

Effects of Smoking and Smoking Cues on Prospective Memory*

Gün Pakyürek¹, Banu Cangöz-Tavat²

¹Department of Clinical Psychology, Izmir Democracy University, Izmir, Türkiye

²Department of Experimental Psychology, Hacettepe University, Ankara, Türkiye

ORCID iDs of the authors: G.P. 0000-0002-1373-9109, B.C.-T. 0000-0003-2213-3261

Main Points

- Smoking had a negative effect on prospective memory.
- The Turkish version of Virtual Week is a reliable measurement tool for evaluating prospective memory performance in young adults and smokers.
- Among smokers, smoking-related cues had only a minor impact on their prospective memory performance.
- This research contributes to our understanding of cognitive processes of smoking behavior.

Abstract

This study aimed to investigate the effects of smoking and smoking-related cues on prospective memory (PM). A total of 120 participants, 60 smokers, and 60 non-smokers, were included in the study. The study utilized a task called “Virtual Week” (VW), which consisted of a training day and three virtual days, encompassing 30 PM tasks. Dependent variables were VW completion duration and correct answers on VW. The study revealed that smokers had a significantly lower rate of correct responses in PM tasks compared to non-smokers. Among smokers, the type of cue (smoking-related or unrelated) had only a slight impact on their PM performance. For smokers, the Spearman-Brown split-half reliability coefficient was found to be .74, and Cronbach’s alpha was .76. In summary, smoking was shown to have a detrimental effect on the ability to remember future tasks, aligning with previous research suggesting that smokers perceive deficits in their PM. However, the study only partially supported the theory of cue reactivity, as the type of cue had only a minor influence on smokers’ PM performance. This research contributes to our understanding of the cognitive consequences of smoking and the role of cues in prospective memory among young individuals.

Keywords: Memory, nicotine, prospective memory, smoking, tobacco

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Corresponding author:

Gün Pakyürek

E-mail:

gun.pakyurek@idu.edu.tr

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Introduction

Although there are approximately 4000 chemicals in tobacco smoke, one of the main components is nicotine, which is seen as the primary factor in the formation, development, and maintenance of addiction (Lujic et al., 2005). A better understanding of the effect of smoking on cognitive processes can contribute to developing models for addiction, discovering the role of nicotine addiction in various psychiatric and neurological disorders, developing new treatment methods to prevent addiction, deciding on stages of treatment to be taken during the addiction phase, and

preventing relapse that may occur after treatment (McClernon & Gilbert, 2004).

The difficulty people have in reducing their smoking is not due to the pharmacological effects of nicotine alone (Lujic et al., 2005). Rather, stimuli associated with nicotine may also reveal similar psychological, physiological, and behavioral effects that occur in the presence or absence of nicotine (Carter & Tiffany, 1999). Nicotine-related visual cues (image of a smoking person), information from various sensory channels associated with cigarettes (holding, the sound of the lighter, and the smell), and contextual cues related to cigarettes (drinking coffee,

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drinking alcohol, and driving) act as conditioned stimuli to the smoker and can lead to differentiation on cognitive processes (Carter & Tiffany, 1999). Thus, other methods of delivery used in nicotine replacement treatment, such as nicotine gum, patches, and spray, are not very successful in the termination of smoking (Stanley & Massey, 2016). One of the reasons for the failure of cue exposure treatment is that the behavior extinguished by classical conditioning in the clinical environment is acquired because of context-specific conditioning which refers to associations formed between stimuli and responses that are influenced by the context in which the learning occurs (Heald et al., 2023). Cue reactivity is particularly relevant in the context of addiction, where cues associated with substance use can provoke cravings, and drug-seeking, and potentially lead to relapse (Carter & Tiffany, 1999). Cue reactivity is inferred from the differences between smoking-related cues and neutral control cues when taking behavioral cognitive measurements.

