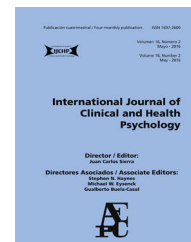




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## ORIGINAL ARTICLE

# Delay discounting in e-cigarette users, current and former smokers



Sara Weidberg\*, Alba González-Roz, Roberto Secades-Villa

Universidad de Oviedo, Spain

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### KEYWORDS

E-cigarette;  
Smoking;  
Delay discounting;  
Impulsivity;  
Experiment

**Abstract** *Background/Objective:* Despite the fact that electronic cigarettes, or e-cigarettes, are being increasingly used as an alternative to smoking tobacco cigarettes, few studies have explored psychological factors associated with e-cigarette use. Prior studies aimed at exploring correlates of e-cigarette use have focused on sociodemographic and smoking-related characteristics. However, no previous work has examined psychological features such as impulsivity among e-cigarette users. The main objective of this study was to compare impulsivity rates across four groups of participants: current e-cigarette users who were former smokers; current smokers; former smokers; and controls. *Method:* A sample of 136 participants completed a computerized delay discounting task for hypothetical monetary values. *Results:* Delay discounting was greater among e-cigarette users than former smokers. E-cigarette users also showed an intermediate discounting that did not differ from smokers and controls. Moreover, delay discounting was significantly greater among current smokers compared to former smokers and controls. *Conclusions:* Taken together, our results extend previous research on delay discounting by providing evidence on impulsivity levels among current e-cigarette users for the first time. © 2016 Asociación Española de Psicología Conductual. Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

### PALABRAS CLAVE

Cigarrillo electrónico;  
Fumar;  
Descuento por demora;  
Impulsividad;  
experimento

**Descuento por demora en usuarios de cigarrillos electrónicos: fumadores y ex-fumadores**

**Resumen** *Antecedentes/Objetivo:* A pesar de que los cigarrillos electrónicos se han usado cada vez más como alternativa al consumo de tabaco, pocos estudios han explorado los factores psicológicos asociados a su uso. Estudios previos que analizan los correlatos del cigarrillo electrónico se han centrado en las características sociodemográficas y de dependencia del

\* Corresponding author: Department of Psychology, Universidad de Oviedo, Plaza Feijóo, s/n, 33003 Oviedo, Spain.  
E-mail address: [weidbergsara.uo@uniovi.es](mailto:weidbergsara.uo@uniovi.es) (S. Weidberg).

tabaco. Sin embargo, ningún estudio ha analizado características psicológicas como la impulsividad en usuarios de cigarrillo electrónico. El objetivo del estudio fue comparar las tasas de impulsividad en cuatro grupos de participantes: usuarios actuales de cigarrillo electrónico que eran ex-fumadores, fumadores de tabaco, ex-fumadores y controles. *Método:* Una muestra de 136 participantes completó una versión informatizada de la tarea de descuento por demora para reforzadores monetarios hipotéticos. *Resultados:* El descuento por demora fue mayor entre los usuarios de cigarrillo electrónico que entre los ex-fumadores. Los usuarios de cigarrillo electrónico mostraron un descuento intermedio que no difirió del de los fumadores y los controles. Además, el descuento por demora fue significativamente mayor entre los fumadores en comparación con los ex-fumadores y los controles. *Conclusiones:* Los resultados obtenidos amplían la literatura previa sobre descuento por demora arrojando nueva evidencia sobre los niveles de impulsividad en los usuarios de cigarrillo electrónico.

