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Differences in Nicotine Dependence and Delay Discounting between Traditional and E-cigarette Users

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Abstract. The present study attempts to explore the differences in nicotine dependence and delay discounting between traditional cigarette and e-cigarette users. According to the Competing Neurobehavioral Decision Systems Theory, this study will also discuss the characteristics of impulsive decisions exhibited by smokers with these two different tobacco products. Study 1 used the Fagerström Nicotine Dependence Test (FTND) to investigate the nicotine dependence levels of traditional and e-cigarette users respectively. Based on study 1, study 2 adopted the Delay Discounting Task (DDT) to compare the difference in delay discounting among the non-smoking group, traditional cigarette group and e-cigarette group, with unrelated variables such as demography variables (gender, age, education) and nicotine dependence level controlled. The results showed that in Study 1, e-cigarette users had significantly higher nicotine dependence than traditional cigarette users. In Study 2, the degree of delay discounting between the traditional cigarette group and the e-cigarette group was significantly higher than that of the non-smoking group, while there was no significant difference in the degree of delay discounting between the traditional cigarette group and the e-cigarette group. The current findings suggest that e-cigarettes may exacerbate smokers' nicotine dependence. Traditional cigarette and e-cigarette users exhibit similar and significantly higher levels of delay discounting than the general population, indicating that the general connection between nicotine dependence and high levels of delay discounting is not influenced by different tobacco products.

Keywords: E-Cigarette; Nicotine Dependence; Delay Discounting; Impulsive Decision.

1. Introduction

The harm that tobacco brings to people cannot be ignored. In recent years, as an emerging tobacco product, the trends in e-cigarette usage have spread worldwide. Electronic cigarettes, as the most common electronic nicotine delivery system (ENDS), often have a similar appearance to cigarettes [1]. Since e-cigarettes entered the market at the beginning of this century, they have been publicized by many businesses and media to reduce smoking addiction and help quit smoking, thus attracting a large number of buyers with younger buying age. But can e-cigarettes help smokers stop smoking? How effective is smoking cessation? Researchers have yet to reach a consensus on the impact on users. Berg et al. studied the changes of smokers after switching from traditional cigarettes to e-cigarettes and found that after 8 weeks of using e-cigarettes, 65.4% of smokers reported improved health status, 57.7% reported reduced coughing, and 53.8% reported significant improvement in smell and taste [2]. Ikonomidis et al. found that after 4 months of e-cigarette use, platelet function in smokers produced neutral changes and effectively reduced arteriosclerosis and oxidative stress [3]. At the same time, some researchers have mentioned the possible negative effects of e-cigarettes on users. The concentration of heavy metals such as tin, silver, iron, and nickel in e-cigarettes is often higher than that in traditional cigarettes, which may cause greater harm to the human body [4]. The popularity of e-cigarettes may also cause a gateway effect among adolescents: non-smokers are more likely to smoke traditional cigarettes after using e-cigarettes [5]. Therefore, this study intends to use FTND to measure the level of nicotine dependence in smokers and compare whether there is a significant difference between traditional cigarette and e-cigarette users' nicotine dependence to investigate the smoking cessation effect of e-cigarettes.

In addition, smoking addiction is an addiction to the nicotine contained in tobacco. Studies have shown that traditional cigarette smokers exhibit a much higher level of delay discounting than other

addicts. This decision-making pattern of high delay discounting is common among different addictive behaviors, indicating that delay discounting may be used as a cross-disease diagnostic basis [6]. However, researchers have paid relatively little attention to the delay discounting of e-cigarette users. In this paper, DDT is used to measure the degree of delay discounting between smokers and non-smokers and compare whether there are significant differences in delay discounting among participants in the non-smoking group, traditional cigarette group and e-cigarette group. To study whether different smoking patterns affect the decision-making pattern of smokers and then discuss their decision-making impulse characteristics.

2. Literature Review

At present, many studies have explored the relationship between traditional cigarettes and delay discounting [7][8]. Delay discounting refers to a phenomenon that people's estimation of the value of things decreases with time, i.e., people's subjective judgment on the value of delayed reward gradually falls below its actual value [9]. Due to the depreciation brought about by waiting time, when facing similar rewards, people always prefer immediate rewards. The Delay Discounting Task (DDT) is a common paradigm for measuring individual impulse to make decisions, which often requires participants to choose between two dimensions: time and quantity. One of the options is an immediate, smaller-value reward, such as getting RMB 100 immediately; another is a future, larger-value reward, such as getting RMB 1000 after one week. If the participants chose more immediate rewards in DDT rather than waiting for higher rewards, it could explain to some extent that they were more likely to make impulsive decisions. In this study, the hypothetical money choice task [10] requires participants to choose between a smaller immediate amount and a larger delayed amount.

