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POTENTIAL PREDICTORS OF SMOKING RELAPSE IN TREATMENT-SEEKING SMOKERS

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Abstract

Impulsive behavior problems are powerful predictors of addiction treatment outcomes. However, a comprehensive assessment of these features has not been examined in relation to smoking cessation outcomes. This study aims to evaluate the capacity of impulsive behavior to predict the risk of relapse and the number of relapses for smokers. The sample comprised 141 participants ($M_{age=}$ 47.3, *SD*= 8.31; 59% females) in psychopharmacology treatment for dependence to nicotine. Participants provided breath carbon monoxide samples for determining smoking throughout the study. The different impulsiveness dimensions were evaluated with a Go/NoGo task, the visual search and attention test and a delayed discount task, while self-informed impulsivity was assessed with Barratt's Impulsiveness Scale. Unplanned impulsivity, attention failures and performance in the Go/NoGo task are postulated among the individual factors related to the number of relapses. Our results contribute to the understanding of relapse components and enable the inference of assiduity by quantifying relapse.
KEY WORDS: *impulsive behavior, smoking, impulsivity, relapse, inhibition*

Resumen

Los problemas del comportamiento impulsivo representan poderosos predictores de los resultados del tratamiento en adicciones. Sin embargo, no se dispone una evaluación exhaustiva de estas características en los resultados del tratamiento de deshabituación tabáquica. Este estudio pretende evaluar la capacidad de las dimensiones de la conducta impulsiva para predecir el riesgo y el número de recaídas. La muestra comprendió 141 fumadores ($M_{edad=}$ 47,3; *DT*= 8,31; 59% mujeres) en tratamiento psicofarmacológico de deshabituación tabáquica. Los participantes proporcionaron muestras de monóxido de carbono para determinar la abstinencia. Las diferentes dimensiones de impulsividad se evaluaron con una tarea Go/NoGo, la tarea de búsqueda y atención visual y una tarea de descuento por demora, mientras que la impulsividad autoinformada se evaluó con la Escala de impulsividad de Barratt. La impulsividad no planeada, los fallos de atención y el rendimiento en la tarea Go/NoGo se postulan entre los factores relacionados con el número de recaídas. Nuestros resultados contribuyen a la comprensión de componentes de reanudación del consumo y posibilitan la inferencia de la asiduidad al cuantificar las recaídas.

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PALABRAS CLAVE: *comportamiento impulsivo, fumar, impulsividad, recaídas, inhibición*.

Introduction

Smoking represents one of the main causes leading to the development of disease and mortality worldwide (World Health Organization [WHO], 2020). The eminent personal and economic cost of tobacco on public health promotes a need to clarify knowledge about the impact of tobacco (Lydon et al., 2014). One focus of interest within smoking research is its impact on neuropsychological health (Martín-Ríos et al., 2021; McCorkindale et al., 2016). There is evidence that links nicotine consumption with possible alterations in inhibitory control (Kräplin et al., 2019), cognitive impairment (Liu et al., 2017) and increased risk of developing neurodegenerative diseases (Durazzo et al., 2012). In addition, smokers show a consistent pattern marked by a strong tendency towards impulsivity (Conti et al., 2019). However, there is a lack of consistency in both the definition and assessment of impulsive behavior as a multifaceted construct composed of different independent dimensions (Reynolds & Fields, 2012). The most commonly identified dimensions included delay discounting, response inhibition, attentional failure (de Wit, 2008) and self-reported impulsivity (Reynolds et al., 2006).

Delay discounting can be assessed in tasks where a choice between a smaller immediate reward or a larger but delayed reward is required. Recent studies have explored whether this dimension of impulsivity was associated with response to smoking cessation treatment reporting that higher rates of delay discounting were associated with both poorer adherence to treatment (Harvanko et al., 2019) and higher risk of relapse after receiving smoking cessation treatment (Garcia-Perez et al., 2021; Sheffer et al., 2014). These findings are in line with a recent meta-analysis that addressed the effects of chronic smoking exposure on various neuropsychological domains where smokers, compared to non-smokers, showed a tendency to choose immediate rewards during delay discounting tasks (Conti et al., 2019).