Cue reactivity studies also address memory, expectations, and attention processes (Franken, 2003). Smokers' smoking level, abstinence level, arousal level, and task characteristics, such as cognitive and attentional load, have been manipulated in various studies (Heishman et al., 2010; Pakyürek & Şenyüz, 2019). In general, smokers forget their intention of quitting smoking when they encounter smoking-related cues. At this point, prospective memory (PM) which is the ability to remember future tasks, is thought to be one of the possible mechanisms to explain this retrieval memory error (Brandon et al., 2004). According to McDaniel and Einstein (2007), remembering the planned action is achieved through automatic or controlled processes depending on the nature of the task or the relevant cue. Which method will be active may vary depending on the strength between the task and the cue (Einstein et al., 2005). Einstein et al. (2005) stated that there were two types of cues: focal and non-focal. While focal cues are located within the ongoing task, nonfocal cues are located outside the ongoing task. Nonfocal cues are generally time-based internal cues that require strategic monitoring to retrieve the planned action and require the use of prefrontal resources. Focal cues spontaneously restore the PM task during the ongoing task, and this process is associated with the hippocampus (Burgess et al. 2011).

Levent and Davelaar (2022) showed that drug users perform worse than non-drug users on PM tasks. Tasks with alcohol, cannabis, ecstasy, and methamphetamine have high ecological validity through behavioral measurement but it is not clear whether smoking has the same negative effect on PM (Platt et al., 2019). Rendell and Henry (2009) used a computerized Virtual Week (VW), which is a task that has relatively high ecological validity and measures both time-based and event-based PM tasks. Therefore novelty of the present study is that smokers' PM performance under the smoking cue condition. This study investigated PM and smoking cues via Turkish Virtual Week (Pakyürek & Cangöz-Tavat, 2023). Smoking status, smoking cues, and focal-ity of cues were independent variables and the dependent variables were VW completion duration and correct answers on VW.

Aim of the Study

The main purpose of this study is to examine how smoking and smoking cues affect performance in terms of PM. The secondary aim of this study is to adapt computerized VW (Rendell &

Henry, 2009), which is considered a PM task, to Turkish culture, as well as to test its functioning on a young smoking sample. The hypotheses are:

1. Smokers have lower performance on the PM task than non-smokers.
2. Smokers who are exposed to smoking-related cues have lower performance on the PM task compared to the groups exposed to non-smoking-related cues and not given any cues.
3. Smokers complete the VW faster than non-smokers.
4. VW is a reliable tool in terms of measuring differences in PM performance in smoking.

Material Methods

The study included 120 volunteers ($M = 21.51$, $SD = 2.85$), 60 smokers (women = 30, men = 30) and 60 non-smokers (women = 30, men = 30). Although a total of 159 people participated in the study, the data of 39 people were not included in the analysis for various reasons (high Beck Depression Inventory [BDI] score, change in the amount or status of smoking, technical problems). According to the G*Power analysis, it was sufficient to collect data from 111 participants with a power of 80% and a margin of error of 0.05. The mean and standard deviation of the participants' BDI and Fagerström Test for Nicotine Dependence (FTND) scores are given in Table 1. Ethics Commission Approval was received from the Aydın Adnan Menderes University Ethics Commission (Approval no: 35853172/433-664 Date: 11.03.2016). Written informed consent was obtained from the participants.

Materials

Fagerström Test for Nicotine Dependence

The FTND is a six-question test that was developed to determine the level of addiction that occurs because of smoking; it was initially developed by Fagerström in 1978, and it was later updated and finalized (Heatherton et al., 1991). The lowest score that can be obtained from this test is 0, whereas the highest score is 10. Cronbach's alpha coefficient of the scale was 0.56 and it was found to be moderately reliable. (Uysal et al., 2004).

Beck Depression Inventory

The BDI is a 21-item scale that measures depression symptoms through self-assessment. Each item is assigned a score between 0 and 3 points, and a high score on the scale is an indicator of high depressive symptoms. The Turkish adaptation of the original scale was established by Hisli (1989). To control for the

Table 1.
Mean and Standard Deviation of Participants' Age, Beck Depression Inventory (BDI) and Fagerström Test for Nicotine Dependence (FTND) Scores

	FTND	BDI	Age
<i>Smokers</i>			
\bar{X} (SS)	3.25 (2.03)	11.08 (4.51)	21.03 (2.25)
<i>Non-Smokers</i>	–		
\bar{X} (SS)		8.20 (4.80)	21.98 (3.30)
<i>Total</i>	–		
\bar{X} (SS)		9.64 (4.86)	21.51 (2.85)

confounding effect of depression, which has the potential to affect the memory performance of participants, the cut-off point for the BDI was determined as 17 or above.