Substance addiction tends to be accompanied by higher levels of delay discounting. Studies have found that patients who are dependent on alcohol, opium, heroin, and other addictive substances often show higher delay discounting than ordinary people, and patients with multi-substance dependence tend to show a higher delay discounting rate than patients with single-substance dependence [11]. However, the abnormal increase in the delay discounting rate may represent the abnormal decision-making function of addicts. The Competing Neurobehavioral Decision Systems Theory (CNDS) believes that individual decision-making behavior is jointly controlled by two independent systems: the impulse system and the executive system. An individual's impulsive system is often directly driven by reward, making individuals more inclined to pursue closer and larger rewards. The executive systems, by contrast, evolved more recently and are responsible for controlling the self-regulatory processes of individuals. When the balance between the two systems is disrupted, individuals may have abnormal decision-making behaviors due to the narrowing range of behavioral choices [12]. In the CNDS theory, different sizes of delay discounting rates indirectly reflect the relative strength of the two systems. The fMRI study on delay discounting shows that the brain regions activated when individuals choose immediate reward and delayed reward are different, which overlap with corresponding brain regions of the impulse system and executive system respectively. That is, choosing an immediate reward is associated with the impulsive system while choosing a delayed reward is associated with the executive system [13]. Therefore, Bickel et al. proposed a hypothesis based on CNDS theory that when addictive substances increase the activity level of an individual's impulsive system and/or decrease the activity level of the executive system, addicts will show more impulsive decision-making patterns [14].

E-cigarette is a new type of equipment that has become popular in recent years, and cognitive psychology research on it is still rare. In addition, current studies exploring the difference in delay discounting among smokers have ignored the possible influence of different levels of nicotine dependence on the degree of delay discounting, which is often positively correlated with the degree of delay discounting shown by smokers [15][16]. Therefore, this study attempts to use the nicotine dependence level of smokers as a control variable to explore whether traditional cigarette and e-cigarette users have different delay discounting characteristics after excluding possible bias.

3. Experiment

3.1. Experimental Purpose and Hypothesis

First, this study intends to measure the level of nicotine dependence among traditional cigarette and e-cigarette users, explore whether the two types of smokers have different levels of nicotine dependence, and then discuss the role of e-cigarettes in smoking cessation. Secondly, this study intends to measure the degree of delay discounting among smokers and non-smokers. Under the condition that influencing factors such as gender, age, education level and nicotine dependence are controlled, the delay discounting presented by participants from the non-smoking group, traditional cigarette group and e-cigarette group is compared so as to discuss the influence of different smoking styles on decision-making modes. Therefore, Hypothesis 1 is proposed: e-cigarette users have a higher level of nicotine dependence than traditional cigarette users. Hypothesis 2: users of traditional cigarettes and e-cigarettes have a higher degree of delay discounting than non-smokers. Hypothesis 3: delay discounting is similar among smokers of different smoking patterns, i.e., there is no significant difference between the delay discounting for traditional and e-cigarette users.

3.2. Differences in Nicotine Dependence among Traditional and E-cigarette Users

3.2.1. Methods

1) Participants

In this study, an online questionnaire was administered to smokers (including traditional cigarette and e-cigarette users) using convenience sampling. A total of 146 questionnaires were collected from smokers, including 91 traditional cigarette users and 55 e-cigarette users. After excluding unsatisfactory questionnaires, a total of 114 valid questionnaires remained, including 106 males accounting for 93.0% and the age range was 18-53 years old (M = 28.59, SD = 10.07).

2) Measures

The Fagerström Nicotine Dependence Test (FTND) was used to measure nicotine dependence in smokers. FTND, as one of the most widely used nicotine dependence scales at present, has been proven to have good reliability and validity [17]. The scale consists of 6 questions. Participants need to choose the description that is most suitable for their own situation according to their usual smoking behaviors. The FTND scores range from 0 to 10 and represent the level of nicotine dependence in smokers: 0-2 for extremely low dependence, 3-4 for low dependence, 5 for moderate dependence, 6-7 for high dependence, and 8-10 for extremely high dependence.

