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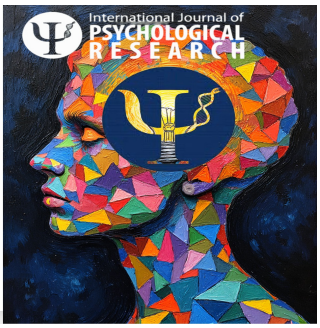

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Gender and Smoking Pattern Differences in Behavioral Disinhibition

Diferencias de género y patrones de consumo de tabaco en la desinhibición conductual

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Abstract.
The influence of behavioral disinhibition may vary according to the way this parameter is assessed and in relation to different patterns of smoke. This study evaluated the effect of gender, levels of addiction, nicotine deprivation and smoking patterns on behavioral disinhibition in smokers and nonsmokers. A sample of 180 participants from 18 to 30 years old was recruited to complete the Parametric Go/No-Go (PGNG) and Stop Signal Task (SST). The results identified that smokers have more difficulty inhibiting a prepotent response than nonsmokers in SST, but not with PGNG. Female nonsmokers presented shorter SSRT than male nonsmokers and smokers. Moderate to high nicotine dependence influenced the poor precision on no-go trials of PGNG. Smoking treatment should not be directly influenced by gender, but understanding the effects of smoking history and nicotine deprivation is a key aspect in facilitating smoking cessation and prevention.

Resumen.
La influencia de la desinhibición conductual puede variar según la forma en que se evalúe y con relación a los diferentes patrones de tabaquismo. Este estudio evaluó el efecto del género, niveles de adicción, privación de nicotina y patrones de tabaquismo sobre la desinhibición conductual en fumadores y no fumadores. Se reclutó una muestra de 180 participantes entre 18 a 30 años para completar el Go/No-Go Paramétrico (PGNG) y el Stop Signal Task (SST). Los resultados identificaron que los fumadores tienen más dificultades para inhibir una respuesta prepotente que los no fumadores en SST, pero no en PGNG. Las mujeres no fumadoras presentaron SSRT más corta que los hombres no fumadores y fumadores. La dependencia de nicotina de moderada a alta influyó en la escasa precisión en los ensayos no-go del PGNG. El tratamiento del tabaquismo no debe estar directamente influenciado por el sexo, pero comprender el impacto del historial de tabaquismo y la privación de nicotina son aspectos clave para facilitar el abandono y prevención.

Keywords.
Smokers, Nonsmokers, Behavioral Disinhibition, Stop Signal Task, Smoking Patterns.

Palabras Clave.
Fumadores, no fumadores, desinhibición conductual, Stop Signal Task, patrones de consumo.

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1. Introduction

There is extensive literature that relates impulsivity to various health risk behaviors, especially those associated with drug use (Kolokotroni et al., 2024; Fantin et al., 2024; Abbott et al., 2022). Several clinical, behavioral and cognitive instruments have highlighted that chronic cigarette smokers have higher levels of impulsivity compared to non-smokers (Conti & Baldacchino, 2022; Masaki et al., 2022; Fattore & Melis, 2016). In addition, impulsivity has been found to play a critical role in the development and maintenance of cigarette smoking, nicotine dependence, relapse, higher levels of craving after a period of withdrawal and tobacco use to alleviate negative affect (Elatfy et al., 2024).

The literature is consistent on the relationship between impulsive behavior and smoking, however, studies have not fully delineated which components of impulsivity contribute to the maintenance of tobacco use in different states of addiction. This is because there are important divergences regarding the epistemological approach adopted for research on impulsivity in the different areas of knowledge, which has given rise to the acceptance of the multifaceted character of the said construct (de Almeida Cunha & Martínez-Munguía, 2021).

Koenn et al. (2023) presuppose that there is a generally accepted notion, from which it is possible to discuss the common factors, which participate in impulsivity in the different theoretical approaches, such as a) attentional failures, which refer to the attentional deficit; b) lack of inhibition, which is related to the motor aspect; and, c) insensitivity to consequences, which is associated with the behavioral dimension of the construct and which is based on the perception of the value of reinforcers. Although there are many ways to measure impulsivity, Strickland & Johnson (2021) argued that impulsive traits and behaviors are largely uncorrelated and fail to load onto a single and superordinate latent variable. Moreover, they found that modern neuroscience has failed to identify a specific and central neurobehavioral mechanism that underlies impulsivity. This suggests that it is recommendable to talk about underlying behaviors of impulsivity.