Virtual Week Task

Virtual week consists of two types of tasks: regular tasks routinely performed every day and irregular tasks conducted only for that day and that hour (Rendell & Henry, 2009). Regular event tasks such as taking medication at breakfast and dinner, regular time tasks taking asthma medication at 11:00 am and 9:00 pm, and time check tasks performing lung function tests at 2 minutes and 4 minutes after the virtual day starts. Irregular tasks are specific to each day.

Some cards provide event-related cues, while others provide time-related cues. Time check tasks that must be done after a certain time has passed.

When the main image of VW in Figure 1 is displayed, the participant has to click on the starting card. A virtual dice is thrown over the main game image illustrated in Figure 1 (by clicking on the dice image) and the game is continued by moving to the left on the squares. In the lower right corner, there is a box "Event Card" in green. When the letter "E", which symbolizes the green event card, is reached or passed over, an event card is drawn and a question with three options is answered on the card about an activity of the day. After reading the event card and choosing the most likely action to take in daily life, the participant rolls the virtual dice again and continues to progress throughout the day. Virtual days start at 7.00 in the morning and end at 22.30. Two squares progress in VW is equal to a virtual time-lapse of 15 minutes. Regardless of the tasks, there is a real-time digital stopwatch on the main screen, and PM tasks are given according to this stopwatch (e.g., having a lung function test when the stopwatch shows the 2nd and 4th minutes after the virtual day starts). The execution of the PM task is provided by clicking the purple-colored "Perform Task" box at the top right of the screen. Participants select tasks given at the beginning, and during the day, when the time comes, by pressing the Execute Task button and choosing from a list of the true PM tasks and distracting options.

Since the tasks in VW were created according to Western culture, some tasks and options were changed according to Turkish culture, and the task was updated (Pakyürek & Cangöz-Tavat, 2023). For example, Australian dishes such as porridge and cereal were replaced with local dishes such as gözleme and kebab. While making updates, the structure and length of the original sentences were adhered to.

Smoking-Related Cue Tasks

Cigarette-related and unrelated cue tasks were inspired by the studies of Özdemir (2018) and Shadel et al. (2001). While Özdemir (2018) made the change in cue tasks through video images, Shadel et al. (2001) had the participants apply it directly. In this study, the changes made by Özdemir (2018) through watching the video footage were carried out by having the participants directly apply them. The objects used for the smoking-related act are a bowl, three cigarettes, a lighter, and an ashtray. The objects to be used in the action not related to smoking are a bowl, three pencils, a sharpener, and a pencil case. In the no-action control condition, the participants waited silently for the duration of the smoking-related or unrelated cue.

Research Design

2 (Smoking Status: Smoker-Non-Smoker) \times 3 (Cue Type: Smoking-Related Cue-No Smoking-Related Cue- No Cue) factorial ANOVA was used for this quasi-experimental study. Smoking and cue type were manipulated between groups. Time check tasks were analyzed separately due to the real-time tasks. In addition, Cronbach's Alpha and Spearman-Brown split-half reliability coefficients of the Turkish-adapted VW were calculated based on PM tasks and smoking.

Procedure

The virtual week started with the first of the virtual days after the practice day was completed. The participants were randomly assigned to the cue-type conditions at the beginning of the virtual days. In the smoking-related action, before starting the first virtual day, they were asked to open the lid of the bowl in front of them and they were told to take out one of the three cigarettes in the bowl and the ashtray. They were then told to leave the ashtray and the cigarette in their hands on the left side of