On the other hand, a growing empirical corpus shows that addictive behaviours are associated with alterations in response inhibition, defined as the ability to inhibit a dominant response (Miyake et al., 2000). Individual differences in inhibitory control among smokers have been shown to have a relevant role in smokers (Zhao et al., 2016) because it has been associated with dependence (Billieux et al., 2010), difficulties to control craving (Liu et al., 2019) and with higher relapses (Luijten et al., 2016).

Impulsivity problems that involve problems in maintaining attention over a period of time can be identified as attentional failures. In this regard, Harakeh et al. (2012) explored smoking and cognitive functioning in adolescents (inhibition of predominant responses, working memory, sustained attention, visuospatial search and processing speed) indicating that poor inhibitory and attentional skills increased the likelihood of initiating smoking (Harakeh et al., 2012). Finally, inhibitory problems have also been studied through measures of self-reported impulsivity.

Specifically, Balevich et al. (2013) assessed the influence of impulsivity on smoking through two self-report and two behavioural measures in adolescent smokers, non-smokers and occasional smokers. Smokers showed higher rates of self-reported impulsivity, specifically cognitive and motor impulsivity. In the same line, Balevich et al. (2013) reported that smokers had higher rates of self-reported impulsivity compared to non-smokers although they found no differences between groups on behavioural tasks (Balevich et al*.,* 2013).

In summary, impulsivity would appear not only as a predictor but also as a consequence of drug use, which in turn may affect people who are trying to control their consumption. However, the divergence of outcomes reflects discrepancies about the relationship between impulsivity dimensions and addiction. Empirical research emphasises the idea of developing a comprehensive assessment that includes critical behavioral variables related to smoking in order to examine nicotine abuse impacts on cognition (Martín et al*.,* 2021). A comprehensive assessment of impulsivity will help to determine which dimensions trigger relapses. To our knowledge, there are no studies that provide information about the number of relapses, so this is an unexplored phenomenon. The aim of this study is to identify the predictive ability of dimensions of impulsivity on the probability of relapse and the number of relapses in smokers at 12 months. The results of this research will provide empirical support for the development of smoking cessation therapies. Based on the findings described above, we hypothesize that self-reported impulsivity and inhibition of response will be the best predictors of relapse.

Method

Participants

This study involved 141 tobacco users seeking treatment in the smoking cessation program of Occupational Health and Risk Prevention Service of the University of Granada. Participants had a mean age 47.3 (*SD*= 8.31) within an age range of 27-69 years of which 59% were women. Inclusion criteria were 18 years of age or older, having a work contract with the University of Granada, willing to participate voluntarily in the treatment. Exclusion criteria were presence of a diagnosed severe mental disorder and concurrent dependence on other substances (cocaine, heroin, alcohol, etc.).

Instruments

a) *Barratt Impulsiveness Scales* (BIS-11; Patton et al., 1995) version adapted to Spanish by Oquendo et al. (2001). It is a self-administered test consisting of 30 questions with four response alternatives that are scored from 0 to 4. The items are scored according to the perceived frequency of behavioral patterns. The test obtains four scores on: cognitive impulsivity, motor impulsivity, unplanned impulsivity and total impulsivity. It has a Crobach's alpha of .79 (Leshem & Glicksohn, 2007). The sum total of the responses shows the level of impulsivity for each of the three subscales: motor impulsivity (refers to a tendency to act

without thinking), cognitive impulsivity (relates to a propensity to make decisions quickly) and unplanned impulsivity (identified with a tendency to not plan and to perform tasks carelessly).

b) *Visual Search and Attention Test* (VSAT; Trenerry et al., 1990). It is a test of visual search for a target (a letter or colored symbol) in a matrix designed to explore the sustained attention component that includes the ability to rapidly activate and inhibit motor responses.The test-retest reliability ranges from .95. In this case, commission errors were used as an independent variable as they indicate greater inattention.