One of the most studied underlying components of impulsivity involves behavioral disinhibition. This has to do with the inability to control a response that has been previously initiated, or the suppression of an automatic response (Weidacker et al., 2016). Kang et al. (2022) assume that inhibitory control does not refer to a single executive function, but consists of several components, such as inhibition of prepotent responses, interruption of an initiated response, and inhibition of processes that interfere with the initiated response. The main tests for measuring behavioral disinhibition are: Stop Signal Task - SST (Verbruggen & Logan, 2009) and Go/no-go Task (Langenecker et al., 2007).

The Stop Signal Reaction Task was developed to investigate response inhibition in a controlled laboratory setting (Verbruggen et al., 2009). The Parametric Go/No-Go Task (PGNG) proposed by Langenecker et al. (2007) considers several factors of behavioral disinhibition and seems to reach cognitive components (such as executive functions) that the other tasks cannot measure. The result is the possibility of eliminating the floor and ceiling effects of traditional Go/No-Go tasks (Weidacker et al., 2016).

Some studies have presented discrepant results regarding response inhibition in traditional Go/no-go Task or the Stop Signal Reaction Task between smokers and nonsmokers. In some studies, smokers tend to present poorer response inhibition compared to non-smokers (Tsegaye et al., 2021; Zhao & Chen, 2023), but in others, the results are not confirmed (Kolokotroni et al., 2024; Wilcockson et al., 2021). These results suggest that, despite evidence for the influence of response control inability on the maintenance of cigarette smoking, the role of behavioral disinhibition or other facets of impulsivity in the different stages of addiction needs further investigation.

The influence of behaviors underlying impulsivity, such as behavioral disinhibition for example, may vary according to the way this parameter is assessed and in relation to different types of smokers, gender, deprivation and levels of nicotine dependence (Kolokotroni et al., 2024). For example, the study by Zhao et al. (2016) analyzed task conditions under which go/no-go task performance deficits can be distinguished in heavy smokers with moderate nicotine dependence compared to non-smokers, and to characterize the nature of such deficits. The results pointed out that under 200-ms but not 600-ms stimulus presentation conditions, the smokers responded faster on go trials and made more errors on both go and no-go trials than the non-smokers did. In the same vein, Tsegaye et al. (2021) used a modified version of the Go/NoGo task to assess differences in task performance between smokers and nonsmokers. Participants performed a go/no-go task with three conditions: unrewarded condition, which the stimuli were neutral color squares, and reward conditions, with smoking-related pictures and money-related pictures. The results indicated that smokers had reduced inhibitory control in both reward contexts, compared to nonsmokers and, the higher the craving, the higher the attentional bias.

Regarding the influence of gender on behavioral disinhibition, the literature suggests inconclusive results. Di et al. (2023) did not identify behavioral cross-sex differences in participants exposed to acute stress tasks. On the other hand, Nguyen et al. (2021) found that women performed better than men in a go/no-go task and activated a greater number of brain connections; and Eriksson et al. (2023) identified significant gender differences in the stop signal reaction time, suggesting that men have greater inhibitory control than women. More stud-

ies should be carried out to identify the impact of gender and other aspects in the behavioral disinhibition.

Taken together, these findings suggest that higher levels of behavioral disinhibition may indeed be associated with smoking maintenance, but it is necessary to examine this using robust methods and to seek to identify the key aspects of smoking and addiction that may be modulated by this facet of impulsivity. The aim of this study is to evaluate the effect of gender, different levels of addiction, nicotine deprivation and smoking patterns on behavioral disinhibition, measured by Parametric Go/No-go and Stop Signal Reaction Task, in smokers and nonsmokers.

2. Materials and Methods

2.1 Participants

180 participants (90 smokers and 90 nonsmokers) within 18 to 30 years old were recruited from Guadalajara metropolitan area, between January 2019 and March 2020. Smokers reported consuming five or more cigarettes a day, and nonsmokers reported not consuming more than 100 cigarettes in their lifetime and not consuming tobacco in the previous six months. Participation in the study was voluntary, and the sample was selected through a digital form. Most of the participants were invited in their classrooms, where they were briefly introduced to the study and asked to participate. Another part of the sample was invited by these students, to whom the link of a Google digital platform was sent. Those who agreed to participate and met the inclusion criteria for one of the groups were scheduled an appointment by telephone to come to the laboratory. Participants were paired in terms of gender and age, using an Excel worksheet, on a first-come, first-served basis. That is, for each man, there was a woman of the same age. In 26 cases it was not possible to perform age-related matching for nonsmokers, so they were discarded from the study. Exclusion criteria included consuming psychotropic substances, addiction to other psychoactive drugs, people diagnosed with heart disease (arrhythmia, uncontrolled blood pressure, etc.), and epilepsy. This study was approved by the Institutional Ethics Committee of University of Guadalajara and was formulated in accordance with APA ethical standards. All participants signed informed consent before participating in the study, which emphasized the voluntary, anonymous, no harm to health and the confidential nature of their participation.