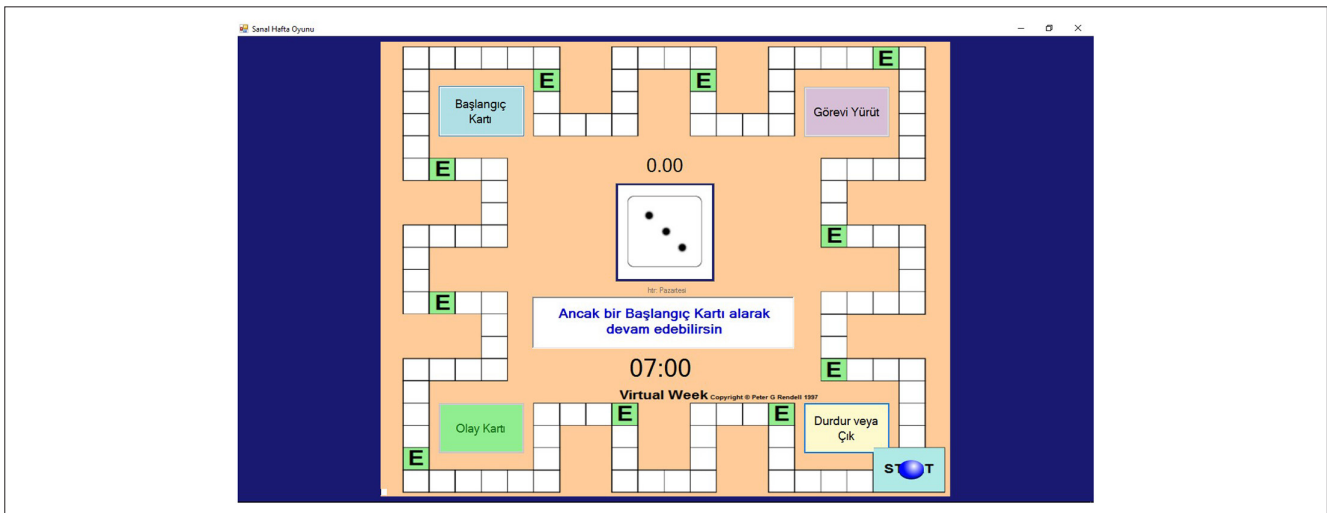


Figure 1. Main Screen of Virtual Week.

the screen. After closing the lid of the bowl and leaving it on the left side of the screen, the first virtual day started. Before starting the second virtual day, they were asked to reopen the lid of the bowl and take out one of the two cigarettes and the lighter in it. They were told to leave the cigarette and lighter on the left side of the screen next to the ashtray and close the lid of the bowl. Before starting the last virtual day, they were asked to open the lid of the bowl again and take out the last cigarette in it. They were asked to light the cigarette with the lighter next to the screen and extinguish it in the ashtray without taking a cigarette puff. In the non-cigarette-related action condition, all the procedures are the same as the cigarette-related action condition with one exception that participants hold a pencil, not a cigarette. In the no-action control condition, the participants were asked to wait silently for the duration of the action-related cues when starting the day. A recognition task was applied for the manipulation check at the end of each virtual day which involved a matching task given during the virtual days. If the participants were unsuccessful on the recognition task, it may indicate a problem in the encoding of information rather than a prospective memory error. VW includes a total of 10 p.m. tasks, including four regular (two event-based, two time-based), four irregular (two event-based, two time-based), and two-time check tasks. A total of 30 PM tasks are used throughout the main task. The dependent variables were time to execute duration and correct answers on VW.

Statistical Analysis

The findings were analyzed using the licensed version 23.0 of the Statistical Package for Social Sciences (IBM SPSS Corp.; Armonk, NY, USA). First of all, data cleaning procedures were performed to test the suitability of the data for statistical analyses; then, descriptives of demographic information, the Fagerstrom Nicotine Dependence Test (FBNT), Beck Depression Inventory (BDI) were analyzed. Finally, inferential/parametric analyses were conducted to test the hypotheses. In this context, Cronbach's alpha and Spearman-Brown two-half reliability coefficients were calculated to test the reliability of the VW, which was adapted to the Turkish culture. Two separate 2 (Smoking Status: Smoker-Non-smoker) \times 3 (Cue Type: Cue Related to Smoking-Cue Unrelated to Smoking- No Cue) factorial ANOVAs were conducted for the time to complete VW and the time check task.