For traditional cigarette users, the questionnaire is presented in the original FTND text; for e-cigarette users, it replaces the wording used to describe a cigarette in the original FTND text with the corresponding term of an e-cigarette product. In this study, the value for Cronbach's α for FTND was α=0.62.

3.2.2. Results

Table 1. Participant Demographics

	Traditional cigarette		E-cigarette	
	n	%	n	%
Sex				
Male	68	95.8%	38	88.4%
Age				
18-25	31	43.7%	34	79.1%
26-40	22	31.0%	7	16.3%
41-53	18	25.4%	2	4.7%
Education				
Middle school and below	8	11.3%	0	0%
High school	11	15.5%	1	2.3%
Bachelor degree	52	73.2%	42	97.7%

A total of 114 participants were divided into the traditional cigarette group (71) and the e-cigarette group (43). The demographic data of the two groups are shown in Table 1.

An independent samples *t*-test was used to explore whether there were significant differences between the FTND scores of traditional cigarette and e-cigarette users. The results showed that e-cigarette users (M=4.23±2.45) achieved higher FTND scores than traditional cigarette users (M=3.04±2.17), and the difference was significant ($t(112)$=2.70, p=0.008, d=0.52). The specific tobacco use and nicotine dependence of the two groups are shown in Table 2.

Table 2. Tobacco use and nicotine dependence

	In the past 30 days		Nicotine dependence level				
	Smoking days	Average smoking	Extremely low	Low	Moderate	High	Extremely high
Traditional cigarette	23.60(9.20)	10.58(7.55)	32(45.1%)	19(26.8%)	8(11.3%)	11(15.5%)	1(1.4%)
E-cigarette	25.17(10.28)	2.73(1.25)	12(27.9%)	13(30.2%)	5(11.6%)	7(16.3%)	6(13.9%)

This study found that e-cigarette users achieved higher FTND scores than traditional cigarette users, indicating a higher level of nicotine dependence among e-cigarette users compared with traditional cigarette users, which supports Hypothesis 1.

3.3. Difference in Delay Discounting for Traditional Cigarette and E-cigarette Users

3.3.1. Methods

1) Participants

The smokers in Study 1 were divided into the traditional cigarette group and the e-cigarette group according to their preferred smoking methods, and participants who met the screening criteria were selected to participate in the study on delay discounting difference. On this basis, a certain number of ordinary people were recruited to form a non-smoking group as the control group in the study. A total of 112 participants were selected to formally take part in the study, including 92 males (82.1%) aged 18-53 (M=32.20, SD=10.67). The participants were divided into the non-smoking group (39), the traditional cigarette group (45) and the e-cigarette group (28). The demographic data of the three groups are shown in Table 3. No participants had experienced a similar experiment and they were right-handed without achromatopsia or color weakness.

Table 3. Difference test on demographics

	Non-smoking		Traditional cigarette		E-cigarette	
	n	%	n	%	n	%
Sex						
Male	23	59.0%	43	95.5%	26	92.9%
Age						
18-25	7	17.9%	16	35.6%	22	78.6%
26-40	20	51.3%	13	28.9%	4	14.3%
41-53	12	30.8%	16	35.6%	2	7.2%
Education						
Middle school and below	0	0%	4	8.9%	0	0%
High school	11	28.2%	9	20.0%	1	3.6%
Bachelor degree	28	71.8%	32	71.1%	27	96.4%

2) Experimental design

This study adopted a mixed design of 3 (Groups: non-smoking, traditional cigarette, e-cigarette) × 2 (Delayed amount: RMB 1000, RMB 50000) × 7 (Delayed time: 1 week, 1 month, 6 months, 2 years, 5 years, 10 years, 25 years), in which the group was a between-subjects variable, and the delayed amount and delayed time were within-subjects variables.

3) Procedures

Based on the classical delay discounting experimental paradigm, E-Prime 2.0 software was used to perform the experimental tasks. During the experiment, two options were presented simultaneously on the computer screen: a small immediate reward and a large delayed reward that would take some time to get. The delayed amount includes two levels: RMB 1,000 and RMB 50,000; the delayed time includes seven levels: 1 week, 1 month, 6 months, 2 years, 5 years, 10 years and 25 years. Participants needed to evaluate different delayed amounts and time on their own and choose between immediate and delayed rewards. The presentation order of the two delayed amounts was set to be randomized to eliminate the influence of the sequence effect.

