# THE EFFECT OF A VERY LOW NICOTINE CONTENT EXPECTANCY ON CIGARETTE HEALTH RISK PERCEPTIONS, SUBJECTIVE EFFECTS, AND SMOKING BEHAVIOR

by

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**THE EFFECT OF A VERY LOW NICOTINE CONTENT EXPECTANCY ON CIGARETTE HEALTH RISK PERCEPTIONS, SUBJECTIVE EFFECTS, AND SMOKING BEHAVIOR**

Danielle Lynne Joel, M.S.

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*Introduction:* The U.S. FDA can regulate tobacco products under the Family Smoking Prevention and Tobacco Control Act, creating the potential for new cigarette standards aiming to reduce harm. Nicotine content could be a target of regulation, since nicotine drives cigarette addiction (Stolerman & Jarvis, 2005), though the FDA cannot mandate zero nicotine (Congress, 2009). The FDA may consider enacting a reduced nicotine product standard for all cigarettes, as the use of very low nicotine content (VLNC) cigarettes (i.e. 0.05 mg nicotine yield) has been shown to decrease smoking rate and dependence over time (Hatsukami, et al., 2010). However, most studies of VLNC cigarettes to date have blinded subjects to the nicotine content, so little is known about how smokers perceive cigarettes with known very low nicotine levels and how this knowledge impacts cigarette use. *Methods:* The present study was a within-subjects experiment with 68 adult daily smokers who tried two identical Quest 3 (0.05 mg nicotine yield) cigarettes in a single session (counterbalanced order). Before smoking they were told that one cigarette contained "average" nicotine, and the other contained "very low" nicotine. Smokers rated each cigarette on several measures after sampling them. *Results:* Smokers rated the "very low" nicotine cigarette as less risky overall than the "average" nicotine cigarette ($p$=0.001); this effect held true for specific diseases including lung cancer, heart disease, emphysema, stroke, chronic bronchitis, and other cancers ($p$'s <0.001). Additionally, smokers rated the "very low" nicotine

cigarette as having less desirable subjective effects than the “average” nicotine cigarette, including reduced satisfaction, psychological reward, and enjoyment of respiratory sensations ($p$’s<0.05). Moreover, smokers predicted having greater interest in quitting smoking in 1 month, 6 months, and 1 year ($p$’s <0.02) when considering exclusive availability of the “very low” nicotine cigarette. Similarly, more smokers predicted being abstinent in 5 years when considering exclusive availability of the “very low” nicotine cigarette ($p$=0.04). *Conclusions:* Explicit knowledge of very low nicotine content changes smokers’ perceptions of VLNC cigarettes, resulting in reduced predicted harm, subjective effects and predicted use.

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# PREFACE

The author would like to thank her committee, Drs. Eric Donny, Michael Sayette, and Kenneth Perkins, for all of their input and support with this study. The author would also like to thank Erin Goldstein, Lee Bennett, Cathy Scott, and Kristin Yahner for their assistance in data collection as well as Rachel Denlinger, Sarah Dermody, and Dr. Andrew Strasser for their input on study design and Tracy Smith for her input on data analysis.

# 1.0 INTRODUCTION

Though the prevalence of cigarette smoking has declined over the past several decades, it remains the leading cause of preventable death in the U.S. (CDC, 2008). Tobacco control efforts are increasing with the aim of decreasing morbidity and mortality. One potential policy with some empirical support is the reduction of nicotine in cigarettes to a level below the "addictive threshold." Theoretically, exclusive availability of cigarettes with nicotine levels below this threshold would decrease both smoking uptake in youth and smoking in established smokers. It is primarily through these two pathways that very low nicotine content (VLNC) cigarettes could decrease the morbidity and mortality associated with smoking, by reducing exposure to particulates, oxidant chemicals, polycyclic aromatic hydrocarbons (PAHs), carbon monoxide (CO), and nitrosamines. Several studies have explored the effect of extended use of VLNC cigarettes and these studies generally support the notion that a nicotine reduction policy might facilitate decreased smoking (Donny, Houtsmuller, & Stitzer, 2007; Benowitz, et al., 2007; Hatsukami, et al., 2010; Benowitz, et al., 2012).