c) *Go/NoGo task* (Verdejo-García et al., 2007). This is a computerized task that requires the inhibition of automatic motor responses. One of two different possible letters of the alphabet is presented on the computer screen. The subject's task is to press a key, as fast as possible, when one of these letters appears (target stimulus), and to avoid pressing when the other letter appears (distractor stimulus). Each participant performs 100 decision trials, divided into 2 phases of 50 trials each. For this study the main variable of interest is the errors of commission (prepotent responses to No-Go stimuli), indicative of a deficit of inhibitory control.

d) *Kirby Delay-Discounting Task* (DDT; Kirby et al., 1999). This is a 27-question questionnaire in which participants must select between a smaller immediate reward or a larger but delayed reward. The area under the curve (AUC) is calculated according to the proposal of Myerson, Green and Warusawitharana (2001). The AUC is calculated for the range of reward magnitudes included in the questionnaire (small-Euro 25-35; medium-Euro 50-60; and large-Euro 75 to 85), according to the formula (x2-x1) [(y1-y2)/2], where x1 and x2 are successive delays, and y1 and y2 are the subjective values associated with these delays.

e) Smoking pattern. Outcome measures were treatment status (abstinent or relapsed) and number of relapses counted at 12 months. Face-to-face follow-up protocols were conducted at 3, 6 and 12 months to check which participants were abstinent. Days to relapse was defined as the number of days from the quit date to relapse or end of observation (Hughes et al., 2003). The treatment program allowed relapsing participants to resume treatment in such a way that the research design was adapted to the natural course of the smoking cessation program by establishing the assessment of treatment status at 12 months as a discrete time event.

f) *Semi-structured interview for smokers* (López-Torrecillas, 1996). This interview collects sociodemographic information, family history, years of addiction, number of cigarettes per day and history of consumption in the first treatment session.

g) *Cooximeter*. Clinical test to detect the loss of oxygenation capacity of hemoglobin by quantifying the carbon monoxide level in exhaled air. Levels of 10 or more ppm of CO in exhaled air correspond to smokers. Levels of 6 to 10 ppm correspond to sporadic smokers, and figures below 6 ppm to non-smokers. Abstinence rates were determined by self-report confirmed by carbon monoxide levels in cooximetry.

h) *Fagerström Test for Nicotine Dependence* (FTND; Fagerstrom & Schneider, 1989), version adapted to Spanish by Becoña & Vázquez (1998). It consists of 6 items that evaluate the degree of physiological dependence. The maximum score is 10 points and it is categorized into mild (0-3 points), moderate (4-7 points) and severe (8-10 points) dependence. It has psychometric guarantees, with a Cronbach's alpha coefficient for the total scale of .80 (Becoña & Vázquez, 1998).

Procedure

We conducted a prospective naturalistic study during the course of a smoking cessation intervention with 12-month follow-up. This program is available to employees of the University of Granada, so the type of sampling was non-random and incidental. The smoking cessation intervention consisted of three phases: (1) psychoeducation phase to reduce tobacco consumption with the performance of neuropsychological tests; (2) controlled prescription of varenicline, a partial agonist drug and antagonist in the presence of nicotine of the neuronal receptors for nicotinic acetylcholine; (3) controlled prescription of varenicline, a partial agonist drug and antagonist in the presence of nicotine of the neuronal receptors for nicotinic acetylcholine of the nicotinic type α4β2, and (3) clinical follow-up with relapse prevention strategies. Regarding follow-ups, participants were contacted at 3, 6 and 12 months in order to corroborate treatment compliance. Based on the results of self-reports and hemoglobin levels from co-oximetry, they were coded as "relapse or abstinence". This coding of treatment adherence has demonstrated efficacy as well as feasibility in previous research integrated in smoking cessation treatment programs (López-Torrecillas et al*.,* 2014). Regarding the data obtained in the outcome variable we had a sample of 196 participants at the 3-month follow-up, 193 participants at the 6-month follow-up and a total of 141 participants at the 12-month follow-up. Participants were informed of the willingness of the program as well as the confidential character of the data treatment, therefore, an informed consent was obtained; based on the legislative framework established by the Code of Ethics (Law 25/2009). In addition, this study has the approval of the Ethics Committee in Human Research of the University of Granada.