Results

As a result of one-way ANOVA of smokers, FNBT scores ($F_{(2,57)} = .248$; $p = .78$), duration of smoking ($F_{(2,57)} = .154$; $p = .86$), and the number of daily cigarettes ($F_{(2,57)} = .597$; $p = .55$) do not show a significant difference according to the cue conditions. Smokers scored higher on BDI than non-smokers, but all participants had lower scores than the cut-off point 17, which is considered an indicator of depression.

According to the correct answers on the PM task, 2 (Smoking Status: Smoker-Non-Smoker) \times 3 (Smoking Cue Type: Smoking-Related Cue, No-Smoking Cue, No Cue) ANOVA result, with the main effect of cue status ($F_{(2,114)} = 1.11$, $p = .33$), smoking*cue type of cue ($F_{(2,114)} = .47$, $p = .63$) interaction effects were not statistically significant, while smoking ($F_{(1,114)} = 4.91$, $p = .03$, $\eta_p^2 = .04$), with the main effect were found to be statistically significant. The mean and standard deviation scores are given in Table 2.

Table 2.
Mean and Standard Deviation of Correct Answers on PM and Time Check Tasks

Smoking Status ($N = 120$)	Cue Type	Tasks	
		PM Tasks	Time Check Task
		Correct Answers $\bar{X} \pm SS$	Correct Answers $\bar{X} \pm SS$
Smokers $n = 60$	Smoking Related $n = 20$	0.65 ± 0.21	0.59 ± 0.17
	Unrelated Cue $n = 20$	0.69 ± 0.22	0.62 ± 0.19
	No Cue $n = 20$	0.74 ± 0.20	0.64 ± 0.19
Non Smokers $n = 60$	Smoking Related $n = 20$	0.75 ± 0.19	0.74 ± 0.19
	Unrelated Cue $n = 20$	0.76 ± 0.19	0.76 ± 0.19
	No Cue $n = 20$	0.77 ± 0.18	0.75 ± 0.18

Note: PM Task, prospective memory task.

The Main Effect of Smoking Status

When the correct answers on PM tasks are examined according to smoking, there is a significant difference between smokers ($M = .70$, $SE = .03$) and non-smokers ($M = .76$, $SE = .03$). see Figure 2.

Smoking and Cue Type Interaction

Post hoc comparisons based on smoking status showed a marginally significant difference between smokers in the smoking-related cue condition ($M = .65$, $SE = .05$) and non-smokers ($M = .75$, $SE = .05$) ($p = .06$) see Figure 3.

Time Check Task

Non-smokers ($M = .75$, $SE = .04$) were more successful on time check tasks with a significant difference compared to smokers ($M = .62$, $SE = .04$). see Figure 4.

The interaction effect of smoking \times cue type ($F_{(2,114)} = .10$, $p = .90$) was not significant.

Time to Execute Duration

Although smokers ($M = 1220.2$, $SE = 24.86$) completed their PM tasks faster than non-smokers ($M = 1287.1$, $SE = 24.86$), the difference between them was found to be marginally significant ($p = .06$). see Figure 5. The interaction effect of smoking*cue type ($F_{(2,114)} = .16$, $p = .85$) was not found significant.

Reliability

Cronbach's Alpha and Spearman-Brown two-half reliability coefficients were calculated to test the reliability of the VW used for the measurement of PM. Accordingly, the Cronbach's Alpha value of VW was 0.75 in all tasks; The Spearman-Brown two-half reliability coefficient was found to be 0.72. When examined in terms of only smokers, the Cronbach's Alpha value was 0.76 in all smokers; The Spearman-Brown split-half reliability coefficient was 0.74, while the Cronbach's Alpha value was 0.67 in

