed, attention, executive functioning, and memory.
Methodology: Forty participants, comprising 20 smokers and 20 non-smokers, were recruited using snowball sampling. Cognitive assessments were conducted using Psychological Experiment Building Language (PEBL) tools, including math processing tests for mental speed, PEBL Continuous Perception Task for attention, Berg's Card Sorting Test for executive functioning, and PEBL's version of digit span for memory. Statistical analysis was performed using SPSS software.
Results: Smokers exhibited significantly inferior performance to non-smokers across various cognitive domains. They demonstrated deficits in mental speed, attention, executive functioning, and short-term memory. Notably, smokers displayed increased perseveration and errors on executive functioning tasks and performed poorly on memory tests compared to non-smoking counterparts.
Conclusions: The primary goal must be to prevent smokers from experiencing early cognitive decline to lessen the burden on public health. It is necessary to educate smokers about the neurologically damaging effects of cigarette smoke and the higher risk of cognitive impairment.
Keywords: Young adults, Cognition, Cigarette, Smoking, Attention, Speed, Memory, and executive functioning.

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INTRODUCTION

Smoking remains a pervasive public health concern, contributing significantly to mortality and morbidity rates across the United States [1]. While the physical health risks associated with smoking are well-documented, an emerging body of research underscores its detrimental effects on neuropsychological function in young adults. Neuropsychological function encompasses the cognitive processes fundamental to human cognition, including attention, memory, executive function, and language.
Despite considerable strides in understanding the neurobehavioral consequences of substance use, the nuanced relationship between smoking and neuropsychological functioning requires further investigation [2]. The objective of this research is to clarify the mechanisms and implications of the complex relationships that exist between young adults' smoking behavior and cognitive function.
Studies have consistently demonstrated that smokers exhibit inferior performance on neuropsychological tests compared to non-smokers, independent of demographic variables such as age, education, and socioeconomic status [3-4]. Functional neuroimaging studies employing techniques like functional magnetic resonance imaging (fMRI) have shed light on altered brain activation patterns in smokers, particularly in regions implicated in cognitive control, reward processing, and decision-making [5-6]. Additionally, investigations into risk-taking behavior among young adult smokers have unveiled intriguing findings. While smokers display a heightened propensity for risk-taking, particularly in contexts akin to the Balloon

Analogue Risk Task (BART), their decision-making under uncertainty, as measured by the Iowa Gambling Task (IGT), may not significantly deviate from non-smoking counterparts [7].

A comprehensive understanding of the cognitive ramifications of smoking necessitates considering various factors such as smoking intensity, duration, and cessation. Studies examining the cognitive performance of current and former smokers underscore the enduring impact of smoking on cognitive abilities, with heavier smokers exhibiting more pronounced deficits [8].

Memory deficits have been a focal point in understanding the neuropsychological consequences of smoking. A study [9] observed that young smokers displayed reduced memory performance, especially in tasks requiring working memory [10], it was also found that nicotine withdrawal negatively impacted spatial working memory. Nicotine's impact on impulsivity and decision-making has also been explored when researchers [11] conducted a systematic review and meta-analysis, revealing that smokers tend to exhibit increased impulsivity compared to non-smokers. Additionally, smokers often demonstrate altered decision-making processes [12], which could contribute to continued tobacco use. Recent advancements in neuroimaging techniques have provided insights into the structural and functional brain changes associated with smoking. A neuroimaging study [13] used functional MRI to show that smokers exhibited altered activation patterns in brain regions associated with cognitive control, suggesting neural adaptations to chronic smoking.

However, the reversibility of these neuropsychological impairments following smoking cessation remains a topic of contention and warrants further investigation. While emerging evidence suggests multifaceted effects of smoking on cognitive processes including attention, memory, executive functions, and emotional regulation, the underlying mechanisms and specific neurocognitive processes affected by smoking necessitate deeper exploration [14].