Data analysis

Statistical analysis was performed using the IBM SPSS Statistics version 20.0 statistical program. Descriptive statistics were used to characterize the participants and Pearson correlations were used to evaluate the relationships between variables with a significance criterion of $p< 0,05$. In addition, multiple regression analysis was performed to examine the specific contribution of the dimensions of impulsive behavior on the number of relapses. On the other hand, in order to detect the independent variables that best predict the probability of abstinence/relapse in one year, a logistic regression analysis was conducted.

Results

We first performed descriptive statistics to characterize the sample (Table 1) where the Fagerström test score for nicotine dependence (FNDT) was moderate (*M*= 4.49, *SD*= 2.32). The sample had an average of 17.9 cigarettes per day (*SD*= 8.94) with an average nicotine level per cigarette of .99 mg (*SD*= 0.13). Participants showed a low level of relapse after 12 months of clinical follow-up (*M*= 0.68, *SD*= 0.70) even though they showed variability in their responses. In particular, female smokers had a higher mean level of relapse (M= 0.61, *SD*= 0.72) than male smokers (*M*= 0.53, *SD*= 0.63). Finally, self-reported impulsivity estimated by the different BIS-11 variables showed moderate rates within the established parameters (Patton et al*.,* 1995), with women showing a higher mean score (*M*= 45.8, *SD*= 15.7) compared to men (*M*= 43.3, *SD*= 17.4).

Table 1
Descriptive statistics of the sample

Variables	*M*	*SD*	Range
Smoking history			
Nicotine dependence Test	4.49	2.32	0-10
Number of cigarettes per day	17.9	8.94	2-60
Packs of cigarettes per year	26.6	18.3	20-120
Number of relapses over 12 months	.68	.70	0 - 4
Impulsivity			
VSAT	4.10	7.36	0-120
Go/NoGo	5.95	7.32	0-50
DDT	.553	.24	.0-1
C-BIS-11	14.85	7.16	3-65
M-BIS-11	15.04	6.77	3-30
UP-BIS-11	16.02	7.05	4-31

Note: C-BIS-11= cognitive subscale of the Barratt Impulsivity Scale (BIS); M-BIS-11= motor subscale of the BIS; UP-BIS-11= unplanned subscale of the BIS; Go/NoGo= errors of commission on the Go/NoGo Task; VSAT= errors of commission on the Visual Search and Attention Test; DDT= Delay Discounting Task.

Table 2 indicates that the majority of the variables show a direct and significant relationship with the outcome variable except for the VSAT variable (commission errors) which shows an inverse relationship as well as the delay discount task score and the Go/NoGo variable (commission errors). Also, we performed a multivariate multiple regression analysis in order to help explain the variables underlying relapse in smokers on clinical follow-up. For this purpose, we selected the stepwise regression method to identify only the most relevant predictor variables. The analysis of variance due to regression emphasized that the number of relapses was significantly predicted by unplanned impulsivity (UP-BIS-11), errors of commission in the Go/NoGo task and errors of commission in the VSAT task significantly predicted the number of relapses $F(3, 137)= 8.338$, $p< .001$, explaining 15.4% of the total variance (Table 3). Statistical significance results for each coefficient indicate that unplanned impulsivity (UP-BIS-11) is directly related to the number of relapses (β=

.032, *t*= 4.067, *p*= .001) and it represents the only significant predictor. On the other hand, the rest of the variables included in the model are inversely related to the outcome variable (β= -.007, *t*= .972, *p*= .333 y β= -.019, *t*= -2.573, *p*= .011).