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Electronic cigarettes (e-cigarettes) are battery powered devices commercialized as harm-reducing alternatives to smoking (Farsalinos, Tsiapras, Kyrzopoulos, Savvopoulou, & Voudris, 2014). They are designed to mimic traditional tobacco cigarettes by enabling users to vaporize a liquid solution containing propylene glycol, vegetable glycerin, flavorings, and—optionally—nicotine (Adkison et al., 2013; Wagener et al., 2014). The awareness and use of e-cigarettes has increased exponentially since their launch in 2004 (Dockrell, Morrison, Bauld, & McNeill, 2013; King, Alam, Promoff, Arrazola, & Dube, 2013). E-cigarette prevalence among American and European users has been reported to increase from 1.8% to 13% between 2010 and 2013 and from 2.7% to 6.7% between 2010 and 2012, respectively (Dockrell et al., 2013; McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2015). In Spain, only one study was conducted to estimate data on e-cigarette use among a representative sample of the city of Barcelona. In this sense, Martínez-Sánchez et al. (2015) showed that 1.6% of participants were current e-cigarette users suggesting that the prevalence of e-cigarette use in Spain might be lower compared to those reported in both America (Vickerman, Carpenter, Altman, Nash, & Zbikowski, 2013) and Europe (Adkison et al., 2013).

Despite the emerging popularity of e-cigarettes, public health authorities have expressed the scarce evidence regarding their safety and effectiveness as a substitute for cigarettes, or an alternative to quitting smoking (World Health Organization, 2014). Research focused on e-cigarettes and smoking cessation has provided mixed results. Whilst several studies suggested e-cigarettes may be effective in promoting tobacco abstinence (Etter & Bullen, 2014; Rahman, Hann, Wilson, Mnatzaganian, & Worrall-Carter, 2015), others have not found such results (Brose, Hitchman, Brown, West, & McNeill, 2015). A growing body of research has explored the characteristics related to e-cigarette use (Dawkins, Turner, Roberts, & Soar, 2013; Etter, Bullen, Flouris, Laugesen, & Eissenberg, 2011). The vast majority of these studies have focused on sociodemographic and smoking-related features associated with its use. Certain characteristics such as male gender (Ramo, Young-Wolff,

& Prochaska, 2015), being a current or former smoker (Martínez-Sánchez et al., 2015), or having a higher level of education (Pearson, Richardson, Niaura, Vallone, & Abrams, 2012) are associated with e-cigarette use.

Less is known regarding psychological features such as impulsivity among e-cigarette users. Impulsivity has shown to be a strong predictor of smoking relapse (Doran, Spring, McChargue, Pergadia, & Richmond, 2004). In this regard, assessing impulsivity levels within e-cigarette users may help to detect individuals with increased difficulty in maintaining smoking abstinence and greater likelihood of dual use of e-cigarettes and tobacco. Although this construct has been traditionally assessed by the use of self-report questionnaires (Martínez-Loredo, Fernandez-Hermida, Fernandez-Artamendi, Carballo, & Garcia-Rodriguez, 2015), a widely used behavioral measure of impulsivity is delay discounting (Odum, 2011). This impulsivity index describes the devaluation of a reinforcer as a function of increasing delay to its receipt (Reynolds, 2006). Cigarette smokers show greater delay discounting when compared to controls (Bickel, Odum, & Madden, 1999). Delay discounting is also associated with smoking onset, maintenance, severity, and relapse (Audrain-McGovern et al., 2009; Sheffer et al., 2014; Sweitzer, Donny, Dierker, Flory, & Manuck, 2008). To our best knowledge, no previous study has assessed delay discounting rates in a sample of e-cigarette users. Whether it differs between e-cigarette users, cigarette smokers and former smokers remains unknown.

This study aims to address this gap in previous research by comparing performance on a delay discounting task across e-cigarette users, smokers, former smokers and controls.

## Method

### Participants

Participants comprised a subset of individuals recruited throughout the community by means of advertisements in

the press and flyers. E-cigarette users were enrolled on vaper forums and flyers posted in e-cigarette stores located in Asturias, Spain. Participants in this study were: 1) 28 e-cigarette users; 2) 40 controls, 3) 40 smokers and, 4) 28 former smokers. Exclusion criteria for all participants were being under 18 years old and reporting any cognitive impairment (e.g., a recent stroke or cerebrovascular accident) that would hinder the execution of the delay discounting task.