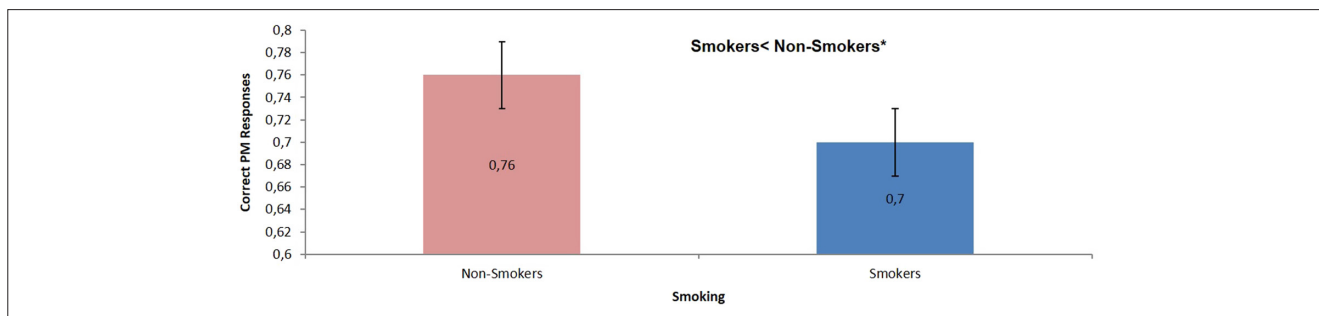


Figure 2. Correct PM Responses According to Smoking.

non-smokers; Spearman Brown’s two-half reliability coefficient was found to be 0.65.

Discussion

Smoking and Smoking Cues

Smokers’ correct answers on PM were found to be significantly lower than non-smokers. The first hypothesis was supported. It has been shown that PM performance decreases in other substance users such as alcohol use (Leitz et al., 2009), opiates (Terrett et al., 2014), ecstasy (Rendell et al., 2007), and methamphetamine (Rendell et al., 2009). Similarly, there was a decrease in PM performance in clinical groups, such as schizophrenia patients (Henry et al., 2007), Parkinson’s patients (Foster et al.,

2013), and patients with stroke (Kim et al., 2009). Although the smokers were young ($M = 21.03$, $SD = 2.25$) and did not have a long history of addiction ($M = 4.10$, $SD = 2.46$), smoking had a negative impact on VW performance. Smokers were more unsuccessful than non-smokers in terms of correct answers in complex PM tasks that also require the use of retrospective memory resources.

In cognitive models explaining cue reactivity, it is suggested that smoking-related cues will activate smoking-related experiences in short-term memory and create a cognitive load, resulting in a deterioration in cognitive performance (Cox et al., 2006). In addition, Carter and Tiffany (1999) emphasize the importance of automatic and non-automatic processes in their cognitive model. Repetitive substance use turns into an automatic behavior such as writing. Thus, cognition related to substance use begins to occur automatically, mostly without requiring effort and awareness. When access to substances is limited, in addition to the automatically activated schema for substance use, the conscious process that uses limited non-automatic resources comes into play in parallel (Carter & Tiffany, 1999).

Since searching requires effort and the cue has a disruptive effect on tasks with high cognitive load, it can be expected to deteriorate the relatively difficult PM performance (Brandon et al., 2004; Einstein et al., 2005). Although there was no significant difference related to the cue in the current study, we found a marginally significant difference between smokers ($M = .65$, $SE = .05$) and non-smokers ($M = .75$, $SE = .05$) in terms of PM performance in the smoking-related cue condition. The second hypothesis was partially supported. This finding suggests that smoking-related cues may be more effective in highly dependent smokers.

Smokers’ correct answers on time check tasks were found to be significantly lower than non-smokers. Time elapsed in time check tasks is real-time independent of VW compared to elapsed time

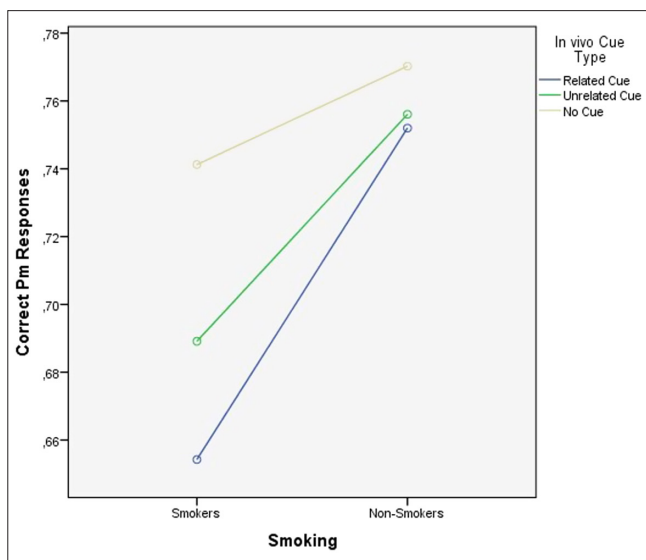


Figure 3. Correct PM Responses According to Cue Type and Smoking.