2.2 Assessment

2.2.1 Smoking history questionnaire

The questionnaire includes a survey covering socio-demographic characteristics (such as age, gender, education, etc.) and smoking habits. It asks when the respondent first smoked, how old they were when they first experimented with tobacco, how many cigarettes they smoke per day, and how long they have maintained that smoking frequency.

2.2.2 Fagerström Test for Nicotine Dependence (FTND)

The Spanish version of the FTND (Becoña & Vázquez, 1998) was used to assess nicotine dependence (Cronbach's alpha = .724). The instrument consists of six scored items that assess physical dependence (e.g. number of cigarettes per day and time until first cigarette). The scores obtained in the test allow nicotine dependence to be classified into five levels: very low (0 to 2 points); low (3 to 4 points); moderate (5 points); high (6 to 7 points); and very high (8 to 10 points).

2.2.3 Parametric Go/No-Go (PGNG).

The task proposed by Langenecker et al. (2007) to assess the attentional load, set-shifting, and inhibitory control and corresponds to the balance between response latency and accuracy and the following formula is given: efficiency rate = overall accuracy/overall latency × 100. The lower the efficiency rate, the lower the inhibitory control. The PGNG consists of three levels, completed in order of ascending difficulty. For all three levels, a sequence of letters on a computer screen was presented with a 500 ms inter-stimulus interval, for a total of 168 trials per session (26 go and 142 no-go stimuli).

2.2.4 Stop Signal Task (SST)

This task evaluates behavioral disinhibition and was originally developed by Verbruggen and Logan (2009). In the stop-signal paradigm subjects are given a primary task to perform and, occasionally, a stop signal is presented that tells them not to respond on that trial. The major dependent variable is the probability of inhibiting or responding to the primary task. Reaction time in stop signal (or no-go) trials refers to an individual's ability to stop a premature response. There are several methods to establish the reaction time of stop signal trials. However, the one used in this research corresponds to the integration method with dynamic stop signal delay, in which the interval between trials increases or decreases by 50 ms if the participant makes a correct or incorrect response, respectively (Verbruggen & Logan, 2009). This procedure ensured that subjects successfully inhibited their responses on approximately 50% of inhibition trials, but for those who did not achieve this percentage, the Stop Signal Reaction Time (SSRT) was calculated by subtracting the SSD from the mean reaction times on Go trials.

2.2.5 CO-oximeter

The Smokerlyzer PiCO (Bedfont Scientific Ltd, Kent, UK) was used to evaluate the concentration of CO exhaled by the participants, to estimate the time of abstinence from tobacco.

2.3 Procedures

The participants selected for the study were invited to the Behavioral Study and Research Center of University of Guadalajara, to carry out the empirical phase of the study. Before the experiment, all attendees signed a informed consent form and underwent a CO-oximetry test. To participate in the study, individuals were required to abstain from nicotine for 10 h before the session, which corresponds to approximately 10 ppm of expired CO verified via breath sample. They then completed the smoking history questionnaire and the FTND.

After that, the participants sat on a comfortable chair and performed the Go/no-go and Stop Signal Reaction Task (SST). In the first block of PGNG, participants were instructed to press the spacebar on the computer keyboard whenever any of the target letters "r", "s" or "t" (go) were present, and not to press it in the presence of the other letters (no-go). In the second block, participants had to respond only to the letters "r" or "s", as long as the previous target letter was not repeated, that is, they had to alternate the emission of the response between "r" and "s". In the third block, participants had to press the spacebar before the target letters "r", "s" or "t", without repeating them in subsequent trials. Responses should be made as quickly as possible with the fingers of the dominant hand. The instructions on the computer screen were presented before each level, followed by a practice of 20 trials each, to ensure that individuals had understood what was required in the task. Except for the practice, there was no trial-by-trial feedback on the responses given during task resolution.

