The Effect of Chronic Cigarette Use on Cognitive Function

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SUMMARY

Objective: In this study, we aimed to investigate the effect of chronic cigarette smoking on the cognitive function in people who have no other mental or physical illness other than tobacco use disorder.

Method: The study was carried out on three groups: current smokers (n = 71), former smokers (n = 39), and non-smokers (n = 49). The Wisconsin Card Sorting Test (WCST), Stroop Color and Word Test (ST), Trail Making Test (TMT), Auditory Verbal Learning Test (AVLT), and Serial Digit Learning Test (SDLT) were applied to the 3 groups participating in the study. Groups were compared with the Three-Factor Covariance Analysis.

Results: Stroop test 4th card time score which determined the basic level of color discourse in the current smoker group was significantly higher than the non-smoker group. The Trail Making Test-B time scores were significantly higher in the current smoker group than the non-smoker group. And Trail Making Test-B time points were significantly higher in the former smoker group than nonsmoker group. Auditory Verbal Learning Test – verbal learning scores were lower in the current smoker group than the non-smoker and former smoker group. There was no significant difference in verbal learning scores between the non-smoking and former smoker groups. The neurocognitive deficits in current smokers appear to be related to dose and duration.

Conclusion: This study suggests that auditory verbal memory, visual-spatial processing, and attention areas may be a selective area of disability in smokers. A major limitation is the fact that general cognitive performance levels of participants was not assessed by a general criteria such as Wechsler Adult Intelligence Scale (WAIS).

Keywords: neuropsychological tests, nicotine, smoking

INTRODUCTION

Nicotine is one of more than 4,000 compounds identified in a cigarette. Its dependence is caused by nicotine's effect on neurocognitive function (Yakir et al. 2007). Given the large number of nicotinic acetyl choline receptors present in the brain and the range of neurotransmitter systems affected, nicotine may affect various cognitive domains such as sensory, motor, attention, executive function, learning, memory, etc. (Campos et al., 2016). However, studies investigating this relationship is lacking when compared to the studies investigating physical health problems associated with smoking as cancer, cardiovascular diseases, lung diseases, etc. (Durazzo et al., 2010).

In acute and chronic smoking as well as nicotine withdrawal, different neurobiological mechanisms are involved. Acute nicotine use leads to a short-term increase in performance (especially on attention and working memory) and also restores the cognitive impairment caused by its withdrawal. Supporting the nicotine use, both cases result in an ongoing cigarette smoking as negative promoting factors (Campos et

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al., 2016, Wagner et al., 2012, Yakir et al., 2007, Ernst et al., 2001, Ettinger et al., 2009).

Chronic cigarette smoking has been reported to be associated with cognitive impairment and regression (Campos et al., 2016, Wagner et al., 2012). Impairment in cognitive domains may be caused by several factors: 1) smokers suffer from cognitive deficiencies that lead them to start and continue smoking; 2) cigarette smoking may directly cause a cognitive impairment due to the neurotoxic & vascular effects of nicotine; and 3) cigarette smoking is associated with psychiatric disorders, and may cause cognitive impairment in accompanying disorders. These various reasons have been investigated by other studies conducted using different methods (Wagner et al., 2012).

It was suggested that the cigarette smoking was used as a self-treatment method by those with psychiatric disorders due to its helpful acute effects on cognitive functions. According to this view, nicotine enhanced attention capacity, and thus led to a positive effect on cognitive performance. The high prevalence of smoking also among the young people and adults with Attention Deficit Hyperactivity Disorder (ADHD) was attributed to this positive effect (Yakir et al., 2007). However, it was stated later on that the positive effect of acute nicotine use on cognitive functions cannot be generalized for those with neuropsychiatric disorders, except for the patients with ADHD (Heismann et al., 2010).

In population-based studies, the auditory verbal memory functions were found to be decreased in old-aged (Reitz et al. 2005) and middle-aged smokers (Richards et al., 2003) without dementia. In addition, it was shown that there was an increased risk of impairment in auditory-verbal memory for smokers compared to non-smokers in another population-based study on middle-aged smokers and former smokers. It was determined in a study by Kalmijn et al. (2002) that smokers obtained worse scores than non-smokers in verbal learning test and in the Stroop test. Durazzo et al. (2012) found in their study that smokers had a weaker auditory-verbal & visual-spatial learning/memory performance than non-smokers. This study excluded the smokers with physical and psychiatric diseases however, former smokers were not considered in that study (Durazzo et al., 2012).