Before implementing a nicotine reduction policy, the FDA should consider possible unintended consequences such as reduced perceived harm. Though the use of descriptors such as "low", "light", and "mild" on cigarette packages are currently banned, smokers receive information about cigarettes in other ways (i.e. package coloring, media). It is important to explore whether knowledge that VLNC cigarettes contain low nicotine distorts smokers' ideas

about their risk of developing smoking diseases, as risk perceptions are known to influence behavior (van der Pligt, 1998). Limited existing survey research has shown that many smokers hold erroneous beliefs about nicotine's impact on smoking diseases (i.e. that nicotine causes lung cancer) (Cummings, Hyland, Bansal, & Giovino, 2004; Shadel et al, 2006; Bansal-Travers, et al., 2010). Though VLNC cigarettes are expected to be less reinforcing, smokers may believe that they can continue to smoke them with fewer negative health consequences, thereby lowering their motivation to quit. Most experimental research conducted with VLNC cigarettes thus far has used blinding procedures such that smokers are not aware of the nicotine content, so the effect of very low nicotine content expectancy on risk perceptions in smokers actually trying these products is unclear. Previous work has identified that low nicotine/tar content expectancies of "light" cigarettes (though false) led to lower perceived harm and delayed cessation (Etter, Kozlowski, & Perneger, 2003; Shiffman, Pillitteri, Burton, Rohay, & Gitchell, 2001; Kozlowski, et al., 1998). Since "light" cigarettes claimed both low tar and low nicotine, it is unclear which factor was responsible for these misconceptions. Thus it is important that the effect of nicotine content expectancy on smoking risk perception be explored specifically in an experimental setting.

Nicotine content expectancies also influence the subjective experience of smoking and the effects felt from using the cigarette. Studies have found significant influences of nicotine content expectancy on craving reduction, mood, wakefulness, calmness, concentration, satisfaction from smoking, and hunger reduction (Juliano & Brandon, 2002; Juliano, Fucito, & Harrell, 2011; Kelemen & Kaighobadi, 2007; Perkins, Jacobs, Ciccocioppo, et al., 2004). In addition, studies have explored the effect of nicotine content expectancies for other nicotine delivery products such as sprays and inhalers, and have found significant influences on

satisfaction and craving relief from these products (Perkins, Jacobs, Clark, et al., 2004, Perkins et al., 2009; Darredeau & Barrett, 2010). These studies suggest that the amount of nicotine one believes is in a nicotine product can supersede their experience of receiving a different nicotine amount and influence their smoking experience. The impact of nicotine content expectancies on subjective effects of smoking is important because it may influence the way cigarettes are used (i.e. feeling the need to smoke more).

In addition to psychological constructs such as risk perception and subjective smoking effects, nicotine content expectancy might influence actual smoking-related behavior. One study exploring this effect by measuring puff count demonstrated an interaction between true nicotine content and nicotine content expectancy; for participants given truly average nicotine-containing cigarettes, the total number of puffs taken was greater when the cigarettes were described as nicotine-containing (compared to a nicotine free or placebo expectancy), but the opposite effect was found in smokers receiving a truly denicotinized cigarette (fewer puffs of the cigarette were taken when described as nicotine-containing) (Juliano, et al., 2011). A couple of studies have explored the effect of nicotine content expectancy on smoking behavior using a progressive ratio task. The first study found that only individuals who were given a truly denicotinized cigarette made greater total responses for smoke puffs (and thus achieved more self-administered cigarette puffs) when they were told the cigarette contained regular nicotine compared to a placebo expectancy (Perkins, Jacobs, Ciccocioppo, et al., 2004). This same nicotine content expectancy effect was found in another study using a progressive ratio task, but the effect held true regardless of the true nicotine content of the cigarette (Darredeau, Stewart, & Barrett, 2013). Though these studies demonstrate that there are effects of nicotine content expectancy on smoking behavior generally, they only describe effects of a placebo expectancy (zero nicotine),

and it is important that we understand how the effect of a very low nicotine content expectancy on smoking behavior may differ because the FDA cannot mandate a zero nicotine product standard. This question has never been specifically explored experimentally.