For the SST, participants were instructed, via the computer screen, to press the "D" key on the keyboard when a left-facing arrow is presented or the "K" key when a right-facing arrow is presented. This situation constitutes the go trials of the task. Occasionally and unexpectedly, after the presentation of the arrows, a stop signal (beep sound) could appear, indicating to the individual that he/she should stop the impulse to respond. This situation corresponds to the no-go trials of the task. Occasionally and unexpectedly, after the presentation of the arrows, a stop signal (beep sound) could appear, indicating to the participant to stop the impulse to respond. This situation corresponds to the no-go trials of the task. The Stop Signal Reaction Task comprised three similar experimental blocks, with 64 trials each, without any feedback (16 trials with the stop signal and 48 without the beep). Before the first session, participants had to complete a practice with 32 trials (8 with stop signal and 24 without the beep) to assess whether they really understood how to respond to the task, and this was the only session where there was feedback after each trial.

2.4 Data Analysis

The cut-off points used to divide participants into the respective groups of nicotine dependence, smoking pattern (number of cigarettes consumed per day), time of abstinence, and years of smoking (smoking level) were the sample averages.

Participants were divided into high or low levels of nicotine dependence when the score on the FTND was > 3 or ≤ 3, respectively. Smoking pattern could be high or low when smoking was > 5 cigarettes per day or ≤ 5 cigarettes per day, respectively. The time of abstinence before the experiment was divided in > 12 h and ≤ 12 h. Smoking level could be high or low when the participants had been smoking for more than four years or less than or equal to four years, respectively.

For comparison of age, education level and CO level, the non-parametric Mann-Whitney U tests were performed, since the sample was not normally distributed.

A two-way analysis of variances (ANOVAs) was used to identify differences in behavioral disinhibition among groups (smokers and nonsmokers) and gender; among smokers grouped into nicotine dependence level and number of cigarettes consumed per day; and among smokers with more and less than 12 hours of abstinence and high or low in smoking level. Tukey's pairwise comparisons or Games-Howell post hoc tests were performed if homogeneity of variance was violated.

3. Results

3.1 Participant's Characteristics

Table 1 summarizes the demographics and smoking profiles for all groups. There was no significant difference in age or education level between smokers and nonsmokers ($U = 4050$, $p > .9999$; $U = 3943$, $p = .7515$, respectively), but the CO level was significantly different ($U = 1121$, $p < .0001$), in which smokers exhibited higher CO level than nonsmokers.

3.2 Behavioral disinhibition among smokers and nonsmokers

Table 2 summarizes the mean behavioral disinhibition assessed by PGNG and SST, of smokers and nonsmokers grouped by gender. There were significant differences between smokers and nonsmokers on SSRT ($F = 11.065$, $p = .001$, $\eta^2 = .060$), which means that smokers have more difficulty inhibiting a prepotent response than nonsmokers. There were no significant differences for all other SST measures ($F = .583$, $p = .446$ for no signal trial's reaction time; $F = 3.438$, $p = .065$ for no signal trial's precision; and $F = .200$, $p = .656$ for signal trial's reaction time). For all PGNG behavioral disinhibition variables there were no significant differences ($F = .007$, $p = .933$ for Efficiency Ratio; $F = .006$, $p = .997$ for global precision; $F = .009$, $p = .923$ for Go trials precision; $F = .080$, $p = .777$ for no-go trials precision; $F = .575$, $p = .449$, for latency).

Table 1

Participant Sample Demographics and Smoking Behavior

	Nonsmokers	Smokers
N	90	90
Age years	22.6 (2.99)	22.6 (2.99)
Gender (%) Male	50	50
Educational level (years)	14.23 (1.24)	14.31 (1.29)
Age at first cigarette	—	14.95 (2.61)
Age of onset (years) weekly smoking	—	15.37 (2.36)
Cigarettes smoked per day	—	7.6 (6.01)
Years smoking tobacco diary	—	4.1 (3.34)
FTND Score	—	2.7 (1.91)
Nicotine deprivation (h)	—	11.88 (10.89)
CO level (parts per million)	2.3 (0.96)	5.1 (2.14)

Note. Data presented as mean (standard deviation).