The risk of developing Alzheimer's disease, vascular dementia, impairment in auditory-verbal learning/memory, visual recognition speed, executive function, and cognitive plasticity functions have been reported for their association with chronic cigarette smoking. It has also been suggested that there is a weak or no relationship between cigarette smoking and cognitive function (Durazzo et al. 2010). Those contradictory results were reported to stem from such possible factors like the inclusion of persons with physical diseases and/or psychiatric disorders, the inclusion of smokers from different age groups, and application of different neurocognitive tests in studies. (Wagner et al., 2012, Durazzo et al., 2012).

In this study, we aimed to investigate the effect of chronic cigarette smoking on cognitive function for a sample group containing people without psychiatric and physical disorders, which may have an extra effect on cigarette smoking and cognitive abilities. With the anticipation that quitting smoking may lead to an improvement in cognitive function, we planned to conduct our study on separate groups that contain current smokers, former smokers, and lifelong non-smokers. To this end, we compared these groups of volunteers in terms of cognitive function.

METHOD

Sample

The study was conducted in the addiction polyclinic of the Department of Psychiatry, Faculty of Medicine, Eskisehir Osmangazi University. The inclusion criteria were as follows: (1) must be between the ages of 18-55; (2) at least primary school graduate; (3) have no other Axis I psychiatric disorder; (4) have no history of substance-use other than cigarette smoking and past head trauma or neurologic disorders; and (5) use no medications that may affect cognitive functions. The group of current smokers (n=71) included, in an consecutively, those smoking at least 10 cigarettes per day for at least 2 years, having applied to the polyclinic for smoking cessation, and meeting the inclusion criteria. The group of former smokers (n=39) included those who quit smoking at a moment when they used to smoke 10 or more cigarettes per day for at least 2 years and those who have not smoked for the last 1 year, whereas the group of non-smokers (n=49) contained those that had not smoked more than 20 cigarettes throughout their lives. The group of former smokers and the group of non-smokers were formed from hospital staff and those who met the inclusion criteria. Former smokers and the group of non-smokers were not matched on the basis of the variables 'age', 'gender' and 'educational background' due to the consensus that these could cause a non-random bias.

Process

Once all the participants were evaluated using Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I), the neurocognitive test battery was administered to those without Axis I psychopathology. In order to find out the severity of dependence, the group of current smokers underwent the Fagerstrom Test for Nicotine Dependence (FTND). The study was ratified by the resolution no. 80558721/210 dated 29 June 2015 of the Ethics Committee, Faculty of Medicine, Eskisehir Osmangazi University. The consent of those participating in the study was also obtained from each patient.

Neuropsychological assessment was performed by a blinded clinical psychologist that was an expert in his field. In order to assess executive functions, Wisconsin Card Sorting Test and Stroop Test was applied whereas, the Trail-Making Test was applied to assess attention and Auditory Verbal Learning Test & Digit Sequence Learning Test to assess verbal learning and memory. Before administering neuropsychological tests to the group of current smokers, those involved in the group were asked to smoke a cigarette of their preferred brand in order to prevent any nicotine withdrawal during the test. It has been reported that the nicotine half-life is 100 to 150 minutes, and the withdrawal symptoms appear after 3 hours (Yakir et al. 2007). Also, the adverse effects of nicotine withdrawal on chronic smokers are typically not significant on neurocognitive function until 8 to 12 hours after last dose of nicotine, and the length of this period depends on the fact that the nicotine plasma level is relatively high due to recurrent smoking (Durazzo et al. 2010).

Tools

Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I): The scale was developed by First et al. (First et al., 1997) to investigate the diagnosis of DSM-IV Axis-I mental disorders. Its Turkish adaptation and reliability studies were conducted (Özkürkçügil et al. 1999).

Fagerstrom Test for Nicotine Dependence (FTND): This is a test developed by Fagerström et al. (1992). Its Turkish validity and reliability study was conducted by Uysal et al., and the Cronbach's alpha coefficient was reported to be 0.56 (Uysal et al., 2004).

