Effects of combined coffee and alcohol use over cigarette demand among treatment-seeking smokers

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1. Introduction

Behavioral economics is the application of both economics and psychology to study multifaceted components of decision-making behavior (Aston & Cassidy, 2019). This approach plays an important role in the study of substance use as it allows us to explain the addictive behavior (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014) and could help to design better treatment approaches (Jarmolowicz, Reed, Bruce, & Bruce, 2019). Within this approach, relative reinforcing efficacy (RRE) is a central concept which refers to the behavior-strengthening or behavior-maintaining effects of a drug or specific dose of a drug (Griffiths, Brady, & Bradford, 1979). One way to address RRE is to assess how much a person is willing to purchase of a substance at a given price (Gray et al., 2017). A useful tool available in the smoking population is the Cigarette Purchase Task (CPT), which consists of evaluating hypothetical cigarette purchases (i.e., demand) as a function of escalating prices (MacKillop et al., 2008). Higher cigarette demand assessed by CPT has been associated with higher daily cigarette consumption and greater nicotine dependence (Higgins et al., 2017; Mackillop et al., 2015), as well as less motivation to quit smoking (Bidwell, MacKillop, Murphy, Tidey, & Colby, 2012). Furthermore, CPT performance predicts smoking cessation outcomes (Mackillop et al., 2015; Murphy et al., 2017; Secades-Villa, Pericot-Valverde, & Weidberg, 2016). On the other hand, reductions in nicotine intake decrease in-treatment cigarette demand (Weidberg, Vallejo-Seco, González-Roz, García-Pérez, & Secades-Villa, 2018).

Previous evidence shows a positive association between smoking and alcohol use (Luczak et al., 2017; Peloquin, McGrath, Telbis, & Barrett, 2014; Richter, Pugh, Smith, & Ball, 2017; Shiffman et al., 2013). This relationship seems to go beyond mere co-occurrence, since the consumption of alcohol may affect tobacco use. For example, alcohol seems to be a complementary tobacco reinforcer since it is positively associated with daily tobacco use and increased nicotine dependence (Falk, Yi, & Hiller-Sturmhofel, 2006). On the other hand, several studies have found a positive relationship between coffee use and smoking (Loftfield et al., 2015; Treur et al., 2016). Again, the consumption of this substance could alter smoking behavior, since previous research has found that caffeine use increases the urge to smoke in smokers and it also increases their positive cigarette appraisals (Treloar, Piasecki, McCarthy, & Baker, 2014). Moreover, the relationship of alcohol and coffee with smoking seems to be maintained when the use of all these substances occurs simultaneously (Stotts, Shipley, Schmitz, Sayre, & Grabowski, 2003; Zavela, Barnett, Smedi, Istvan, & Matarazzo, 1990). Nonetheless, there is no previous evidence on how the interaction of alcohol and coffee may affect cigarette consumption.

These associations lead us to think that alcohol and coffee use could affect cigarette demand. Despite this, no study to date has examined how alcohol and coffee use relates to cigarette demand using the CPT. However, there are similar studies that address how coffee and tobacco consumption impact alcohol demand assessed by the Alcohol Purchase Task (APT; Amlung et al., 2013; Amlung et al., 2017; Yurasek et al., 2013). These studies have shown the association of tobacco and/or caffeine consumption with increased alcohol demand in college students. Additionally, two other studies (Lee, 2007; Lee et al., 2010) compare the elasticity of these substances, using the Central Bureau of Statistics demand model, concluding that reducing the consumption of one substance can reduce the consumption of the others.

Assessing how alcohol and coffee use is associated with cigarette demand is important because it could shed light on whether the use of these substances needs to be considered when designing interventions to quit smoking. Therefore, the aim of this study is to overcome this gap in the research by assessing, for the first time, CPT performance as a function of alcohol and coffee consumption of treatment-seeking smokers.

2. Material and Methods

2.1 Participants and procedure

Participants were 88 treatment-seeking smokers from the general population who enrolled in a clinical trial for smoking cessation (López-Núñez, Martínez-Loredo, Weidberg, Pericot-Valverde & Secades-Villa, 2016). Inclusion criteria for the study were being 18 or over, meeting the diagnostic criteria for nicotine dependence according to the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; DSM-IV-TR) (APA, 2000), and smoking 10 or more cigarettes per day for the last year. Participants were excluded if they had been diagnosed with a current severe psychiatric disorder.