Table 2
Correlation matrix between criterion variable and predictor variables (*N*= 141)

Variables	1	2	3	4	5	6
1. Relapses	--					
2. C-BIS-11	.269*	--				
3. M-BIS-11	.275*	.661*	--			
4. UP-BIS-11	.327*	.654*	.634*	--		
5. Go/NoGo	-.076	.023	.079	.019	--	
6. VSAT	-.218*	-.017	-.048	-.042	.026	--
7. DDT	-.036	.003	.024	-.020	-.049	-.019

Notes: Relapses= number of relapses in one year; C-BIS-11= cognitive subscale of the Barratt Impulsivity Scale (BIS); M-BIS-11= motor subscale of the BIS; UP-BIS-11= unplanned subscale of the BIS; Go/NoGo= errors of commission on the Go/NoGo Task; VSAT= errors of commission on the Visual Search and Attention Test; DDT= Delay Discounting Task. **p*< .05.

Table 3
Multiple linear regression model summary (*N*= 141)

Outcome variable: Relapses	Predictors	β	*t*	Sig.	R^2	R^2 Change
Step 1	UP-BIS-11	.032*	4.078	.000	.107*	
Step 2	UP-BIS-11	.033	4.097	.000	.114*	.101
	Go/NoGo	.008	-1.020	.310		
Step 3	UP-BIS-11	.032	4.067	.000	.154*	.136
	Go/NoGo	-.007	-.972	.333		
	VSAT	-.019	-2.573	.011		

Notes: Relapses= number of relapses in one year. Predictors are listed in decreasing order of importance. UP-BIS-11= unplanned subscale of the Barratt Impulsivity Scale; Go/NoGo= errors of commission on the Go/NoGo Task; VSAT= errors of commission on the Visual Search and Attention Test.**p*< .05.

Finally, logistic regression was used to predict abstinence/relapse, categorizing the outcome variable (abstainers vs. smokers). Table 4 shows that only the impulsivity variable evaluated by the BIS-11 (Wald= 23.704, *p*= .001) was significant, while the rest of the variables were not significant (*p*> .05). The beta-coefficients (β) indicate that impulsivity is directly related to the risk of relapse, meaning that the higher the BIS-11 scores, the higher the risk of relapse (OR= 1.068). However, regarding the other variables, it is noted that they are inversely associated with the probability of relapse (OR= .981, .987, .946). In terms of CoxSnell's R^2, the overall model allows an estimate of 23.4% of the abstinence/relapse variability due to the relationship with the impulsivity variable (total score on the BIS-11), VSAT (commission errors), Go/NoGo (commission errors) and DDT (delay discount score). In turn, the Nagelkerke coefficient indicates that 31.5% of the variability of abstinence/relapse is explained by all three variables included in the model. Furthermore, the model is acceptable as it correctly classifies 58,2% of the cases.

Therefore, the fitted logistic model is appropriate since χ^2_{exp}= 6.710 (*df*= 8), *p*= .568 > .05 indicating that observations are sufficiently adjusted to what is expected

Table 4
Logistic regression model summary (*N*= 141)

Variables	β	Standard error	Wald	*p*-value	OR	95% CI
BIS-11	.066	.014	23.704	.000	1.068	1.040-1.097
VSAT	-.020	.031	0.405	.525	0.981	0.923-1.042
Go/NoGo	-.013	.029	0.202	.653	0.987	0.932-1.045
DDT	-.056	.903	0.004	.951	0.946	0.161-5.548
Constante	-2.440	.836	8.520	.004	0.087	

Notes: BIS-11= total score on the Barratt Impulsivity Scale; Go/NoGo= errors of commission on the Go/NoGo Task; VSAT= errors of commission on the Visual Search and Attention Test; TDD= Delay Discounting Task. **p*< .05.

Discussion

The purpose of the study aimed to evaluate the predictive capacity of impulsive behavior dimensions (delay discounting, response inhibition, attentional failure, and self-reported impulsivity) on the probability of relapse and on the prevalence of relapse among smokers over a period of 12 months. First, our results indicate that global self-reported impulsivity is directly related to the risk of relapse after a prolonged period of clinical follow-up. These findings are in line with other research emphasizing the predictive power of self-reported measures in predicting treatment outcomes (Balevich et al., 2013; Bourque et al., 2013; López-Torrecillas et al., 2014; Patterson et al., 2010). The more withdrawal symptoms are experienced, the greater the need for drug seeking. This fact is explained by the fact that drug seeking represents a measure to reduce undesirable effects of the abstinence period, generating more vulnerability to relapse (Hall et al., 2015). This is explained by empirical research through the phenomenon described as "drug craving incubation", which has been widely demonstrated in animal models (Abdolahi et al., 2010) as well as clinical models (Bedi et al., 2011). This phenomenon is defined as an increased sensitivity to drug-related stimuli, restoring drug-seeking and preventing abstinence even after prolonged periods. In this regard, several authors reported an attentional bias to smoking cues among smokers, present even after prolonged abstinence. This bias modulates the involuntary processes of ex-smokers, which could be a vulnerability factor for relapse. (Rehme et al., 2018).