Wisconsin Card Sorting Test (WCST): The test was developed by Heaton (Heaton 1981). This is one of the tests used to measure the frontal lobe functions (Weinberger et al., 1986). It helps to assess both the abstraction & conceptualization skills and the frontal complex attention system such as shifting a set that one created when it is necessary to be able to maintain such set. The test is applied using two card decks containing 4 stimulant cards and 64 response cards. The subject is asked to sort each response card with a stimulant card that the subject think is correct. After each sorting, the subject is informed whether the subject matched the cards correctly or incorrectly. As the subject matches the cards correctly 10 times in a row in the same category, the correct category is replaced by the next category. The test is over when the subject completes all 6 categories or when all cards are used. Its Turkish adaptation studies were performed by Karakaş et al. (Karakaş et al., 1998). This study used the scores obtained from the number of completed categories (WCST category), the number of perseverative responses (WCST response), and the number of perseverative errors (WCST error). Perseverative response is the response repeated according to a perseveration principle repeated or generated according to the previous correct sorting after 10 consecutive correct responses. Perseverative error is the case that the perseverative responses are concurrently erroneous. The subject starts with a principle different from the initial sorting principle, and neither can correct nor give up making a mistake despite being advised that the sorting is erroneous. Another form of the perseverative error is where the subject starts with correct sorting. However, the subject becomes unable to change the response pattern after 10 correct sorting trials and insists on giving a response according to the previous category (Karakaş et al., 1998).

Stroop Test (ST): This is a test based on naming colors against reading words to investigate the ability to neglect interference stimuli (interference) (Golden 1978). The scores obtained from tests consist of the scores from completion time (ST time), number of errors (ST error), and number of corrections (ST correction). The sub-tests of ST consist of reading the color names written in black (ST-1), reading color names written in a color different from such color represents (ST-2), saying the colors of color-printed circles (ST-3), saying the colors of neutral words (ST-4), and saying the print color of color names written in a color different from such color represents (ST-5). In the ST, ST-1 and ST-2 is used for checking the reading speed, whereas ST-3 and ST-4 are used to check the speed of saying the color name. The part of test that measures the fulfillment of a task under an interference effect (reading) is ST-5. Its Turkish adaptation studies were performed by Karakaş et al. (Karakaş et al., 1998).

Trail-Making Test (TMT): This is a widely-used, easy-to-apply test for evaluating executive functions and attention (Reitan 1958). This test allows for assessing frontal lobe functions by eliminating the factors such as psychomotor speed and ability (Jarvis and Barth 1986). Passing the test successfully requires having robust visual tracking and attention functions. The test is composed of two parts, namely TMT-A and TMT-B. The time spent until the test is completed is identified and recorded (TMT A/B time). The errors made are also recorded both for the part A and part B (TMT A/B error). Its Turkish validity and reliability study has been conducted (Cangöz et al. 2007). The purpose of the test is to assess processing speed based on visual scanning ability by part A of TMT, and the ability to shift set and tracking the sequence among the stimulus sets by part B. Part B is completed within a time frame longer than that taken to complete part A, and requires more visual-spatial processing because of its complex structure. Besides, the difficulty level of section B is higher than that of part A since it requires more motor speed, agility and attention (Türkeş et al. 2014).

Auditory Verbal Learning Test (AVLT): The test was developed by Rey (Rey 1964) and adapted into Turkish culture by Genç-Açıkgöz and Karakaş (1996). This test helps evaluating verbal learning, short-term memory, long-term memory and recognition memory. A fifteen-word vocabulary list is

repeated five times, and the number of words retained-recalled each time by the subject is recorded (A1-5 total score). Then a second list is read and those remaining in the subject's mind are recorded (B1/interference list). Immediately, the first list is repeated (A6 score) and, after 20 minutes, the subject is asked to enumerate the words he/she recalls from the first list again (A7 score). Subsequently, the subject is given a 50-word vocabulary list consisting of words from lists A and B as well as words not included in both lists (20 words), and asked to mark the words included in the first list (list A) (A8 score). This study employs total free recall score/verbal learning score (A1-5), one of the most frequently-used scores of AVLT in the literature, post-interference recall score/early recall score (A6), delayed recall/delayed recall score (A7), and auditory verbal recognition test score (A-8).