However, there have been two studies exploring the effects of prolonged use of VLNC cigarettes that disclosed the reduced nicotine content to subjects switched to these products (Benowitz, et al., 2007; Benowitz, et al., 2012). These two studies did not demonstrate the same decreased smoking rate that other blinded studies (Donny, Houtsmuller, & Stitzer, 2007; Hatuskami, et al., 2010) demonstrated, which may suggest that a lower nicotine content expectancy blunts the effect of VLNC cigarettes on smoking rate. However, it is important to note that other study design differences could be responsible for the difference in smoking behavior results; namely that these subjects' nicotine levels were dropped progressively over time as opposed to abruptly and they were not treatment seeking. Overall, there is mixed evidence and little understanding about the effect of nicotine content expectancy on smoking behavior, and there has never been an experimental study that has specifically explored a very low nicotine content expectancy.

The present experimental study investigated the effect of a very low nicotine content expectancy on cigarette health risk perceptions, subjective cigarette effects, and both short-term and predicted long-term future smoking behavior. Nicotine content expectancies were manipulated using an instructional set, and included "very low" and "average" nicotine content. In both conditions, the same type of VLNC cigarette (Quest brand, 0.05 mg nicotine yield) was smoked through a puff topography device. In a within-subjects design, subjects underwent both conditions during a single session in counterbalanced order. Subjects completed cigarette ratings after smoking each cigarette; this design aimed to determine whether the nicotine content

expectancy and its effects on dependent measures persisted after smokers experienced the true nicotine level. It was predicted that the “very low” nicotine cigarette would be perceived as less risky for contributing to various smoking-related diseases, rated as less subjectively desirable, and smoked more intensely through the puff topography devices. It was also hypothesized that smokers would predict higher smoking rate and/or lower interest in quitting in the future when considering the exclusive availability of the “very low” nicotine cigarette due to reduced health risk perceptions.

# 2.0 METHOD

## 2.1 PARTICIPANTS

Current daily smokers aged 18 and older who had smoked at least 10 cigarettes per day for at least one year were recruited from the Pittsburgh community via Internet and flyer advertisements. Exclusion criteria included significant medical changes in the previous week that contraindicated smoking (i.e. myocardial infarction), currently seeking treatment to quit smoking, alcohol intoxication at the time of the visit, and pregnancy/breastfeeding. Participants had to demonstrate a carbon monoxide level of at least 8 ppm (or NicAlert cotinine strip level of at least 3) to be eligible for the study.

## 2.2 PROCEDURES

Prior to study participation, volunteers provided verbal consent to be screened over the telephone by research assistants. All volunteers were asked about their smoking history and recent health changes. Female volunteers were asked if they are pregnant or breastfeeding. Volunteers determined to be eligible were scheduled for the study session, which lasted approximately three hours. At the start of the study session, volunteers first read and signed the informed consent document before completing the in-person screening procedures. Smoking status was determined

via expired breath carbon monoxide (CO) level (at least 8 ppm) using a Microlyzer, or urine cotinine testing (at least level 3 on NicAlert strip) if CO was below 8 ppm. Volunteers needed to demonstrate a breath alcohol level (BAL) less than or equal to 0.01% to continue with the visit. Volunteers whose first BAL fell between 0.011-0.03% were allowed to wait in the laboratory (for up to 30 minutes) until it dropped to 0.01%. Any volunteers who did not meet one or more of these requirements were dismissed from the study without payment. Volunteers that did not meet the BAL requirement only were allowed to return once another day to screen again. Volunteers that passed the screening procedures were then assigned a randomization code that determined the order of study conditions they would complete. Two identical randomization schedules were used separately for males and females.