Considering the complexities surrounding smoking behavior and its implications for cognitive function in young adults, this paper aims to provide a comprehensive synthesis of current literature, offering insights into the multifaceted relationship between smoking and neuropsychological functioning. By elucidating the cognitive consequences of smoking in young adults, this research endeavors to inform targeted interventions and public health initiatives aimed at mitigating the adverse effects of smoking on cognitive health [15].

METHODOLOGY

The aim of the study was to compare the cognitive functioning of smoking and non-smoking individuals

Objectives

- To assess the cognitive domain of mental speed using a math processing test.
- To assess the domain of attention using the PEBL Continuous perception task
- To assess the Executive functioning: perseverance using PEBL's version of the Wisconsin Card Sorting Test [16].
- To assess the Domain of memory (Short-term memory) using the Digit Span test.
- To compare the domain scores of smoking individuals and non-smoking individuals.

Hypothesis

- H01: There is no significant difference between the mental speed of smoking and non-smoking individuals.
- H02: There is no significant difference between the attention of smoking and non-smoking individuals.
- H03: There is no significant difference between the perseverance of smoking and non-smoking individuals.
- H04: There is no significant difference between the short-term memory of smoking and non-smoking individuals.

Sample

This study recruited 40 participants (20 smokers and 20 non-smokers; 20 males and 20 females) for the assessments after the screening of 120 people using the snowball sampling method.

The sample included only acute smokers. Acute smokers are individuals who have been smoking cigarettes for more than 6 months but less than a year and less than 100 cigarettes per week.

The study's exclusion criteria include individuals with a history of head injury, psychology students, those who regularly indulge in board games, engage in regular sports/workout routines, have diagnosed psychiatric disorders, use substances regularly, have a history of hospitalization within the past 15 days, do not take supplements, or have chronic/acute medical conditions.

For smokers, the inclusion criteria for the study encompass individuals aged 18 to 29 who are students and engage in sustainable and consistent use of cigarettes, consuming between 0 to 10 cigarettes per day.
The inclusion criteria of non-smokers for the study include individuals aged 18 to 29 who are students and have never smoked cigarettes.

Tools:
A Google form was used to recruit the participants who fulfilled the inclusion and exclusion criteria.
PEBL version 2.1: The Psychological Experiment Building Language (PEBL version 2.1) [16] was used to assess the level of cognitive functioning of the participants.

- **Speed:** Math processing was used to assess mental speed. The test required the participants to press keys depending on the solution of the math problem. These math problems were single-digit addition or subtraction sums. The length of these problems varied depending on the condition (if the condition was 2 then the math problem would look like 5-3; if the condition was 3 the problems looked like 9-3+1 and so on; there were only 3 conditions in total). This experiment investigated the number of problems attempted. Depending on the condition, the problems were supposed to be solved within a stipulated time.
- **Attention:** This experiment used the PEBL Continuous Perception Test. It assessed the participant's sustained attention. The experiment demanded the participants keep an eye on the screen for the alphabet or numbers and press the spacebar as they appeared and avoid pressing the spacebar if they saw an X. This test would go on for 14 minutes
- **Executive Functioning:** For executive functioning, this experiment is considered perseveration. To assess preservation, Berg's Card Sorting Test (a PEBL's adaptation of the Wisconsin Card Sorting Test), was administered.
- **Memory:** Short Term Memory was assessed using PEBL's version of digit span. This assessment was digit span-forward. In this test, numbers appeared on the screen one by one, varying by length, and the participant had to type the numbers in the same order they saw the numbers in.

Design
This study employed ex post facto quasi-experimental study design. The independent variable was acute smoking and how did it impact the different neuropsychological functioning. The descriptive statistics were computed using SPSS software.