Serial Digit Learning Test (SDLT): The test was developed by Zangwill (Zangwill 1943), and standardized for Turkish society (Karakaş et al., 1996). Its goal is to assess the memory and learning ability. The test is sensitive to any damages in medial temporal area, hippocampus, limbic system, and frontal lobe structures. The test has two serial digits composed of 8- and 9-digit series where digits 1 to 9 are sorted in a mixed manner. One of these series is selected based on the age and educational background of the subject. Such series is read to the subject in an orderly manner and the subject is asked to recall and enumerate the series in the correct order. This is repeated 12 times in total. The test is terminated when the subject correctly recalls the series twice in a row. In the evaluation phase, the number of attempts until the full learning is achieved and the total score is considered.

Statistical Analysis

The data obtained was analyzed using the IBM SPSS 21.0 package program. The numeric variables were compared using the One Way Variance Analysis & Three Factor Analysis of Covariance whereas, the Post Hoc Sidak test was used to determine the groups giving rise to the difference. Categorical variables were analyzed using the Chi-Square Analysis, and the Spearman Correlation Analysis was employed to analyze the relationship between the continuous variables. In the results obtained, a p-value less than 0.05 was considered statistically significant.

RESULTS

The current smokers participants consisted of 28 females (39.4%) and 43 males (60.6%) whereas, former smokers consisted of 18 females (46.2%) and 21 (53.8%) males. Non-smokers consisted of 38 females (77.6%) and 11 males (22.4%). On the other hand, current smokers consisted of 20 elementary education graduates (28.2%), 27 secondary education graduates (38.0%), and 24 university graduates (33.8%), whereas former smokers consisted of 4 elementary education graduates (10.3%), 12 secondary education graduates (30.8%) and 23 university graduates (59%). The non-smokers consisted of 6 elementary education graduates (12.2%), 24 secondary education graduates (49.0%), and 19 university graduates (38.8%). The mean age of the group of current smokers was 41.28±11.98 whereas, that of the group of former smokers and non-smokers was 43.85±9.16 and 32.51±10.92, respectively. Among the three groups, a statistically significant difference was found in terms of gender, educational background and age (respectively x^2=17.80 p<0.05; x^2=11.79 p<0.05; F=13.75 p<0.001). The FTND score average for the group of current smokers was found to be 4.77±2.87. The group of former smokers were smoke-free for about 457.52±811.72 days on average. A comparison made between the study groups in terms of their sociodemographic characteristics and variables related to the cigarette smoking are given in Table 1.

While the WCST response, WCST error, and TMT-B time scores were found to be significantly higher in the group of

Table 1. Comparison of the sociodemographic characteristics of the study groups with respect to the variables related to cigarette smoking and smoking cessation

	Current smokers (n=71) n (%)	Former smokers (n=39) n (%)	Non-smokers (n=49) n (%)	X^2	p
Gender					
Female	28 (39.4%)	18 (46.2%)	38 (77.6%)	17.80	<0.05
Male	43 (60.6%)	21 (53.8%)	11 (22.4%)		
Education					
Elementary	20 (28.2%)	4 (10.3%)	6 (12.2%)		
Secondary	27 (38.0%)	12 (30.8%)	24 (49.0%)	11.79	<0.05
University	24 (33.8%)	23 (59.0%)	19 (38.8%)		
	mean±sd	**mean±sd**	**mean±sd**	**F/t**	
Age	41.28±11.98	43.85±9.16	32.51±10.92	13.75	<0.001
Age of smoke starting	16.47±5.08	16.23±4.99		0.23	>0.05
Age of first package	18.13±5.18	18.25±4.28		-0.13	>0.05
Total amount cigarettes/day	18.98±11.24	17.74±9.52		0.56	>0.05
Year of smoking	21.62±11.95	11.59±9.46		4.19	>0.05
Number of quit attempts	2.49±2.01	2.06±0.99		0.86	>0.05

Table 2. Variables showing significant differences among the groups according to one way ANOVA