On the other hand, the linear regression model indicates that the best predictors of the number of relapses are the NP-BIS-11 variable, the VSAT variable and the Go/NoGo variable. These results are in line with the conclusions of the study conducted by Conti et al. (2019) where high unplanned impulsivity among chronic smokers involved reward devaluation. Other authors also identified unplanned impulsivity as a measure that reflected a strong association with craving (Bourque et al., 2013) and higher probability of relapse (López-Torrecillas et al., 2014). In addition, inhibitory control problems evaluated by the Go/NoGo task represent another key factor, that is consistent with other studies that associate higher rates

of commission errors with higher risk of relapse and with higher levels of nicotine dependence (Kräplin et al., 2019; Luijten et al., 2016). However, this task did not show statistical significance in our study. In this sense, these inconsistencies between results may be explained because previous studies used modest sample sizes (Liu et al., 2019; Luijten et al., 2011; Zhao et al., 2016).

On the other hand, the delayed discounting task did not show statistical significance which may reveal that the inconsistency with previous studies is due to the disparity of tasks used. Furthermore, another plausible explanation could be that the predictive capacity of delayed discounting tasks exhibited a moderate effect in adults (Syan et al., 2021) compared to the results found in adolescent samples (Harvanko et al., 2019; Reynolds & Fields, 2012).

In summary, self-reported impulsivity measures are useful to predict the likelihood of relapse and the number of relapses in advanced stages of abstinence. In addition, both inhibitory control and attentional impulsivity showed a considerable (although not significant) contribution to smoking cessation. Taken together, the impulsive behavior pattern of smokers could become a risk factor that hinders self-control and prompts nicotine-seeking (García-Rivas & Deroche-Gamonet, 2019). Among the limitations of this study, it should be noted that using a non-random and incidental sample does not guarantee the representativeness of the sample. In addition, it would be desirable to explore impulsive behavior profiles in conjunction with emotional variables (Pérez-Pareja et al., 2020), mood (Gallego et al*.,* 2014), and personality traits because of their potential impact on treatment adherence.

On the other hand, the main strength of our study lies in the multidimensional approach to the assessment of impulsivity within a long-term prospective design. Our results are novel because they allow us to analyze individual differences that predict consumption resumption and make it possible to infer consumption assiduity. Hasta donde alcanza nuestro conocimiento, ningún estudio previo ha cuantificado el número de recaídas durante el tratamiento. To the best of our knowledge, no previous study has quantified the number of relapses during treatment. The importance of these findings derives from the fact there is evidence that relapse could be modulated by different dimensions of impulsive behavior. This fact would make it possible to determine a psychological profile linked to relapsing smokers despite treatment. On the other hand, the naturalistic approach allows for greater similarity with clinical practice, for instance, we propose research based on this methodology in order to investigate the implication of cognitive and behavioral variables in the process of abstinence. Specifically, we suggest the inclusion of new instruments for impulsivity assessment, such as the *UPPS Impulsive Behavior Scale* (UPPS; Whiteside & Lynam, 2001) and *Stop Signal Task* (SST; Logan et al., 1997). Secondly, it is important to establish different impulsivity profiles that identify severe smokers in order to adapt treatment based on cognitive approaches and prevention strategies based on behavioral control. And finally, it is essential to promote explanatory models that determine the role of each impulsive component (delay discounting, response inhibition, attentional failures and trait impulsivity) during the abstinence process.

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