Participants made six choices under each of the different delay conditions. The first selection usually shows that the delayed reward is twice as great as the immediate reward. After each choice, the two rewards presented on the screen would change according to certain rules: if participants chose a delayed reward, the immediate reward of the next choice would increase; if participants chose an instant reward, the immediate reward would decrease. As the number of choices increases, the reward changes less and less. After several consecutive choices, the subjective value of different rewards was calculated by analyzing the choices made by the subjects each time.

The whole experimental process of this study was carried out in a quiet and closed room with sufficient light, and each participant was tested individually by computer. They kept a distance of about 50cm from the screen and selected by pressing keys. Press "F" to select the left option and "G" to select the right option. Stimuli are presented in black text on a white background. Before the formal experiment, the participants will do four sets of exercises. Following the exercises, the corresponding subjective values obtained by the participants in the exercises will be presented on the screen. Only after ensuring that the participants have correctly understood the experimental task and gradually become familiar with the testing process, can they be guided to complete the formal experiment.

3.3.2. Results

The area under the curve (AUC) was calculated according to the choices made by the participants as an index representing the degree of individual delay discounting. The values of delayed time (D) and subjective value (V) were normalized first, and then the AUC trend charts of each group of subjects under two delayed amounts were drawn with delayed time as the x-axis and subjective value as the y-axis respectively [18]. As shown in Figures 1 and 2, the area between the curve and the x-axis is AUC. A smaller AUC value reflects greater individual delay discounting. It can be seen that with the increase of delayed time, AUC_{1000} and AUC_{50000} of subjects in each group showed a decreasing trend, reflecting the existence of the delay discounting effect ($M_{AUC1000}$=0.23±0.23; $M_{AUC50000}$=0.33±0.27).

Secondly, whether gender, age, education level and nicotine dependence will affect the AUC value of participants was studied. (1) An independent sample *t* test was used to explore whether the AUC value was affected by gender factors. The results showed that there was no significant difference in AUC_{1000} ($t_{(110)}$=0.17, *ns*, *d*=0.04) among participants of different genders, but under the condition of AUC_{50000} ($t_{(110)}$=1.98, *p*=0.001, *d*=0.49), the AUC value of male participants was significantly higher than that of female participants. (2) A one-way ANOVA was used to explore whether the AUC values of participants were affected by their educational background. The results showed that there was no significant difference in AUC_{1000} ($F_{(2, 109)}$=1.61, *ns*, η^2=0.029) and AUC_{50000} ($F_{(2, 109)}$=1.44, *ns*, η^2=0.03) between participants with different education levels. (3) Correlation analysis was used to explore the relationship between age, FTND score and the AUC value. The results showed that there

was no significant correlation between age and AUC_{1000}, but a significant negative correlation with AUC_{50000} (r= -0.28, p=0.002); The FTND score was significantly negatively correlated with both AUC_{1000} (r=-0.24, p=0.009) and AUC_{50000} (r=-0.23, p=0.016). Based on the above results, the interference of education level can be excluded. However, when analyzing the differences in delay discounting among different groups of participants, it is still necessary to consider the influence of gender factors, age factors and nicotine dependence levels on the results.