Inclusion criterion for e-cigarette users was self-reporting using any kind of e-cigarette (exclusively, that is, not dual use of e-cigarettes) continuously during 30 days on a daily basis. Interested participants were screened by telephone to verify eligibility. In order to collect urinalyses and measures of breath carbon monoxide as an indicator of smoking status, only participants living in Asturias were assessed by face-to-face interviews. E-cigarette users were asked to bring the e-cigarette device and e-liquids they were actually using at the time of the interview. Inclusion criteria for smokers consisted of smoking 10 or more cigarettes per day during the last year and meeting diagnostic criteria for nicotine dependence according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; American Psychiatric Association, 2000). Former smokers and e-cigarette users were included in this study if they self-reported smoking abstinence and presented a breath CO level  $\leq 10$  parts per million (ppm) (Becoña, López-Durán, Fernández del Río, & Martínez, 2014; Bullen et al., 2013). Control participants were included if they were not current smokers and reported not having smoked  $\geq 100$  cigarettes during their lifetime.

This study was approved by the Institutional Review Board of the University of Oviedo and it followed the ethical principles of the Declaration of Helsinki. Informed consent was obtained from all participants prior to study initiation.

## Procedure and instruments

Participants' sociodemographic and smoking-related characteristics were gathered by means of face-to-face interviews (see Table 1). Data on sociodemographic variables (e.g., age, sex) and features related to vaping or smoking history (e.g., age at smoking onset, whether or not e-cigarette users were vaping e-liquid containing nicotine, and their preferred flavorings, etc.) were collected. Smokers completed the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) and the Nicotine Dependence Syndrome Scale (NDSS; Shiffman, Waters, & Hickcox, 2004). These instruments were adapted to assess e-cigarette dependence (Etter & Eissenberg, 2015). Smokers and e-cigarette users were assessed through biochemical measures that included breath carbon monoxide (CO) (using a Micro Smokerlyzer, Bedfont Scientific, Rochester, United Kingdom) and urinary cotinine levels (using a BS-120 chemistry analyzer, Shenzhen Mindray Bio-medical Electronics, Shenzhen, China). Due to former smokers were recruited previously than the remaining groups, we only assessed CO levels within this group.

The delay discounting task was presented to all participants using a laptop computer. Although they were informed

that they would not receive any of the monetary amounts presented, participants were asked to respond as if the choices were real. Participants were presented with several choices, ranging from notionally being given €1,000 after a fixed delay, versus various amounts of money given immediately using an adjusting-amount procedure (Holt, Green, & Myerson, 2012). The delay values used were one day, one week, one month, six months, one year, five years, and 25 years. The value of the immediate monetary option varied from €5 to €1,000 in €5 increments and was adjusted via a titration procedure that honed in on the indifference point based on the participants' responses. This titration procedure took the lower and upper limit of possible values (initial €0 and €1,000) and divided this total range randomly by 2, 3, or 4 in order to obtain an interval value. The value of the immediate option was one interval value above or below the upper and lower limits. If the immediate value was outside €0 and €1,000, another value was randomly chosen. New lower and upper limits were chosen based on the participant's response, adjusting the total range, and the titration procedure was repeated. Once the total range was at or less than €40, the average of the upper and lower limits was taken as the indifference point, and the next delay was presented.

## Data analysis

Participants' indifference point were fitted to the equation defined by Mazur (1987):

$$V = A/(1 + kD) \quad (1)$$

Equation 1 is a hyperbolic function that describes how the value ( $V$ ) of a reward of some amount ( $A$ ) is discounted as a function of the delay ( $D$ ) to receiving such a reward. The free parameter  $k$  indicates the rate at which delayed rewards are discounted. Higher  $k$  values indicate delay discounting and impulsivity (Reynolds, 2006). With the aim of assessing  $k$  values for each individual, the hyperbolic model was fitted to each subject's delay discounting data (i.e., indifference points) with nonlinear regression (SAS, PROC NLIN). As the distribution of  $k$  values was skewed, analyses were performed on log-transformed  $k$  values. Owing to nonsystematic delay discounting data were not identified among participants following Johnson and Bickel criteria (2008), none of participant's delay discounting rates were discarded. Additionally, the degree of discounting was also measured by calculating the area under the curve (AUC) (Myerson, Green, & Warusawitharana, 2001) as a secondary dependent measure. Its values range from a minimum of 0 to a maximum of 1, with smaller values indicating greater delay discounting.