Table 2

Measures of Performance on the PGNG and SST, by Group and Gender

	Male ($n = 45$)	Female ($n = 45$)	Male ($n = 45$)	Female ($n = 45$)	Group	Gender	Group × Gender
PGNG							
Efficiency Ratio	13.08 (4.05)	12.85 (3.73)	13.10 (3.34)	12.74 (3.92)	$p = .933$	$p = .567$	$p = .930$
Global Precision (%)	55.35 (15.45)	54.61 (14.73)	54.97 (12.54)	54.37 (15.40)	$p = .997$	$p = .726$	$p = .967$
Go trials precision (%)	55.35 (14.88)	54.55 (14.88)	54.80 (12.39)	53.76 (15.45)	$p = .923$	$p = .277$	$p = .145$
No-go trials precision (%)	81.19 (13.18)	82.99 (12.68)	82.60 (11.53)	81.32 (13.51)	$p = .777$	$p = .116$	$p = .243$
SST							
Latency (ms)	424.75 (24.24)	428.88 (16.42)	423.31 (24.33)	426.82 (18.19)	$p = .449$	$p = .218$	$p = .864$
SSRT (ms)	201.95 (35.89)	187.8 (22.13)	209.14 (44.71)	212.4 (36.13)	**p = .001***	$p = .149$	**p = .043***
No signal trial's reaction time (ms)	832.30 (180.69)	833.81 (133.22)	879.23 (148.29)	822.51 (159.09)	$p = .446$	$p = .239$	$p = .214$
No signal trial's precision (%)	93.94 (5.55)	93.92 (6.30)	91.58 (11.68)	91.81 (6.87)	$p = .065$	$p = .930$	$p = .915$
Signal Trials reaction time (ms)	757.53 (179.59)	735.33 (145.35)	796.25 (167.14)	718.47 (160.85)	$p = .656$	**p = .043***	$p = .258$

Note. Data presented as mean (standard deviation). Analysis of ANOVA (2×2) across group of smokers and nonsmokers and men and women: $^*p < .05$. PGNG: Parametric Go/No-go; SST: Stop Signal Task; ms: milliseconds; SSRT: Stop Signal Reaction Time.

3.3 Behavioral disinhibition between gender

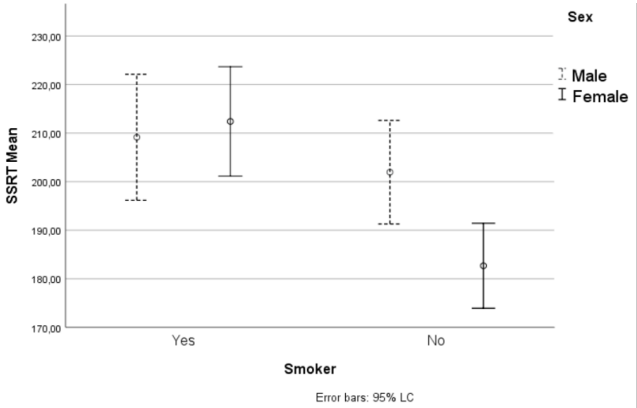
There were significant differences between males and females on signal trial's reaction time evaluated by SST ($F = 4.171$, $p = .043$, $\eta^2 = .023$), in which female smokers were faster to respond, but they made more mistakes compared to male smokers and nonsmokers (Figure 1). There were no significant differences between men and women regarding other behavioral disinhibition measures ($F = 2.100$, $p = .149$ for SST; F = 1.399, $p = .239$ for no signal trial's reaction time; and $F = .008$, $p = .930$ for no signal trial's precision). For all PGNG behavioral disinhibition variables there were no significant differences between gender ($F = .328$, $p = .567$ for efficiency ratio; $F = .123$, $p = .726$ for global precision; $F = 1.528$, $p = .218$ for latency; $F = 1.191$, $p = .277$ for go trials precision; $F = 2.498$, $p = .116$ for no-go trials precision). An interactive effect was observed for group and gender ($F = 4.163$, $p = .043$, $\eta^2 = .023$), in which women nonsmokers exhibited a slower reaction time in SST than women smokers, men smokers and men nonsmokers.

3.4 Behavioral disinhibition related to smoking history

There were significant differences between no-go trials precision evaluated by PGNG between participants high

Figure 1

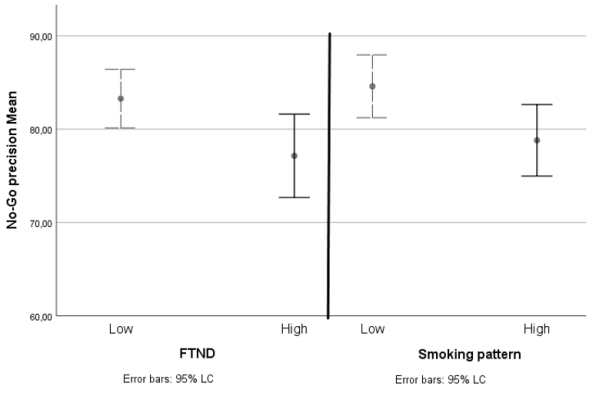
Mean Stop Signal Reaction Time between smokers by gender



and low in FTND ($F = 4.695$, $p = .033$, $\eta^2 = .051$), in which participants with high score on FTND committed more mistakes (Figure 2). The results were similar regarding no-go trials precision evaluated by PGNG between participants who consume more than 5 cigarettes per day compared to those who smoke less ($F = 5.088$, $p = .027$, $\eta^2 = .055$), in which high consumption participants committed more mistakes. There were no significant differences regarding other behavioral disinhibition measures among smoking history group, computerized by one-factor one-way ANOVA.