	Current smokers (n=71) mean±sd	Former smokers (n=39) mean±sd	Non-smokers (n=49) mean±sd	F	p	PostHoc Sidak
WCST						
response	34.35±24.71	24.23±19.14	22.76±14.57	5.45	<0.01	1>2, 1>3
error	29.42±19.28	20.59±15.11	20.12±12.26	6.05	<0.01	1>2, 1>3
ST-2 correction	0.66±0.23	0.21±0.52	0.02±0.14	4.25	<0.01	2>3
ST-3 time	12.97±3.74	12.62±3.98	11.31±2.51	0.08	<0.05	1>3
ST-4 time	18.12±7.34	16.79±7.49	14.43±3.19	4.83	<0.01	1>3
TMT-A time	37.11±20.36	32.69±13.74	27.62±8.29	5.09	<0.01	1>3
TMT-B time	93.41±54.24	79.95±37.05	61.33±21.12	8.17	<0.001	1>2, 1>3
AVLT						
Verbal learning	47.35±9.51	52.62±8.47	53.47±7.23	8.83	<0.001	1>2, 1>3
Free short recall	10.01±2.77	10.89±3.25	11.51±2.01	4.62	<0.01	1>3
Free delayed recall	9.53±3.39	11.60±3.39	11.00±2.39	4.32	<0.01	1>3
recognition	12.33±3.98	14.56±2.26	14.43±2.23	9.19	<0.001	1>2, 1>3

1=current smokers, 2=former smokers, 3=non-smokers
WCST= Wisconsin Card Sorting Test, ST=Stroop Test, TMT= Trail Making Test, AVLT=Auditory Verbal Learning Test

Table 3. Variables that show significant differences among groups according to the result of three factor covariance analysis

	Difference between the averages	SF of difference	T PostHoc sidak	P
ST-4 time				
Smokers*	-3.51	1.25	-2.86	<0.01
Non-smokers				
TMT- B time				
Smokers*	-22.90	8.93	-2.57	<0.05
Non-smokers	-26.08	10.55	-2.47	<0.05
Former smokers*				
Non-smokers				
AVLT verbal				
learning Smokers*	4.43	1.80	2.46	<0.05
Former smokers	4.08	1.73	2.35	<0.05
Smokers*				
Non-smokers				

ST=Stroop Test, TMT= Trail Making Test, AVLT=Auditory Verbal Learning Test

Table 4. The mean of the test and scale scores, which differ significantly according to the results of three-factor covariance analysis

	Current smokers (n=71) mean±sd	Former smokers (n=39) mean±sd	Non-smokers (n=49) mean±sd
ST-4 time	18.13±4.64	16.79±4.52	14.43±2.31
TMT-B time	93.23±31.35	79.95±26.23	61.31±12.12
AVLT verbal learning	47.35±5.76	52.62±4.66	53.47±4.49

ST=Stroop Test, TMT= Trail Making Test, AVLT=Auditory Verbal Learning Test

Table 5. The correlation of between test scores and total amount cigarette/day, year of smoking

	Total amount cigarettes/day r (p)	Year of smoking r (p)
ST-time		
Current smokers	0.06 (>0.05)	0.65 (<0.01)
Former smokers	.35 (<0.05)	0.26 (>0.05)
TMT-B time		
Current smokers	0.40 (<0.01)	0.72 (<0.01)
Former smokers	0.29 (>0.05)	0.21 (>0.05)
AVLT verbal learning		
Current smokers	-0.31 (<0.01)	-0.34 (<0.05)
Former smokers	-0.45(<0.01)	-0.45 (<0.01)

ST=Stroop Test, TMT= Trail Making Test, AVLT=Auditory Verbal Learning Test
Spearman Correlation Analysis

current smokers compared to the group of former smokers and of non-smokers, the AVLT free recall/verbal learning & AVLT recognition scores were significantly lower in the group of current smokers compared to the two other groups ($p<0.01$, $p<0.01$, $p<0.001$, $p<0.001$, and $p<0.001$, respectively). ST-2 correction scores were also higher in the group of former smokers compared to the group of non-smokers ($p<0.01$). In the group of current smokers, the ST-3 time, ST-4 time, TMT-A time scores were significantly higher than those in the group of non-smokers. However, AVLT short-term free recall/memory and AVLT long-term free recall/memory scores were significantly lower ($p<0.05$, $p<0.01$, $p<0.01$, $p<0.01$, and $p<0.01$, respectively) (Table 2).