A one-way between-groups analysis of variance (ANOVA) was conducted to assess whether log $k$  and AUC values differed between e-cigarette users, current smokers, former smokers and controls. Post-hoc comparisons between groups were performed by means of least significant difference (LSD) test. Effect size of principal comparisons was calculated using partial eta squared ( $\eta^2p$ ) statistic. Confidence level was 95% and the statistical package was the SPSS (V19; SPSS, Inc., Chicago, IL).

**Table 1** Comparison of demographic and smoking-related characteristics among groups.

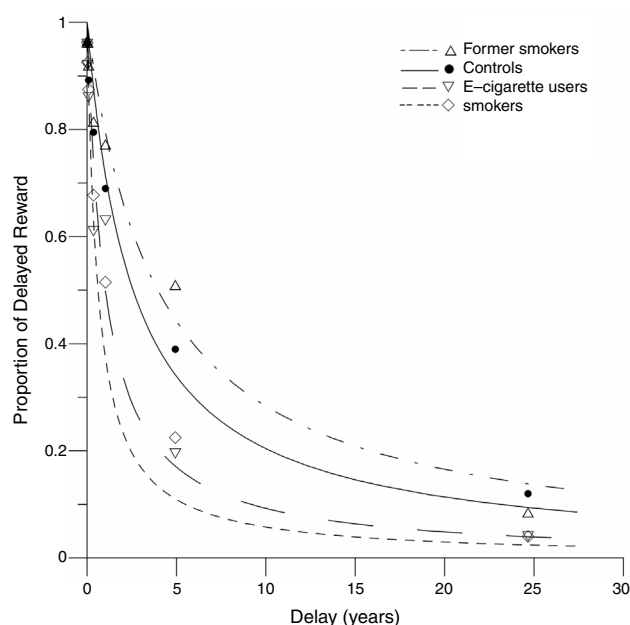
	E-cigarette users (n = 28)	Smokers (n = 40)	Controls (n = 40)	Former smokers (n = 28)	Statistic value	p
Gender (% men)	92.9	77.5	60	35.7	23.711	<.01
Age (years) <sup>a</sup>	40.29 ± 10.61	43.95 ± 12.56	39.60 ± 12.70	37.54 ± 14.89	1.546	.206
Marital status (% married)	64.3	47.5	75	50	13.751	.131
Cigarettes per day <sup>a</sup>	–	22.50 ± 9.42	–	–	–	–
Age at smoking onset <sup>a</sup>	21.14 ± 5.20	19.20 ± 5.75	–	19.72 ± 6.92	.897	.411
Months of regular e-cigarette use <sup>a</sup>	17.54 ± 11.21	–	–	–	–	–
Use nicotine- containing e-liquid (%)	89.3	–	–	–	–	–
E-liquid per cartridge (ml) <sup>a</sup>	30.54 ± 24.70	–	–	–	–	–
Nicotine per pack- age/cartridge (mg) <sup>a</sup>	7.75 ± 6.10	15.56 ± 2.79	–	6.282	–	<.01
Daily use of e-cigarette (puffs per day) <sup>a</sup>	274.29 ± 419.77	–	–	–	–	–
Preferred Flavour (%)						
Tobacco	28.6	–	–	–	–	–
Fruity	75	–	–	–	–	–
Food	7.1	–	–	–	–	–
Mint/menthol	45.4	–	–	–	–	–
FTND (tobacco/e- cigarette) <sup>a</sup>	4.71 ± 1.90	5.78 ± 1.97	–	–	2.218	0.030
NDSS (tobacco/e- cigarette) <sup>a</sup>	25.32 ± 5.20	39.85 ± 8.97	–	–	7.701	<.01
CO (ppm) <sup>a</sup>	3.96 ± 2.08	15.44 ± 5.58	–	2.52 ± 1.282	115.66	<.01
Cotinine (ng/ml) <sup>a</sup>	1,558.41 ± 1,485.47	2,799.92 ± 1,599.70	–	–	3.120	.003

Note. <sup>a</sup> = Means ± SD; FTND = *Fagerström Test* for Nicotine Dependence; NDSS = Nicotine Dependence Syndrome Scale; CO = carbon monoxide; ml = milliliter; mg = milligrams; ppm = parts per million; ng/ml = nanograms/milliliter.