RESULTS AND DISCUSSION

This study was carried out to understand the cognitive implications of smoking. This study employed a comparative assessment of cognitive profiles i.e., all the participants who smoked cigarettes were assessed for speed, attention, executive function, and memory and were compared to the equivalent control group's profiles.
It has been a fact that long-term smoking causes deficits in the areas of attention, encoding new information, cognitive flexibility, and problem-solving [17]. Contradictorily, the smoking individuals performed better on the continuous perception task as acute nicotine usage in the form of cigarettes boosts cognitive abilities beyond those typically seen in smokers, counteracting any decline in cognitive function caused by nicotine withdrawal. These neurological effects serve as incentives for continued nicotine consumption, significantly fostering nicotine addiction. This can be likened to how enhanced cognitive performance contributes to better results on continuous perception tasks or other vigilance tests [18].
While some studies observed contradictory results [19-20] involving 91 current and 40 former young adult female smokers, aged approximately 23.9 years; performed poorly on sustained attention tasks because it has also been observed by imaging studies that young adult smokers had reduced white matter integrity in the frontal lobe compared to non-smokers [21]. The same study mentioned above also found that reduced white matter integrity was associated with lower mental speed.
The present research conducted has similar findings. Similar findings were seen in an assessment-based study [22]. They conducted their study on 30 male smokers which led to statistically significant reduced psychomotor speed, assessed by digit symbol substitution test.
Poor performance on the Math processing test could also indicate deficits in the working memory of individuals smoking. Another research [10] had similar findings in their study when they compared the working memory of 14 former smokers and 15 present smokers; it was concluded that smokers had poor working memory which was assessed by a verbal fluency test. This might happen because smoking harms the brain by causing oxidative damage, inflammation, atherosclerosis, thrombosis, disruption of the blood-brain barrier, and disorganization of cell connections. Cigarette smoke causes changes in brain structures,

including narrower frontal cortical regions, frontal gray matter aberrations, and decreased functional connectivity between the orbitofrontal cortex, superior frontal gyrus, temporal lobe, and insula [23].

Table 1: Showing descriptive statistics of the Number of trials completed and trials hit of the PCPT test for Non-Smokers and Smokers and Z-test values of Mann Whitney U-test.

	Participant Type	N	Mean Rank	Z value	Sig.
Number of Trials completed	Non-Smoker	20	10.50	5.415	.000
	Smoker	20	30.50		
Number of Correctly hit Targets	Non-Smoker	20	10.53	5.443	.000
	Smoker	20	30.48		

Table 2: Showing descriptive statistics of the Number of trials completed and missed trials of the Math processing test of the smokers and non-smokers and the Z-value of Mann Whitney U test.

	Participant Type	N	Mean Rank	Z value	Sig.
Condition 2: Trials	Non-Smoker	20	29.63	5.415	.000
	Smoker	20	11.38		
Condition 2: Missed trials	Non-Smoker	20	17.75	1.501	0.142
	Smoker	20	23.25		
Condition 3: Trials	Non-Smoker	20	27.80	3.953	.000
	Smoker	20	13.20		
Condition 3: Missed trials	Non-Smoker	20	17.55	1.605	0.114
	Smoker	20	23.45		
Condition 4: Trials	Non-Smoker	20	10.50	2.993	.000
	Smoker	20	30.50		
Condition 4: Missed trials	Non-Smoker	20	10.50	1.170	0.253
	Smoker	20	30.50		

Table 3: Showing descriptive statistics of Perseverative responses and errors for the BCST assessment of the smokers and non-smokers and Z-value of Mann Whitney U test.

	Participant Type	N	Mean Rank	Z value	Sig.
Perseverative responses	Non-Smoker	20	10.50	5.429	.000
	Smoker	20	30.50		
Perseverative Errors	Non-Smoker	20	10.50	5.437	.000
	Smoker	20	30.50		

Table 4: Showing descriptive statistics of Memory Span and correct responses of the digit span test forward of the smokers and non-smokers and Z-value of Mann Whitney U test

	Participant Type	N	Mean Rank	Z value	Sig.
Memory Span	Non-Smoker	20	30.20	5.544	.000
	Smoker	20	10.80		
Correct Responses	Non-Smoker	20	30.30	5.370	.000
	Smoker	20	10.70		