In order to eliminate the effects of variables 'age', 'gender' and 'educational background' on comparisons of cognitive functions, the groups were compared using Three-Factor Analysis of Covariance in terms of retest results and underwent post-hoc Sidak test. Whereas the AVLT free recall/verbal learning score was significantly lower in the group of current smokers compared to the group of former smokers and of non-smokers ($p<0.05$ and $p<0.05$, respectively), there was no significant difference between the group of former smokers and that of non-smokers. The time scores obtained from ST-4 determining the basic level of color-naming speed at the Card 4 in Stroop Test were significantly higher in the group of current smokers compared to the group of non-smokers ($p<0.01$). The Trail-Making Test-B time score was significantly higher in the group of current smokers compared to the group of non-smokers, and in the group of former smokers compared to the group of non-smokers ($p<0.05$ and $p<0.05$, respectively) (Table 3 and 4).

There was a significant negative correlation between the AVLT verbal learning scores and the amount and duration of smoking of the group of current smokers and the group of former smokers. In addition, a significant positive correlation between the TMT-B time and the amount and duration of smoking of the group of current smokers. A significant positive correlation was also shown between the S4-time score & duration of smoking of the group of current smokers and the S4-time score and amount of smoking of the group of former smokers (Table 5).

DISCUSSION

This study is of particular importance since it is the first study in our country to analyze the correlation between smoking and cognitive functions, and participants with no physical diseases and psychiatric disorders other than nicotine dependence.

Independent of age, sex and educational level, the data obtained in our study showed that people with chronic cigarette smoking displayed a performance weaker than the non-smokers in AVLT free recall/verbal learning. In addition, they had a lower processing speed, which was evaluated by TMT-B time & ST-4 time. In Trail-Making Test, the processing speed of former smokers was found to be lower than that of the non-smokers. The performance of former smokers was higher than that of smokers in AVLT free recall/verbal learning. Also, there was a correlation between the scores obtained by current smokers from all three tests and the years of smoking, TMT-B time and AVLT verbal learning scores, and the amount of smoking.

In their study assessing the correlation between childhood IQ, smoking and cognitive changes from age 11 to 64, Whalley et al. (2005) found that the smoking history of smokers had a correlation with lower performance psychomotor speed and cognitive tests, including the AVLT, compared to former smokers and non-smokers. Multiple regression analysis showed that smoking cigarettes had a small but significant effect on cognitive functions. The study conducted by Starr et al. (2007) also analyzed the correlation between cognitive functions and smoking from age 11 to 66, and reported the adverse effects of smoking on the verbal memory and information processing processes evaluated by the AVLT. Consistently with our study, both studies revealed that the verbal memory was weaker in smokers compared to former smokers and non-smokers. A study conducted by Richards et al. (2003) investigated the correlation between cognitive loss and smoking from age 43 to 53 in a community based study. In this study, the verbal memory is assessed using a measurement tool different from AVLT (15-word vocabulary learning task). Cigarette smoking was found to be associated with greater loss in verbal memory from age 43 to 53. In addition, this loss was reported to be more severe in those smoking more than 20 cigarettes a day compared to those who smoke less. Our study showed that the AVLT free recall scores was associated with both the smoking history (in years) and the daily amount of smoking. In their study, Paul et al. (2006) employed a computer-assisted cognitive test battery and found that the auditory attention and executive functions of the group of current smokers was poorer compared to the group of non-smokers. These studies, conducted using different measurement tools, found a correlation between smoking and verbal memory impairment consistently with the present study. Fried et al. (2006) found that there was a loss in the domains of word comprehension and expression, verbal arithmetic, auditory memory in smokers, and the duration of smoking predicted the loss in cognitive functions. It was also put forward that nicotinic receptors are included in the cholinergic system and the cholinergic pathways play a role in the hearing system, which may theoretically be responsible for cognitive loss related to hearing function (Fried et al., 2006). In their study, Sabia et al. (2008) reports that the cigarette smoking is a risk factor in terms of impairment in cognitive functions such as short-term verbal memory, vocabulary, verbal fluency. This risk was lower for those who were smoke-free for a long time compared to current smokers and those who recently quit smoking. It was also revealed by the present study that the auditory-verbal learning performance was poorer in current smokers compared to former smokers and non-smokers, and there was no significant difference between former smokers and non-smokers.