As in previous studies (Haardörfer et al., 2016; Matsuura et al., 2012; Nielsen, Gjerstad, & Frone, 2018; Noroozi et al., 2018; Park et al., 2017; Takami et al., 2013), smokers were divided into two categories of alcohol consumption (alcohol drinkers [≥ 1 standard drink per week] and non-drinkers) and coffee consumption (high consumption coffee users [≥ 4 cups of coffee per day] and low consumption coffee users [≤ 1.5 cups of coffee per day]). The statistical analysis could not be carried out on heavy drinkers (> 14 standard drinks per week; [U.S. Department of Agriculture, 2010]) or on smokers who do not drink coffee because there were not enough participants in either of these groups. However, the low prevalence of heavy drinkers and participants who do not drink coffee in our sample is in accordance with the epidemiological data concerning smokers (Falk et al., 2006). Socio-demographic and smoking-related characteristics of the sample are reported in Table 1. [Table 1 near here]

The study was approved by the Institutional Review Board of the University of Oviedo, and all participants provided informed consent prior to study initiation.

2.2 Measures

2.2.1 Smoking and nicotine dependence

During the intake session, participants completed a clinical history to provide data on socio-demographic (age, gender, marital status, income, and level of education) and smoking-related characteristics (cigarettes per day and years of regular smoking). The Fagerström Test for Nicotine Dependence (FTND, Heatherton, Kozlowski, Frecker, & Fagerström, 1991) was used to assess nicotine dependence.

2.2.2 Alcohol and coffee consumption

Alcohol and coffee consumption were measured in standard drinks (10 grams of pure alcohol) and cups of coffee respectively. The participants were asked about their use per week averaged over the past month for both substances.

2.2.3 Cigarette demand

Participants completed the CPT following the instructions based on MacKillop et al. (2008). Participants were then asked to respond to the following question: "How many cigarettes would you smoke if they were _____ each?" The following 19 prices were inserted: zero (free), €0.01, €0.02, €0.05, €0.10, €0.25, €0.50, €1, €2, €3, €4, €5, €10, €20, €50, €100, €250, €500, and €1,000. The prices were adapted from MacKillop et al. (2008) and presented in escalating order.

2.3 Data analyses

Five indices from the CPT were generated, including (1) intensity: cigarette consumption at zero cost; (2) O_{max}: maximum amount of money allocated to cigarettes; (3) P_{max}: price at which expenditure was maximized; (4) breakpoint: first price at which a subject reports zero consumption; (5) elasticity: the proportional change in consumption relative to the proportional change in price (Bickel et al., 2014), with values of less than 1 indicating insensitivity of demand to rises in costs (i.e., higher demand for cigarettes). Elasticity was estimated by fitting each participant's informed consumption across the interval of prices using an exponential demand curve equation proposed by Koffarnus, Franck, Stein, and Bickel (2015):

$$Q = Q_0 \times 10^{k(e^{-\alpha Q_0 C} - 1)}$$

where Q = consumption at a given price (with zeroes set to 0.01); Q_0 = consumption at zero/minimal price; k = range of dependent variable (number of cigarettes); C = price, and α = elasticity (slope of the demand curve). As in previous studies with the CPT (Farris, Aston, Abrantes, & Zvolensky, 2017), the appropriate k value was determined by subtracting the log10-transformed average consumption at the highest price from the log10-transformed average consumption at the lowest price. A fixed value of k = 3.55

was collapsed for all participants. A nonlinear regression was used to generate an R^2 value, in order to assess the goodness of fit of the data. CPT values were observed in order to detect contradictions, which were defined as misunderstanding or bounce during the task performance. Following the criteria of >2 contradictions at escalating prices (Acker & MacKillop, 2013), CPT data from six participants were removed from the analyses. In addition, demand indices were examined in order to detect outliers and distribution abnormalities. Following the recommendation of Tabachnick, Fidell, and Osterlind (2001), CPT indices were standardized and compared to a critical value of $Z = \pm 3.29$. Seven outliers (high extreme values) were identified and recoded as the highest non-outlying value (plus 0.01 for elasticity and plus 1 for the remaining indices).