Eligible participants first completed the baseline questionnaire battery on MediaLab software. Carbon monoxide was measured again four minutes before participants smoked their preferred brand cigarette. Participants then smoked four puffs of their usual brand cigarette through a handheld puff topography device in a well-ventilated smoking room. This primarily served to standardize the amount of time since each participant last smoked and allowed them to acclimate to the device. Participants then answered the cigarette rating measures in reference to their usual cigarette after they were finished smoking. Four minutes after finishing the cigarette, CO was measured again. The difference between their initial CO level and the post-smoking CO level (CO boost) was used as an index of smoke exposure.

Next, participants tried the two study cigarettes at 45-minute intervals to avoid satiation. The first study cigarette was smoked 45 minutes after the usual brand cigarette. The cigarettes used in this study were Quest 3 brand cigarettes that were genetically modified to reduce the nicotine content, and the nicotine yield is 0.05 mg determined by the ISO method (tar yield is

approximately 10 mg). The Quest logo was crossed out with a black marker so that participants could not see the cigarette type. Carbon monoxide was measured four minutes before the participant smoked the study cigarette. The research assistant used the randomization code to determine the order of conditions while blind to which conditions were first and second.

PowerPoint slideshows were used to instruct the participant during each condition. The slideshows for each condition differed in the screen that described the study cigarette to be smoked that time. The cigarette description screen appeared for 30 seconds and a recorded voiceover read the text aloud to ensure attention to the information. The text was as follows:

"The next cigarette that you will be smoking contains a ***very low/average*** nicotine level, compared to most cigarettes available in the U.S. First, you will smoke as much or as little of this cigarette as you would like to smoke. Then, you will be asked to answer some questions about your opinions of the product."

The next screen of the slideshow instructed the participant to choose the corresponding study cigarette from a large manila envelope placed on the desk next to them. Inside the manila envelope, the participant found two smaller white envelopes labeled "very low nicotine cigarette" and "average nicotine cigarette." The slideshow instructed the participant to place the small white envelope back into the large manila envelope to keep the research assistant blind. The participant was also instructed not to discuss with the research assistant which cigarette they smoked during each condition. The next slideshow screen instructed the participant to place the cigarette into the puff topography device, light it, and smoke as much as desired. The participant then completed the cigarette rating measures in reference to the study cigarette just smoked. After four minutes passed since smoking, CO was measured again to assess CO boost. This process was repeated for both study cigarettes.

Participants were paid $50 plus transportation costs for completing the study. Participants received a debriefing letter in the mail once all recruitment was completed. Debriefing did not occur immediately following the visit to prevent future participants from being informed of the deception involved in this study.

## 2.3 ASSESSMENTS

### 2.3.1 Baseline Assessment

*Sample Characteristics.* Demographic variables including age, gender, race, education, employment, and annual income were measured to characterize the diversity of the sample. Variables such as cigarettes per day, years of daily smoking, and menthol status were measured to characterize the type of smokers in the sample.

*Nicotine Dependence*. The Fagerstrom Test for Nicotine Dependence (*FTND*; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) and Wisconsin Index of Smoking Dependence Motives - Brief Version (*WISDM* Brief; Smith et al., 2010) were used to measure the nicotine dependence of the sample. The *FTND* is a six-item, psychometrically validated measure that assesses both heaviness of smoking and behaviors that reflect nicotine dependence. The *WISDM* Brief is a psychometrically validated and multidimensional measure of tobacco dependence with 37 items (answered on a 1-7 Likert scale) that load onto 11 subscales, each measuring a distinct, theoretically-derived smoking motive. The subscales include affective enhancement, affiliative attachment, and automaticity, loss of control, cognitive enhancement,

craving, cue exposure /associative processes, social/environmental goads, taste /sensory properties, tolerance, and weight control.

*Interest in Quitting*. Participants completed the Stages of Change Questionnaire (Prochaska & Goldstein, 1991) and Contemplation Ladder (Biener & Abrams, 1991). The Stages of Change Questionnaire assesses whether smokers are considering quitting smoking within the next 30 days or six months. On the Contemplation Ladder, smokers indicated which rung of a pictured ladder represented their current thinking about quitting. The ladder consists of rungs from level 0 to 10, with 0 representing "I am not ready to quit" and 10 representing "I am ready to quit now."