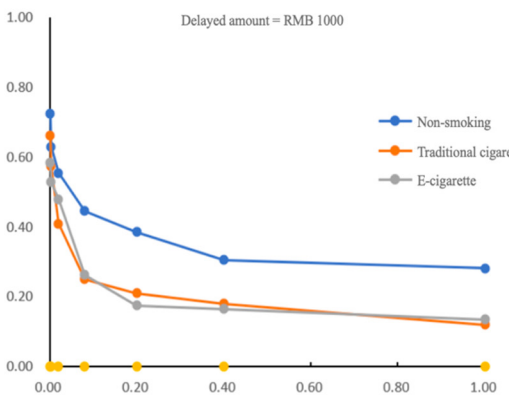

Figure 1. Trend chart for AUC1000

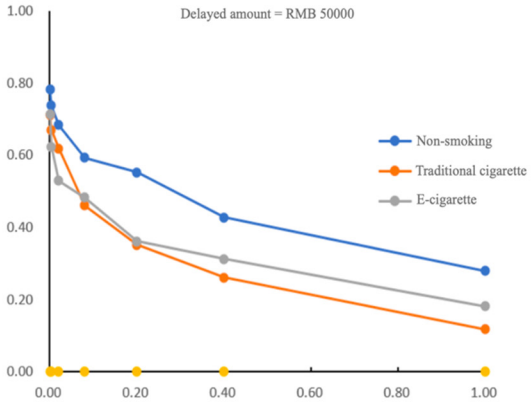

Figure 2. Trend chart for AUC50000

Finally, a two-way ANOVA was performed on the AUC value, while sex, age and FTND scores were treated as covariates. The results showed that the interaction between the delayed amount and the group was not significant. The main effect of the delayed amount is significant, $F_{(1,\ 106)}$=13.32, p<0.001, η^2=0.11. When the delayed amount is 1000, the AUC is significantly smaller than that when the delayed amount is 50000; the main effect of the group is significant, $F_{(2,\ 106)}$=5.49, p=0.005, η^2=0.09. Post hoc analysis using LSD showed that participants in both the traditional cigarette group (M=0.22, SD=0.04, p=0.002) and e-cigarette group (M=0.18, SD=0.05, p=0.004) presented significantly lower AUC values compared with non-smokers (M=0.42, SD=0.05), while there was no significant difference between the traditional and e-cigarette groups. See Figure 3.

Therefore, the study showed that smokers obtained lower AUC values in the DDT than non-smokers, and smokers had a greater discounted value of delayed rewards and stronger decision impulsivity during the selection process, which supported Hypothesis 2. Another finding of this study is that after controlling unrelated variables such as gender, age and nicotine dependence, there is no significant difference in delay discounting between participants in the traditional cigarette group and those in the e-cigarette group, indicating that the relationship between smoking and delay discounting is universal and not affected by smoking methods. This result supports Hypothesis 3.

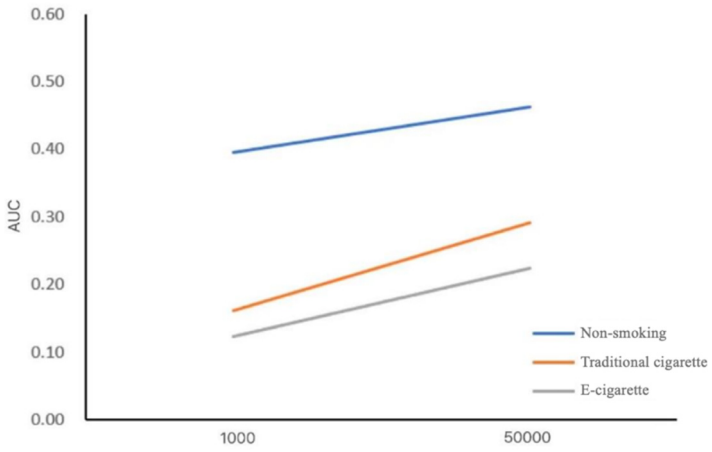

Figure 3. Comparison of the AUC value among three groups

4. Conclusion

First, by comparing the FTND scores of the two groups, this paper found that e-cigarette users had a higher level of nicotine dependence than traditional cigarette users. This suggests that e-cigarettes do not help smokers quit as the public claims, but may increase their level of nicotine dependence. This result is consistent with the research results of some other researchers. Secondly, this paper adopts the delay discounting paradigm. By comparing the AUC value of the three groups, it is found that the degree of delay discounting in non-smokers is smaller than that in traditional smokers and e-cigarette users, while there is no difference between the delay discounting shown by the latter two groups of smokers. This result suggests that the difference in delay discounting between smokers and non-smokers can be seen as a reflection of the complex relationship between substance use addiction and decision-making impulses, i.e., addicts tend to exhibit more decision-making impulses than the general population. This study also found similarities in delay discounting between traditional cigarette and e-cigarette users, regardless of how they choose to consume nicotine. This reflects the fact that they may have adopted similar decision-making patterns, tending to make similar and more impulsive choices than non-smokers. This similarity helps to understand the pervasiveness of substance addiction in shaping higher levels of delay discounting and impulsive decision-making, i.e., the link between substance addiction and impulsivity is not constrained by how substances are consumed.

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