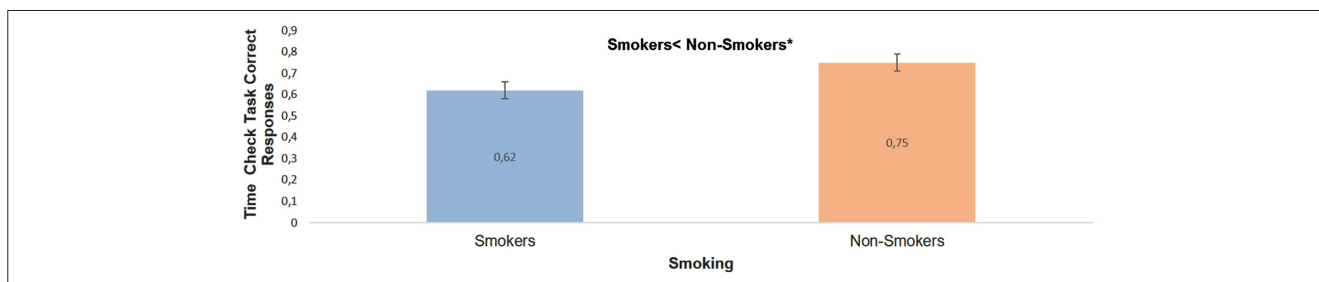


Figure 4. Time Check Correct Responses According to Smoking.

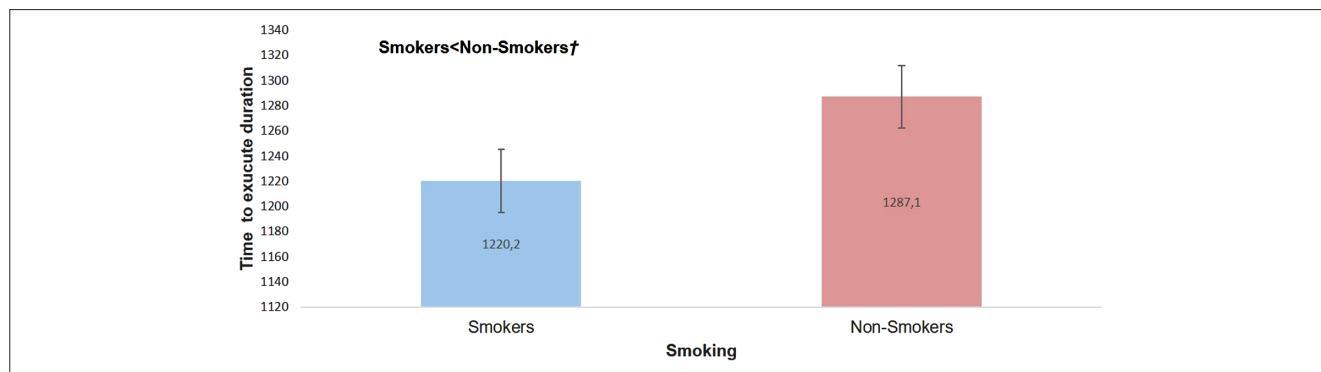


Figure 5. Time to Execute Duration According to Smoking.

in time-based tasks. Time check tasks were also analyzed (Mioni et al., 2015) because they were affected by time-related reasoning and time estimation ability (Einstein et al., 2005). The time check task was more difficult as it was done only in a certain time period and did not contain environmental cues compared to event-related tasks. Smokers are more unsuccessful in the task of time check, which is a difficult task compared to non-smokers. It has been suggested that nicotine negatively affects the time estimation ability by differentiating the perception of time in smokers (Klein et al., 2002).