Figure 2

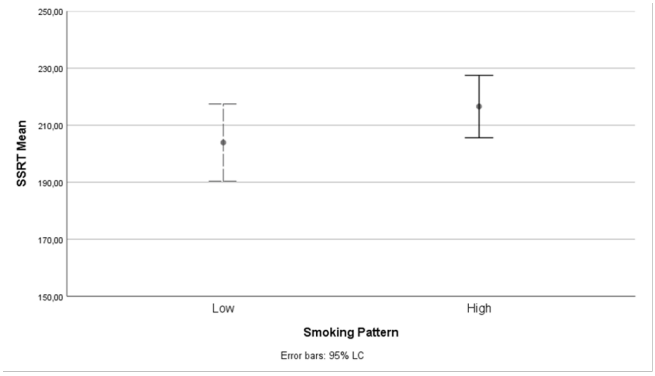
Mean No-go Trials Precision by Nicotine Dependence Level and Smoking Pattern Categories



A direct effect of the number of cigarettes on SSRT is showed Figure 3, in which smokers who smoke more than 5 cigarettes per day exhibited longer reaction time on stop signal trials than lighter smokers ($F = 4.095$, $p = .046$, $\eta^2 = .045$). Furthermore, an interaction effect was observed on no signal trials reaction time ($F = 4.341$, $p = .040$, $\eta^2 = .048$) and on signal trials reaction time ($F = 4.403$, $p = .039$, $\eta^2 = .049$), when considering nicotine dependence and number of cigarettes smoked per day. High dependence and less than 5 cigarettes consumed per day was related to longer reaction time in signal and no-signal trials in SST. For all other disinhibition behavioral measures there were no significant differences between groups.

Figure 3

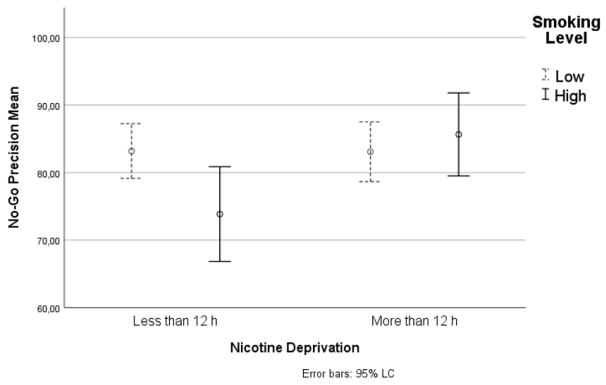
Mean Stop Signal Reaction Time by Smoking Pattern Categories



The results highlight a significant interaction between nicotine deprivation and duration of smoking on inhibitory control performance. Specifically, the combined effect of having smoked for more than four years and experiencing less than 12 hours of nicotine deprivation led to poorer performance on no-go precision ($F = 4.871$, $p = .030$, $\eta^2 = .054$) assessed by PGNG (Figure 4).

Figure 4

Mean No-go Trials Precision by Nicotine Deprivation and Smoking Level Categories

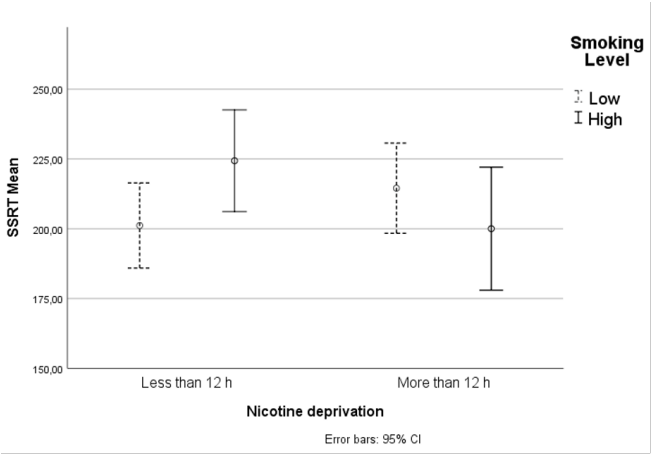


In the same vein, Figure 5 exhibited the interaction effect of nicotine deprivation and duration of smoking on SSRT, evaluated by SST ($F = 4.281$, $p = .042$, $\eta^2 = .047$, respectively). Participants with more than 4 years of

smoking patterns and with less than 12 hours of nicotine deprivation were more imprecise in no-go trials in PGNG task and had longer SSRT in SST. There were no other significant direct or integration effects of nicotine deprivation and years of smoking pattern on disinhibition behavioral measures.