In addition to attention, the Stroop Test was reported to also evaluate an individual's cognitive rigidity-plasticity degree and information processing speed (Karakaş et al., 1998). Caspers et al. (2010) reported that the negative effect between cigarette smoking and ST performance was found in women, and there was no relationship between cognitive abilities and smoking in men. This study assessed the part 'fulfillment of a task under interference effect' of ST. However, in their study using curtailed ST, Kalmijn et al. (2002) reported that ST performance was weaker in the group of current smokers compared to the group of lifelong non-smokers. No significant difference was found compared to the group of former smokers. There were also other studies reporting no significant differences between the smokers and non-smokers in terms of ST (Wagner et al., 2012, Schinka et al., 2002, Schinka et al., 2003). Furthermore, the study of Wagner et al. (2012) assessed the performance in the part 'fulfillment of a task under an interference effect', namely Card 5, of ST. Our study evaluated both time and error scores of each of the 5 cards in ST and found that only the processing speed of the Card 4 was lower in the group of smokers compared to the group of non-smokers. There was no significant difference between the group of former smokers and the group of smokers, and this loss of function was associated with the year of smoking. In Stroop Test TBAG (The Basic Sciences Research Group of

TUBITAK) form reliability study conducted by Karakaş et al. (1996), the highest reliability coefficient was obtained for the ST-4 time score. The contradictory difference in selection of sample groups among the study results (in terms of size, gender, age) may be due to the use of different ST forms and scoring systems.

Evaluating such executive functions as working memory, such as complex attention, planning and set shifting, the TMT has been shown to constitute a test that requires visual-spatial processing and motor abilities. IST-B was more difficult than part A that evaluated the visual scanning and mental scanning. In the present study, the TMT-B processing speed was found to be lower in smokers and former smokers compared to the non-smokers. Such slowdown was found to be associated with the duration and amount of smoking. In their study, Schinka et al. (2003) found no significant difference in TMT results between the smokers and non-smokers. However, in this study, the age range of sample group was 60 to 84 years, and the cigarette smoking was accompanied by the history of alcohol use. In their study conducted on 2.163 people in 7 centers, Wagner et al. (2012) reported that the performance in TMT-A and TMT-B, evaluating the visual attention, were lower in current smokers than non-smokers, which is consistent with the present study.

The correlation between cessation of smoking and cognitive abilities is complex. In certain studies, no significant difference was found between former smokers and non-smokers in terms of cognitive functions. Nevertheless, the studies taking into consideration how long ago smoking was quit found that those who quit long ago had better cognitive functions than those who quit recently (Sabia et al., 2008). In terms of AVLT verbal learning scores, however, no difference was found between the non-smokers and former smokers, and both groups showed better performance than smokers in AVLT verbal learning. The present study, however, found no statistical difference between the former smokers and non-smokers in terms of verbal learning. The TMT-B processing speed of both the current smokers and former smokers was found to be lower than non-smokers. In addition, TMT-B processing speed of former smokers was lower than the current smokers although not statistically significant. The results of our study indicate that the cognitive impairment caused by smoking can be recovered after quitting smoking. In the study conducted by Yakir et al. (2007), non-smokers were found to be better at sustaining attention and better at impulse control and planning performances. Conversely, no difference was found between current smokers and former smokers. Wagner et al. (2012) commented that the deficiencies identified by Yakir et al. may be a susceptibility factor for cigarette smoking behavior. Since the neuropsychological deficiencies we found in our study are present in former smokers among non-smokers and current smokers, we believe that these deficiencies stem from chronic use rather than leading to disposition. The fact that cognitive deficiencies we found in the present study are associated with the amount and duration of smoking supports the view that the toxicity caused by the accumulated nicotine or tobacco leads to cognitive impairment in smokers. It has been supported by many studies that the amount and duration of cigarette smoking was closely associated with neurocognitive impairment (Wagner et al., 2012, Yakir et al., 2007, Durazzo et al., 2010, Durazzo et al., 2012, Kalmijn et al., 2002).

The major limitation in our study were the facts that the sample was relatively small. In addition, there were differences between groups in terms of educational background, gender, and age. Even though these variations were statistically controlled, the level of general cognitive performance of the participants in the study was not evaluated using a more general criterion such as WAIS (Wechsler Adult Intelligence Scale).

This study draws attention to the fact that, in a group with no physical disease and psychiatric disorder, the domains of auditory-verbal memory, visual-spatial processing, and attention may be a selective deficiency domain in smokers. Our results need to be verified through future research that focuses on the areas of deficiency identified in this study.

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