*Impression Management.* The Balanced Inventory of Desirable Responding (*BIDR*; Paulhus, 1991) is a 40-item scale designed to measure socially desirable responding to enhance self-presentation. Responses are given on a 7-point Likert scale from "not true" to "very true". A sample question is *I sometimes tell lies if I have to.* This measure was given to determine whether effects of nicotine content expectancy on dependent measures were specific to individuals with high impression management.

### 2.3.2 Cigarette Health Risk Perceptions

The Perceived Health Risk Questionnaire (*PHRQ*; Hatsukami, et al., 2010) assessed smokers' perceived risk for developing smoking-related health problems associated with each cigarette. Smokers were asked to assume the same smoking rate; thus, it was a measure of the perceived risk of the product itself. The measure includes eight items for which the participant responds on a 1-100 visual analog scale (very low risk to very high risk). The items include lung cancer,

emphysema, chronic bronchitis, other cancers, heart disease and stroke, overall health risk and risk of addiction.

### 2.3.3 Cigarette Subjective Effects

A modified version of the Cigarette Evaluation Scale (*MCES*; Westman, Levin, & Rose, 1992) was used to measure subjective cigarette effects. The *MCES* includes 15 items for which the participant responds on a 7-point Likert scale to report how much they agree with each statement (not at all to extremely). Cigarette effects measured include satisfaction, taste, enjoyment of sensations in throat/chest, harshness, strength, flavor, calming, awakening, less irritable, help concentrating, hunger reduction, dizzying, nauseating, craving reduction, and enjoyment. Five reliable factors can be derived from the MCES items including satisfaction (items include satisfaction, taste, and enjoyment), psychological reward (items include calming, awakening, less irritable, help concentrating, and hunger reduction), aversion (items include dizzying and nauseating), craving reduction, and enjoyment of respiratory tract sensations (enjoyment of sensations in throat/chest) (Cappelleri et al., 2007). An additional item was included in the *MCES* for the two study cigarettes to assess perceived level of nicotine. Smokers were asked, "How does the nicotine content of the study cigarette differ from your usual brand? Please answer on the following scale from 1-100, and imagine that your usual brand is 50." The visual analog scale was anchored on the ends by "much less nicotine" and "much more nicotine."

### 2.3.4 Puff Topography

CReSS Version 3 handheld puff topography devices measured puff number, puff volume, puff duration, inter-puff-interval, peak flow, average flow, and time to peak flow. Devices were calibrated prior to each use.

### 2.3.5 Predicted Future Smoking Behavior

A novel survey named the Future Smoking Survey was created to assess how hypothetical exclusive availability of each type of cigarette would influence predicted smoking rate and interest in quitting smoking in the future. This assessment was designed to capture what participants think they would do in a regulated marketplace, similar to what would occur if the FDA were to enact a low nicotine product standard. Participants were asked to rate on a 1-100 visual analog scale how interested they would be in quitting (not at all interested to definitely interested) at four future time points (in 1 month, 6 months, 1 year, and 5 years). Participants were also asked to predict how many cigarettes per day they would be smoking at each of those time points.

In addition, participants completed the Cigarette Purchase Task (MacKillop et al., 2008), a self-report measure that assesses cigarette consumption at a range of increasing prices. The task is designed to assess the reinforcing value or abuse liability of a drug by assessing how elastic drug taking behavior is to price changes. For example, if consumption levels changed very little as price increased, this would indicate a highly reinforcing drug. The data collected with a Cigarette Purchase Task generates a demand curve, which depicts the relationship between demand for cigarettes and increases in price. Multiple indices of relative reinforcing efficacy are