Figure 5

Mean SSRT by Nicotine Deprivation and Smoking Level Categories



4. Discussion

The purpose of the study was to evaluate the behavioral disinhibition, measured by Parametric Go/No-go and Stop Signal Reaction Task, in smokers and nonsmokers, considering gender, levels of addiction, nicotine deprivation and smoking pattern.

The results identified that smokers have more difficulty inhibiting a prepotent response than nonsmokers in SSRT, measured by SST. These results are not in line with most of the studies, which do not evidence significant differences between smokers and nonsmokers in SSRT (Logemann et al., 2014; Kolokotroni et al., 2024; Galván et al., 2011). The main reason for these discrepancies could be differences in smoking history, addiction patterns (i.e., first cigarette consumed, nicotine deprivation, light or heavy smokers, etc.) or sample size. The present study is consistent with works that considered the nicotine deprivation and similar addiction patterns (age of first cigarette and age of onset weekly smoking $\approx$ 15 years and at about 4 years as smoker), which found that smokers have longer SSRT than nonsmokers (Kalhan, et al., 2022; Ashare & Hawk, 2012). The nicotine deprivation was suggested to play an important role in the response inhibition, since it may reflect an abstinence-induced deficit in sensorimotor gating, which may interfere with an individual's ability to inhibit the urge to smoke (Hou et al., 2024; Le et al., 2021).

The results also showed significant differences regarding no-go precision in PGNG in smokers with different levels of consumption and nicotine deprivation. Smokers with more years of consuming tobacco, but who had less time of nicotine deprivation prior to the experiment, were more imprecise than the other groups. Previous works have found poorest inhibitory control in smokers during acute abstinence than after smoking (Ashare & Hawk, 2012; Chen & Li, 2023; Pericot-Valverde et al., 2023), although there may be a temporal effect of abstinence on the ability to inhibit a prepotent response which may vary according to participant's profiles (Hou et al., 2024). It seems that years of smoking had more impact on poor inhibitory response, measured by no-go precision and SSRT, than nicotine deprivation time. Mashoon et al. (2018) found that early onset cigarette smokers ($<$ 16 years) made more errors, took more time to respond, and performed less accurately than lately onset smokers and nonsmokers on nearly every response accuracy and response inhibitory outcome measured during the smoking Go/NoGo task. These results are consistent with Tobacco-Induced Neurotoxicity of Adolescent Cognitive Development theory - TINACD (DeBry & Tiffany, 2008), which suggests that persistent nicotine exposure in early onset cigarette smokers implies to structural and functional impairments in frontostriatal brain regions, disrupting sensitive neurobiological processes and elevating risks for developing nicotine dependence throughout adulthood. In other words, the earlier the initiation of smoking, the greater the likelihood of suboptimal executive functioning and poor management of impulsivity and decision-making in adult smokers (Maurage et al., 2022). Taken together, it is possible to assume that the early onset smoking pattern of the experiment sample ($\approx$ 15 years) could impact more the inhibitory responses in the present experiment than nicotine deprivation, since the latter is more prone to vary across individuals physiology.

Female nonsmokers presented shorter SSRT than male nonsmokers and smokers, independent of the gender. Gender direct effect on behavioral disinhibition was not identified, but the smoker condition and gender have interaction effects on the ability to inhibit a response. According to Fattore and Melis (2016), women possess on average greater intentional control ability than men and outperform men on behavioral tasks (i.e., continuous performance test), self-report and delay discounting tasks. A neuroscientific explanation is well established for those differences, in which the dorsolateral prefrontal cortex (DLPFC), specifically, left dorsal anterior cingulate cortex (dACC) and right middle frontal gyrus (MFG) play an important role on the direction of impulsive choice responding (Le et al., 2021). According to Le et al. (2021) females have a larger DLOFC than men in this brain region that displays high density of dopamine receptors; additionally, women smokers have hypoactivation of the

dACC and MFG than men. The present results are partially in line with the literature, since women exhibited more inhibitory control than men, but the main differences were in the nonsmoker group. Fields et al. (2011) suggested that female smokers were more impulsive than male smokers, although the opposite was described for nonsmokers. Since the differences between men and women tend to be more pronounced in adolescence than in adulthood, the results could be explained by the early onset smoking pattern registered for the present study sample, as a result, impulsivity was developed uniformly in both sexes.