Pearson's correlations assessed the relationship between baseline smoking-related characteristics, coffee and alcohol consumption, and CPT demand indices. Student t-tests (for continuous variables) and $\chi 2$ tests (for categorical variables) were used to examine group differences in baseline socio-demographic variables. A multivariate analysis of variance (MANOVA) and a multivariate analysis of covariance (MANCOVA) were used to compare intake of alcohol (consumers and abstainers of alcohol) and coffee (high coffee consumers and low coffee consumers) on CPT indices. Covariates included in the MANCOVA were those variables that showed significant differences (at a p value $\leq .05$) across groups in baseline comparisons. Exponential demand curve modeling was conducted using GraphPad Prism 6.0 (La Jolla, California), whereas SPSS software (version 24, SPSS Inc., Chicago IL, USA) was used for the remaining analyses. Significance for all statistical comparisons was defined at $p \leq .05$.

3. Results

Relationship among cigarette demand, cigarette smoking, coffee consumption, and alcohol use

Table 2 includes correlations among smoking-related characteristics, consumption of coffee and alcohol, and CPT demand indices. Smoking was positively related to coffee consumption, but not to alcohol. All CPT demand indices correlated with the number of cigarettes per day and the total score of the FTND. Moreover, standard drinks were positively associated with breakpoint, O_{max} and P_{max}.

[Table 2 near here]

Differences in cigarette demand between study groups

Figure 1 depicts cigarette demand curves by group. There were statistically significant differences in demand between groups. The overall multivariate effect was significant for coffee consumption [Pillai's Trace = .160, F (5, 79) = 3.02, p = .015, η^2 = .160] and the coffee × alcohol interaction [Pillai's Trace = .134, F (5, 79) = 2.436, p = .042, η^2 = .134]. Table 3 shows the complete results of the univariate effects based on the consumption of coffee, of alcohol, and the interaction of the two. The univariate effects of the coffee × alcohol interaction were significant for elasticity (p = .038) and intensity (p = .010). The simple effects displayed in the bottom panel of Table 3 show that alcohol abstainers had higher intensity and were more inelastic when they had higher coffee consumption. This can be seen graphically in Figure 2. Related to this aspect, low consumption coffee users were more inelastic when they were alcohol drinkers. Lastly, high consumption coffee users showed higher intensity when they were alcohol abstainers. The remaining indices, O_{max}, P_{max}, and breakpoint were not statistically significant. The primary effects of these indices for the alcohol and coffee groups were also not statistically significant.

[Figure 1 near here]

[Figure 2 near here]

Group differences were maintained after adjusting for age and years of regular smoking in both multivariate [Pillai's Trace = .146, $F\,(5, 77) = 2.625$, $p = .030$, $\eta^2 = .146$] and univariate effects (elasticity, [F (1, 81) = 5.048, $p = .027$, η2 = .059] and intensity of coffee × alcohol interaction [F (1, 81) = 7.401, $p = .008$, η2 = .084]). No covariate was significantly related to demand indices ($p > .19$).

4. Discussion

To our knowledge, this is the first study to assess the relationship among tobacco demand, alcohol and coffee use in treatment-seeking smokers. We highlight three major findings: First, smokers who do not drink alcohol show greater intensity and are more inelastic (i.e., greater cigarette demand) when they have high coffee use. Second, smokers who have low coffee use are more inelastic when they are alcohol drinkers; and third, smokers who have high coffee use show greater intensity when they are alcohol non-drinkers.

The first two findings show that alcohol and coffee use are associated with an elevated cigarette demand among treatment-seeking smokers. This result is consistent with evidence showing that higher frequency of alcohol (Kim, 2014; Leeman et al., 2008; Zimmerman et al., 1990) and coffee (Ahn et al., 2017) use is related with a lower likelihood of successful smoking cessation and a higher risk of smoking relapse (Krall, Garvey, & Garcia, 2002) and that individuals who have previously reduced their drinking are more successful in decreasing (Roberts, Ralevski, Verplaetse, McKee, &