captured, including: 1) breakpoint (the lowest price associated with zero consumption); 2) intensity (observed value of consumption at zero cost), 3) alpha (elasticity, or how sensitive consumption is to increases in cost), 4) *O*max (the maximum expenditure for cigarettes), 5) *P*max (the price increment associated with maximum expenditure), and 6) $Q_0$ (consumption at zero cost derived from demand equation). The instructions to this task read, "The following questions ask how many cigarettes you would consume *within a 24-hour period* if they cost various amounts of money. Assume the available cigarettes are your usual brand/the most recent study cigarette. Assume that you have the same income/savings that you have now and NO ACCESS to any cigarettes or nicotine products other than those offered at these prices. You cannot save or stockpile cigarettes for a later date. Be sure to consider each price increment carefully." The progression of prices was: free, 2 cents, 5 cents, 10 cents, 20 cents, 30 cents, 40 cents, 50 cents, 60 cents, 70 cents, 80 cents, 90 cents, 1 dollar, 2 dollars, 3 dollars, 4 dollars, 5 dollars.

## 2.4 STATISTICAL METHODS

The estimated necessary sample size was 55 participants, which was determined by a power analysis from preliminary data (9 participants), with d=0.45, a=0.05 (two-tailed test) and 90% power. Thus, the final sample size of 68 participants was expected to be sufficient to detect significant effects of nicotine content expectancy. Statistical analyses were conducted using SPSS 21 (SPSS, Chicago, IL). Descriptive statistics were used to characterize the sample's demographic and smoking history variables, as well as ratings of the usual brand cigarette. No comparisons were made between the usual brand cigarette responses and study cigarette

responses because the usual brand cigarette was always smoked first, but descriptive data on responses to the usual brand cigarette are provided as a reference point. Paired-samples t-tests were used to compare normally distributed dependent variables across the two experimental conditions. Repeated measures ANOVA was used to test interactions between nicotine content expectancy and between-subjects variables including order of study conditions, gender, menthol status, and impression management score when appropriate. Non-normally distributed dependent variables were analyzed using the Wilcoxon matched pairs test. The McNemar's test was used to assess differences in proportions.

For the cigarette purchase task data, exponential demand equations were fit using Prism 5 curve-fitting software (GraphPad, La Jolla, CA, USA) to determine the alpha and $Q_0$ values. Since the GraphPad software uses logarithmic transformations in the analysis, the breakpoint response (first 0 response) was changed to 1 and all prior responses were increased by 1 to keep the relative difference between these responses and the breakpoint equal. Responses subsequent to the breakpoint were removed before analyzing the data. The k value used for the analyses was 2 since responses ranged from 0 to 60 cigarettes per day ($\log_{10} 60=1.78$, which was rounded to the nearest whole number). In cases in which no breakpoint was reached, the breakpoint was defined as the highest price of $5 per cigarette.

In addition, some participants misunderstood the wording of the questions on the Future Smoking Survey assessing predicted cigarettes per day at four future time points. There were responses in the thousands, indicating that participants mistakenly thought the question was asking about total cigarettes smoked over the time period assessed. To rectify this issue, any response over 100 cigarettes per day was excluded from analyses as this was chosen as the highest reasonable value for someone who understood the question. Furthermore, many

participants predicted smoking zero cigarettes per day in the future (at all four time points) if only these study cigarettes were available. Thus, two processes were explored with regard to the predicted cigarettes per day data. First, the percentage of zero cigarettes per day responses was compared across study cigarette types at each future time point using a McNemar's Test. This captured the percentage of participants that predicted being abstinent. Secondly, the zero responses were removed and the remaining responses (which were adequately normally distributed) were tested using a paired-samples t-test to explore differences in predicted cigarettes per day amongst participants who did not predict being abstinent.