Moderate to high Nicotine Dependence (FTND > 4) influenced the poor precision on no-go trials of PGNG. These results are consistent with Kolokotroni et al. (2024) and Kalhan et al. (2022) who found that heavy smokers with moderate to high nicotine dependence require more effort and/or have a greater difficulty inhibiting their prepotent go-processes, evaluated by SST; and Martín Ríos et al. (2021) who detected the same results, using Go/no-go tasks and other tasks. Despite the two tasks measuring behavioral disinhibition, different aspects of inhibition are evaluated in them: cancellation of an initiated response, for SST, and withholding a planned, but uninitiated response, for Go/no-go tasks. It appears that the stop-signal task is more sensitive to deficits than the Go/NoGo task, as several studies show larger effects for SST than commission errors collected from the same sample (Smith et al., 2014). These differences could be the reason for discrepancies in studies, but it is important to define the exact aspect of inhibitory response evaluated in future investigations. Another important aspect for the deviation on the findings is related to the direction of the relation between nicotine dependence and impairment. While impaired inhibitory control may facilitate the development of nicotine dependence, early onset smoking, at brain development, may generate poor behavioral disinhibition characteristic of dependence (Conti & Baldacchino, 2021). In order to solve this paradox, neuroimaging studies which use event related brain potentials (ERP) could provide more reliable results and address the direction of the relationship between inhibitory control impairment and addiction.

Although the results of the study are important to understand the variabilities in behavioral disinhibition of nonsmokers and smokers, at different level of addiction and pattern of smoking, this work has some limitations. First, a non-deprived smokers group were not taken into consideration, which may jeopardize the generalization of the results, since the dependent variables would be affected by the nicotine deprivation. Second, psychological comorbidities were not evaluated. Deficits in behavioral disinhibition are also apparent in attention-deficit/hyperactivity disorder (ADHD), obsessive compulsive disorder, reading disability, depression and traumatic brain injury. These and other psychiatric disorders often co-occur with substance use disorders, this reflects the recent notion that different mental disorders share common genetic, behavioral and cognitive factors (Smith et al., 2014). In the same sense, it was not recollected information about concurrent consumption of another drug. Literature pointed out for collective contributions of poor task performance when drugs are combined; for example, alcohol, tobacco and cannabis (Naudé et al., 2022) and, cocaine, heroin and others (Dousset et al., 2022). Future studies may reach the influence of gender and early onset cigarettes smoking related to the response inhibition at different smoking pattern, using more reliable methodology, such as neuroimaging of ERP simultaneously with PGNG or SST.

Overall, this study represents a significant contribution to the understanding of inhibitory control deficits in male and female smokers with different consumption patterns.

The findings indicate that, although non-smoking women show better behavioral disinhibition, being a smoker, regardless of gender, for a period of more than four years and being abstinent for less than 12 hours, favor worse inhibitory control. On this basis, smoking treatment is not directly influenced by gender, but understanding the impact of smoking history and nicotine deprivation are key aspects in facilitating cessation, as these factors are associated with a stronger compulsion to smoke. One strategy that could be implemented in the short term to achieve success is to maintain the patient in abstinence for at least 12 hours a day, since during this period the ability to inhibit prepotent or already initiated responses is limited. Additionally, training regimens aimed at improving general cognitive skills, such as working memory or inhibitory control, which could be adopted. In the case of inhibitory control training (ICT), training regimens are generally based on the Stop-Signal Task and the Go/No-Go Task paradigms (Motka et al., 2025). Similarly, understanding the impact of behavioral disinhibition on tobacco use may represent an important factor in prevention. Inhibitory control training can also be used to develop skills that control prepotent or already initiated responses or processes; thus, providing a preventive behavioral repertoire for substance use.

Recognition of an inhibitory deficit in substance use implies the possibility of new approaches to address this impairment. Training or stimulant medication is known to improve inhibitory control in different samples and may improve outcomes among substance abusing individuals (Motka et al., 2025; Stein et al., 2023). These tools can improve inhibition and be an effective treatment when behavioral inhibition is lacking in drug users. Further investigation of training and medication approaches to improve behavioral disinhibition, as it relates to substance use, should be the focus of future research.

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