Petrakis, 2018) or quitting smoking (Zimmerman et al., 1990). Several factors may explain these findings. Alcohol use increases craving for tobacco (Burton & Tiffany, 1997; King & Epstein, 2005; Piasecki et al., 2011; Sayette, Martin, Wertz, Perrott, & Peters, 2005), anticipation of positive reinforcement of smoking, and the expectation of feeling better after smoking (Glautier, Clements, White, Taylor, & Stolerman, 1996). In addition, concurrent use of alcohol and tobacco is associated with significantly increased pleasure and decreased punishment derived from smoking (Piasecki et al., 2011), and is more satisfying and calming (Rose et al., 2004). On the other hand, caffeine consumption increases both urges to smoke (Treloar et al., 2014) and actual smoking (Shiffman et al., 2009; Treloar et al., 2014). Likewise, smokers report believing that alcohol and coffee use enhances the taste of cigarettes (McClernon, Westman, Rose, & Lutz, 2007). Lastly, some experimental studies suggest that both ethanol (Rose et al., 2004; Verplaetse & McKee, 2017) and caffeine (Celik, Uzbay, & Karakas, 2006) can potentiate the rewarding effects of nicotine. Alternatively, there may be other variables not accounted for that have shown to be associated with elevated tobacco demand, such as impulsivity or environmental reward deprivation (Field, Santarcangelo, Sumnall, Goudie, & Cole, 2006).

The finding that smokers who report high coffee consumption show greater intensity when they are alcohol abstainers is counterintuitive. Nevertheless, according to previous research (Kalman, Morissette, & George, 2005; Luczak et al., 2017), it is possible that in the alcohol abstainers group there are smokers with a history of alcoholism, and that nicotine is more reinforcing in smokers with a history of alcoholism than in smokers from the general population (Hughes, Rose, & Callas, 2000). However, it should be noted that in this study a history of alcohol use disorder was not assessed.

The present work has several implications. From a clinical standpoint, assessing coffee and alcohol use is essential in smoking cessation interventions, as demand indices predict treatment outcomes (Mackillop et al., 2015; Murphy et al., 2017; Secades-Villa et al., 2016). Addressing co-occurring coffee and alcohol use may be an especially important treatment need. Training to avoid smoking-related cues and practicing nonsmoking coping responses in typical smoking settings (Cook et al., 2012), may be specifically useful in helping smokers with concurrent alcohol use to quit. Moreover, health professionals who are in charge of developing effective treatments for smoking cessation should encourage restricting the use of these substances before quitting smoking (Haug, Castro, Kowatsch, Filler, & Schaub, 2017). Also, it would be interesting to study whether these findings also take place in the early stages of substance use, since it would add evidence to the gateway drug theory (Chen et al., 2002) and would have implications in the area of prevention.

Some limitations should be informed. First, the cross-sectional design of our study precludes examination of the causal relationship between cigarette demand and consumption of alcohol and coffee. Second, although we ensured that the subsamples of alcohol and coffee users were balanced, the group of alcohol abstainers who were low consumption coffee users was small. This reduces the statistical power of the analysis that includes this specific group. Third, other caffeinated beverages, other than coffee, were not analyzed, so the present findings can only be extrapolated to coffee beverages. Fourth, this study did not explore the impact of the time of the last coffee and/or alcohol consumption on CPT, which could contribute to explain the current results. Fifth, in this study no information was collected on whether the participants tended to consume any of these substances together. Despite this, since the current sample smoke a high number of cigarettes per day, it is feasible that on some occasions the smokers accompanied the smoking behavior with the consumption of coffee or alcohol.

5. Conclusions

Despite these shortcomings, the present findings yield evidence of the enhancing effects of combined coffee and alcohol use on the relative reinforcing value of cigarettes among treatment-seeking smokers. Thus, health providers should encourage the reduction of these substances when implementing interventions for smoking cessation. Future studies could study the impact of experimentally manipulating these substances on cigarette demand, as well as analyzing the interactions between these commodities using a cross-price elasticity task.

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Table 1. Characteristics of the sample at baseline