The working memory forms an integral part of executive functioning which is also responsible for planning, decision-making, goal-oriented behavior, and inhibitory control [24]. Thus, just like the working memory other aspects are affected specifically set-shifting behavior which was assessed by Berg's Card sorting test. This study investigated persevering errors and responses just like the study that found that in the study using the Wisconsin Card Sorting Test-64 (WCST-64), non-smokers demonstrated slightly better Executive function capacity compared to smokers. This was indicated by fewer Perseveration errors ($p < 0.011$, $d = 0.34$) and non-perseveration errors ($p < 0.026$, $d = 0.23$), with significant and small effect sizes favoring the non-smoking control group [25].

Another assessment-based study [25] used the digit span task as well in their study to assess the short-term memory of their participants. A similar approach was obtained in this study but was restricted only to the digit span forward test while the study employed both digit span forward and backward. The Digit Span Task and the Contextual Memory Test results indicated similar findings regarding short-term memory performance. Specifically, the non-smokers outperformed the smoking group ($p = 0.003$, $d = 0.40$) on both tasks. This consistency strengthens the justification for the observed differences in short-term memory capacity between smokers and non-smokers.

Smoking affects blood counts and cerebral flow rate in the anterior, middle, and posterior cerebral arteries. Cigarette smoke contains cytotoxic chemicals such as carbon monoxide, ketones, aldehydes, nitrosamines, and dihydroxybenzenes, which can damage neuronal and cellular function in the cerebral hemisphere. Cigarette smoke includes increased quantities of free radicals, which can cause oxidative damage to neurons. These variables may lead to cognitive impairment in smokers. These individuals are more likely to develop cognitive impairment and dementia later in life [26-28].

CONCLUSION

The cognitive impact of smoking is a multifaceted phenomenon, encompassing both acute nicotine-induced enhancements and chronic deficits associated with long-term tobacco use. While certain studies suggest improved cognitive performance in smokers during acute nicotine exposure, chronic smoking is consistently linked to adverse effects on attention, memory, executive function, and working memory.

Structural brain changes, such as reduced white matter integrity in the frontal lobe, further contribute to cognitive impairments observed in tasks requiring sustained attention and executive functioning. Deficits in working memory, as revealed by various assessments, underscore the broader implications of smoking on cognitive processes crucial for decision-making and inhibitory control. Additionally, studies assessing set-shifting behavior consistently demonstrate diminished executive function capacity among smokers compared to non-smokers. These findings collectively emphasize the intricate relationship between smoking and cognitive function, urging further exploration and the development of targeted interventions to address cognitive health in individuals affected by prolonged nicotine use.

Limitations of the study

This study was based on a self-report questionnaire. Participants may have underreported or overreported their smoking habits or other health habits due to social desirability bias or memory recall issues. Adding to the previous limitation, participants may not have reported their comorbidities (if any are present) or many may not have been aware of their condition due to the stressful environment they're currently living in. While the study assesses various cognitive domains such as mental speed, attention, executive functioning, and memory, it may overlook other important cognitive functions affected by smoking, such as language abilities, visuospatial skills, and decision-making under uncertainty.

Recommendations

Further research on people who smoke occasionally or have been smokers in the past and assess their cognitive performance: assessing the impact of smoking patterns on cognitive performance. A longitudinal study can be conducted to see the recovery path (reversibility extent) or the impact of any intervention on cognitive performance at every milestone of the process. Future studies could explore how factors like genetics, socioeconomic status, and mental health conditions moderate the relationship between smoking and cognitive function.

Ethics

Since deception was used in the study, i.e., the participants were not informed about the actual purpose of the study before the assessments were conducted, each participant was debriefed about the experiment and its actual purpose after the completion of the experiment. The participants were also given a resource kit that contained a brochure that mentioned the side effects of smoking and contacts of health care providers who were qualified to help them in the process of quitting smoking.

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