Task Completion Duration

Smokers completed the VW approximately 1 minute and 10 seconds faster than nonsmokers. This difference was found marginally significant. The third hypothesis was partially supported. Overall, although smokers completed the VW faster, they were less accurate than nonsmokers. Smokers respond more quickly than nonsmokers (Heishman et al., 2010; Pakyürek & Şenyüz, 2019), and personality measures reveal that they tend to be more impulsive than nonsmokers (Geist & Herrmann, 1990). Impulsive individuals fail to inhibit and/or suppress their response to rewarding stimuli (Geist & Hermann, 1990). The fact that smokers are more impulsive may be one of the reasons why they complete the VW more quickly. Thus, it may be that smokers spend more effort using the cognitive strategies they have developed and prefer to complete the task faster at the expense of making more mistakes. In addition, smokers' number of cigarettes smoked per day ($M = 12.62$, $SD = 5.21$) may influence their level of abstinence. Because smokers know that they will experience the negative effects of nicotine withdrawal after a certain time period, they may learn to finish the task before withdrawal begins.

Based on cognitive models explaining cue reactivity (Cox et al., 2006) participants in the smoking-related cue condition were expected to complete the VW faster than in the non-smoking cue and no cue conditions. However, in the current study, the lack of a significant difference in the time it took to complete the VW compared to the cue type may be due to the short duration of the cue-type effect and the fact that the participants were young and had just developed an addiction.

Reliability

In reliability studies on VW, Rose et al. (2010) found that the Spearman-Brown split-half reliability coefficient was .71 for the healthy young group and .93 for the healthy elderly group. The Spearman – Brown split-half reliability coefficient was found to

be .74 for schizophrenia patients (Henry et al., 2007) and .85 for long-term opiate users (Terrett et al., 2014). The internal consistency coefficient (Cronbach's alpha) of VW was found to be .89 in individuals with brain injury (Mioni et al., 2013) and .89 in patients with Parkinson's disease (Foster et al., 2013). The internal consistency coefficient (Cronbach's alpha) was .64 for the Italian version of the VW, which was adapted for cultures whose native language was not English; it was found to be .92 for the elderly group (Mioni et al., 2015). The internal consistency coefficient (Cronbach's alpha) of the VW applied to healthy young and old people in Poland was found to be .61 and .87, respectively, while Spearman Brown's two-half reliability coefficient was found to be .75 for young people and .95 for the elderly (Niedźwieńska et al., 2016). Lastly, Spearman Brown's two-half reliability coefficient was found to be .85 for young people and .95 for the elderly in the French version of VW (Blondelle et al., 2024). Virtual week has been adapted to Turkish culture and shown to be reliable (Spearman-Brown: .82). The fourth hypothesis was supported but the reliability was relatively lower compared to Western countries. Smoking status and cue manipulation might be the reason for lower reliability but it is still at an acceptable level.

Limitations and Future Directions

Smoking had a negative effect on PM, but smoking-related cues did not create a sufficiently disruptive effect in terms of correct responses or task completion duration in the PM task. Using the level of abstinence as an independent variable and looking at the difference in VW performance between light smokers and heavy smokers could also provide useful information. It is known that participants who smoke are more impulsive. For this reason, using impulsivity levels as covariables can contribute to the data analysis.

In the smoking-related cue, and unrelated cue conditions, participants held a cigarette or pen as an in vivo cue before and after the task and performed a specific action with them. Because these cues were performed independently of the VW, the incorporated effect of smoking-related cues attached to tasks such as "buy a cigarette on the way home" in the VW may provide useful information. In addition, presenting cigarette-related cues daily in a laboratory environment where smoking is prohibited may have reduced the effectiveness of contextual cues.

In general, smoking can negatively affect the PM process. In addition, smokers who want to quit smoking may benefit from avoiding smoking cues. Lastly, we show that the Turkish version

of the VW is a reliable measurement tool for evaluating PM performance in young adults and smokers.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Aydın Adnan Menderes University (Approval No: 35853172/433-664; Date: 11.03.2016).

Informed Consent: Written informed consent was obtained from the participants who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

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