## Results

There was a statistically significant difference in delay discounting rates for the four groups of participants,  $F_{\log k}(3, 132) = 5.96$ ,  $p = .001$ ,  $\eta^2 p = .119$ ;  $F_{AUC}(3, 132) = 3.24$ ,  $p = .024$ ,  $\eta^2 p = .069$ . Post-hoc comparisons revealed that smokers ( $M_{\log k} = -2.34$ ,  $SD_{\log k} = 1.005$ ;  $M_{AUC} = 0.25$ ,  $SD_{AUC} = 0.17$ ) exhibited significantly greater delay discounting when compared to former smokers [ $(M_{\log k} = -3.15$ ,  $SD_{\log k} = 0.77$ ;  $M_{AUC} = 0.39$ ,  $SD_{AUC} = 0.25)$ ,  $p_{\log k} = <.01$ ;  $p_{AUC} = .012$ ] and control participants [ $(M_{\log k} = -2.97$ ,  $SD_{\log k} = 0.80$ ;  $M_{AUC} = 0.37$ ,

$SD_{AUC} = 0.22)$ ,  $p_{\log k} = .002$ ;  $p_{AUC} = .025$ ]. Delay discounting among e-cigarette users ( $M_{\log k} = -2.57$ ,  $SD_{\log k} = 0.89$ ;  $M_{AUC} = 0.27$ ,  $SD_{AUC} = 0.22$ ) differed significantly from former smokers [ $(M_{\log k} = -3.15$ ,  $SD_{\log k} = 0.77$ ;  $M_{AUC} = 0.39$ ,  $SD_{AUC} = 0.25)$ ,  $p_{\log k} = .015$ ;  $p_{AUC} = .041$ ]. Nonetheless, e-cigarette users did not showed greater delay discounting rates compared to either smokers ( $p_{\log k} = .294$ ;  $p_{AUC} = .072$ ) or control participants ( $p_{\log k} = .763$ ;  $p_{AUC} = .080$ ). Following the guidelines proposed by [Hartley \(2012\)](#), [Figure 1](#) depicts a comparison of delay discounting across groups. Curves represent the best fitting hyperbolic functions on  $k$  values derived from Eq.



**Figure 1** Comparisons of delay discounting across groups. Curves represent best fitting hyperbolic functions based on  $k$  values to group indifference points for each group. The symbols represent the median indifference points for each delay in each group: white triangles for the former smokers group, black circles for the control group, inverted white triangles for the e-cigarettes users group and white rhombus for the smokers group.

(1). Plots of median indifference points for each group as a function of the delay are also included.

## Discussion

To our knowledge, this is the first study to compare delay discounting rates among e-cigarette users, cigarette smokers, former smokers and controls. We highlight three major findings: (1) e-cigarette users discounted more by delay when compared to former smokers; (2) e-cigarette users exhibited an intermediate discounting that did not differ from the one presented by both the smoker and control groups; and (3) cigarette smokers showed steeper delay discounting rates when compared to former smokers and control participants.

A novel finding of this study is that e-cigarette users had greater delay discounting rates than former smokers. Despite these two groups are not currently smoking tobacco cigarettes, the fact that the vast majority of e-cigarette users are self-administering e-liquids containing nicotine might explain this result. This finding is in agreement with several laboratory studies conducted with rats showing that chronic nicotine exposure produces increases in impulsive choice by reducing the value of delayed reinforcers (Dallery & Locey, 2005; Locey & Dallery, 2009). Although there are no analogous studies conducted in humans, these preclinical studies suggest that nicotine intake may increase delay discounting rates. Moreover, another explanation might be related to previous evidence showing that other forms of nicotine self-administration rather than tobacco cigarettes

(e.g., nicotine patch) do not produce decreases in delay discounting (Dallery & Raiff, 2007). Lastly, e-cigarette users presented low to moderate levels of nicotine dependence. Previous studies showed that delay discounting rates are positively associated with the daily amount of nicotine consumed (Ohmura, Takahashi, & Kitamura, 2005), which may in fact account for the high delay discounting rates among this group.