	Coffee			Alcohol			
Characteristic	Low (n = 44)	High (n = 44)	*p*	Drinkers (n = 61)	Non-drinkers (n = 27)	*p*	Total (n = 88)
Age (years)[a]	41.2 ± 13.1	45.5 ± 11.3	.099	41.5 ± 12.5	47.7 ± 11.0	**.032**	43.4 ± 12.3
Sex (% women)	63.6	56.8	.513	62.9	53.8	.428	60.2
Marital status (% married)	34.1	50.0	.131	41.9	42.3	.974	42.0
Years of Education (%)			.391			.098	
10 or less	13.6	25.0		19.3	30.8		29.5
11 to 15 years	50.0	45.5		47.7	50.0		37.5
16 years or more	36.4	29.5		33.0	19.2		33.0
Monthly income (%)			.269			.871	
Less than 600€	40.5	20.0		30.9	27.3		29.9
601€ to 1200€	29.7	37.5		30.9	40.9		33.7
1201€ to 2000€	21.6	30.0		27.3	22.7		26.0
2001€ or more	8.2	12.5		10.9	9.1		10.4
FTND[a]	4.8 ± 2.1	5.6 ± 3.6	.083	5.0 ± 2.1	5.9 ± 2.0	.056	5.2 ± 2.1
Standard drinks per week[a]	8.3 ± 9.6	3.9 ± 6.0	**.012**	8.7 ± 8.6	0.0 ± 0.0	**<.001**	6.1±8.3
Cups of coffee per week[a]	5.4 ± 3.6	41.3 ± 16.6	**<.001**	17.2 ± 17.2	38.1 ± 17.2	**<.001**	23.4±21.6
Cigarettes per day[a]	18.6 ± 7.9	22.9 ± 9.4	**.024**	19.1 ± 8.0	24.7 ± 9.9	**.007**	20.8 ± 8.9
Years of regular smoking[a]	22.1 ± 11.2	27.4 ± 11.8	**.032**	22.9 ± 11.3	29.2 ± 11.7	**.021**	24.7 ± 11.8

Note. [a] mean ± standard deviation; Low = low consumption coffee users; High = high consumption coffee users; FTND = Fagerström Test for Nicotine Dependence.

Table 2. Correlations among smoking-related measures, alcohol and coffee consumption, and cigarette demand indices

	1	2	3	4	5	6	7	8	9	10
1 – Cigarettes per day	-	-	-	-	-	-	-	-	-	-
2- Years of smoking	.35**	-	-	-	-	-	-	-	-	-
3- FTND	.62**	.28**	-	-	-	-	-	-	-	-
4 - Cups of coffee per week	.26*	.15	.15	-	-	-	-	-	-	-
5 – Standard drinks per week	.06	-.01	.08	-.23*	-	-	-	-	-	-
6 - Breakpoint	.27**	.11	.28**	.01	.15	-	-	-	-	-
7 - Omax	.44**	.16	.39**	-.01	.25*	.70**	-	-	-	-
8 - Pmax	.26*	.08	.25*	-.07	.21*	.87**	.68**	-	-	-
9 - Intensity	.80**	.19	.51**	.17	.06	.26*	.35**	.20	-	-
10 - Elasticity	-.46**	-.11	-.37**	-.03	-.06	-.33*	-.39**	-.27*	-.23**	-

FTND = Fagerström Test for Nicotine Dependence
* *p* < .05; ** *p* < .01

Table 3. Results of univariate effects and simple effects of interaction

	Alcohol			Coffee			Coffee × Alcohol		
Index	F^a	p	η^2	F^a	p	η^2	F^a	p	η^2
Breakpoint	.575	.450	-	.057	.812	-	.313	.577	-
O_{max}	.485	.488	-	.254	.616	-	2.745	.101	-
P_{max}	.191	.663	-	1.172	.282	-	.001	.976	-
Intensity	.048	.826	-	3.944	**.050**	.045	6.972	**.010**	.077
Elasticity	7.873	**.006**	.087	7.716	**.007**	.085	4.435	**.038**	.051

Simple effects of coffee × alcohol[b]

Index	Group		Mean differences	SEM	p	η^2
Intensity	Non-drinkers	High Coffee Low Coffee	11.619	4.436	.010	.076
Elasticity	High Coffee	Alcohol drinkers Non-drinkers	-7.184	2.691	.009	.079
	Low Coffee	Alcohol drinkers Non-drinkers	-.014	.005	.005	.092
	Non-drinkers	High Coffee Low Coffee	-.014	.005	.007	.084

Note. [a] degrees of freedom of test were 1 and 83; [b] Only significant comparisons are displayed; SEM = standard error of the mean; High Coffee = high consumption coffee users; Low Coffee = low consumption coffee users.

Figure 1. CPT demand curve by group. The x-axis provides price in euros (€) and the y-axis provides self-reported consumption in cigarettes.

Figure 2. CPT demand curve for high and low consumption coffee users who are non-drinkers. The x-axis provides price in euros (€) and the y-axis provides self-reported consumption in cigarettes. At the statistical level there are differences in both intensity [$F(1, 24) = 5.031$, $p = .034$] and elasticity [$F(1, 24) = 4.575$, $p = .043$].