Another finding of the present study was that e-cigarette users showed intermediate discounting rates compared to those exhibited by smokers and controls. Several mechanisms may explain this result. First, engagement in unhealthy behaviors such as smoking has been positively associated with delay discounting (Story, Vlaev, Seymour, Darzi, & Dolan, 2014). Moreover, abstinence from smoking has shown to promote healthy behaviors such as having adequate dietary habits and taking exercise (Jang et al., 2012; Nagaya, Yoshida, Takahashi, & Kawai, 2007). Thus, the execution of these healthy behaviors associated with smoking abstinence might result in delay discounting decreases (Bickel et al., 1999; Secades-Villa, Weidberg, García-Rodríguez, Fernández-Hermida, & Yoon, 2014). In this regard, abstinence from cigarettes among e-cigarette users may promote the adoption of healthier lifestyles and these changes might result in an intermediate delay discounting. Another possible etiological mechanism underlying this result is that greater delay discounting has been associated with higher cigarette consumption and nicotine dependence among smokers (Amlung & MacKillop, 2014; Sweitzer et al., 2008). In this sense, the fact that our sample of e-cigarette users had lower levels of nicotine dependence when compared to smokers may explain their intermediate performance on delay discounting.

Additionally, the present study adds support to previous evidence consistently showing that delayed reinforcers lose value more rapidly in smokers than former smokers and control participants (Bickel, Yi, Kowal, & Gatchalian, 2008; Johnson, Bickel, & Baker, 2007; Reynolds, 2004; Reynolds, Leraas, Collins, & Melanko, 2009; Rezvanfard, Ekhtiari, Mokri, Djavid, & Kaviani, 2010). Previous research has proposed several factors as plausible explanations for this finding. Cigarette consumption produces neural changes in the brain-reward system [see (Wolf, 2002) for a review]. Specifically, smoking causes an incremental activation of dopamine (DA) neurons extending from the ventral tegmental (VT) area to the nucleus accumbens (NA), a phenomenon called sensitization (Robinson & Berridge, 2000). It is possible that sensitization caused by smoking could have behavioral effects that generalize to rewards presented in the delay discounting task, resulting in greater delay discounting (Reynolds, 2004). Another possible explanation of this finding may derive from the competing neurobehavioral systems hypotheses of addiction (Bechara, 2005). According to this hypothesis, substance abuse is explained by both a hyperactivity of the impulsive system associated with preference for immediate reinforcers and a lessened activity of the executive system associated with preference for delayed reinforcers (Bickel et al., 2007). Thus, smoking increases the activity of the impulsive decision system while it reduces the activation of the executive system, leading to greater delay discounting among smokers (Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013).

Some limitations of the present study should be noted. First, the small number of e-cigarette users may have limited the ability to detect significant differences between this group and their smokers and control counterparts. Second, this was a cross-sectional study so these results cannot shed light on the temporal sequence in the association between e-cigarette use and delay discounting. Third, this study used hypothetical instead of real monetary rewards, so it is possible to argue that hypothetical choices may not reflect real ones. Nevertheless, previous research has found comparable results when hypothetical and real rewards are used (Johnson et al., 2007; Lagorio & Madden, 2005).

Despite these limitations, the present study makes a noteworthy contribution to e-cigarette literature showing that e-cigarette users exhibited greater delay discounting rates than former smokers. As evidence has emerged regarding the role of delay discounting in predicting smoking cessation outcomes (Weidberg, Landes, García-Rodríguez, Yoon, & Secades-Villa, 2015), further research should explore which neurobiological and psychological factors explain the association between e-cigarette use and delay discounting.

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