# 3.0 RESULTS

## 3.1 SAMPLE BASELINE CHARACTERISTICS

In total, 71 eligible participants completed the single laboratory session. However, three participants were excluded from all analyses. One participant explicitly stated that he saw the Quest logo on the study cigarettes and knew that they were identical. The second participant misunderstood instructions and smoked both study cigarettes during the first experimental smoking session. The third participant marked “very low nicotine cigarette” when asked which cigarette he had just smoked during both experimental sessions, so it was unclear whether he understood the experimental manipulation. The final sample consisted of 68 individuals (38 male, 30 female) between the ages of 19-65 years (*M*=40.37, *SD*=13.05). The racial composition of the sample was 41.2% White, 50% Black, 2.9% Asian, and 4.5% mixed race. The mean household income for this sample was $23,546.25 (*SD*= $15,993.40), and 25% of the sample was unemployed at the time of the study. For highest level of education obtained, 4.4% of the sample had at least some high school education, 47.1% were high school graduates, 35.3% obtained some college education or had a 2-year degree, 11.8% were college graduates with a 4-year degree, and 1% had a graduate or professional degree.

The mean number of cigarettes smoked per day was 16.53 (*SD*=4.76, range=10-30) and the mean number of years that participants had been smoking daily was 21.95 years (*SD*=12.7,

range=1-47). The mean baseline CO reading was 16.32 ppm (*SD*=7.74, range=3-42). About 66% of the sample smoked mentholated cigarettes. The mean total score on the *FTND* for the sample was 5.85 (*SD*=1.60, range=2-9), while the mean average score on the *WISDM* was 4.42 (*SD*=0.93, range=1.97-6.41). On the Stages of Change Questionnaire, 2.9% of participants were planning to quit within 30 days of their participation in the study, and 10.3% were seriously considering quitting smoking within 6 months of their participation in the study. The mean score on the Contemplation Ladder was 4.35 (*SD*=2.48, range=0-10).

## 3.2 MANIPULATION CHECK

A paired-samples t-test determined that when participants were asked to rate the nicotine content of the study cigarettes, the "very low" nicotine cigarette was rated as having significantly lower nicotine content (*M*=23.56, *SD*=23.54) than the "average" nicotine cigarette (*M*=40.19, *SD*=23.91), $t(67)=-5.09$, $p<0.001$. However, 12 participants rated the "average" nicotine cigarette as having lower nicotine content than the "very low" nicotine cigarette, and nine participants rated the study cigarettes equally. Since the nicotine content ratings were made after sampling the cigarettes, these participants could have experienced the cigarette in a way that was not consistent with the message delivered to them about the nicotine content. For example, these participants may have noticed that both cigarettes were very light because of the true very low nicotine content. It is unknown, however, what would have driven 12 participants to rate the "average" nicotine cigarette as containing lower nicotine than the "very low" nicotine cigarette. Nevertheless, since the primary interest for this study was to determine the effects of the very low nicotine content expectancy combined with the experience of actually smoking the VLNC

cigarette, there was no *a priori* plan to separate the sample based on this question about perceived nicotine content. Thus, the primary outcome data used for final analyses come from the total sample. For exploratory purposes, the sample was split between the 47 participants who reported nicotine content in the expected direction ("very low" nicotine cigarette less than "average" nicotine cigarette) and the 21 participants who reported nicotine content in the unexpected direction ("average" nicotine cigarette less than "very low" nicotine cigarette, or equal values), and separate analyses were conducted to determine whether effects held for both groups. However, it should be noted that splitting the sample in this way could have lead to insufficient power issues.

### 3.3 HEALTH RISK PERCEPTIONS

When the data from all 68 participants were analyzed**,** smokers rated the "very low" nicotine cigarette as less risky to their health overall compared to the "average" nicotine cigarette [$t(67)=-3.318$, $p=0.001$]. This effect held true for all individual disease risks assessed including lung cancer [$t(67)=-4.635$, $p=<0.001$], heart disease [$t(67)=-3.953$, $p<0.001$], emphysema [$t(67)=-4.521$, $p<0.001$], stroke [$t(67)=-3.738$, $p<0.001$], chronic bronchitis [$t(67)=-4.001$, $p<0.001$], and other cancers [$t(67)=-3.870$, $p<0.001$] (Figure 1). Participants also rated the "very low" nicotine cigarette as having a lower addiction risk than the "average" nicotine cigarette [$t(67)=-2.647$, $p=0.01$].

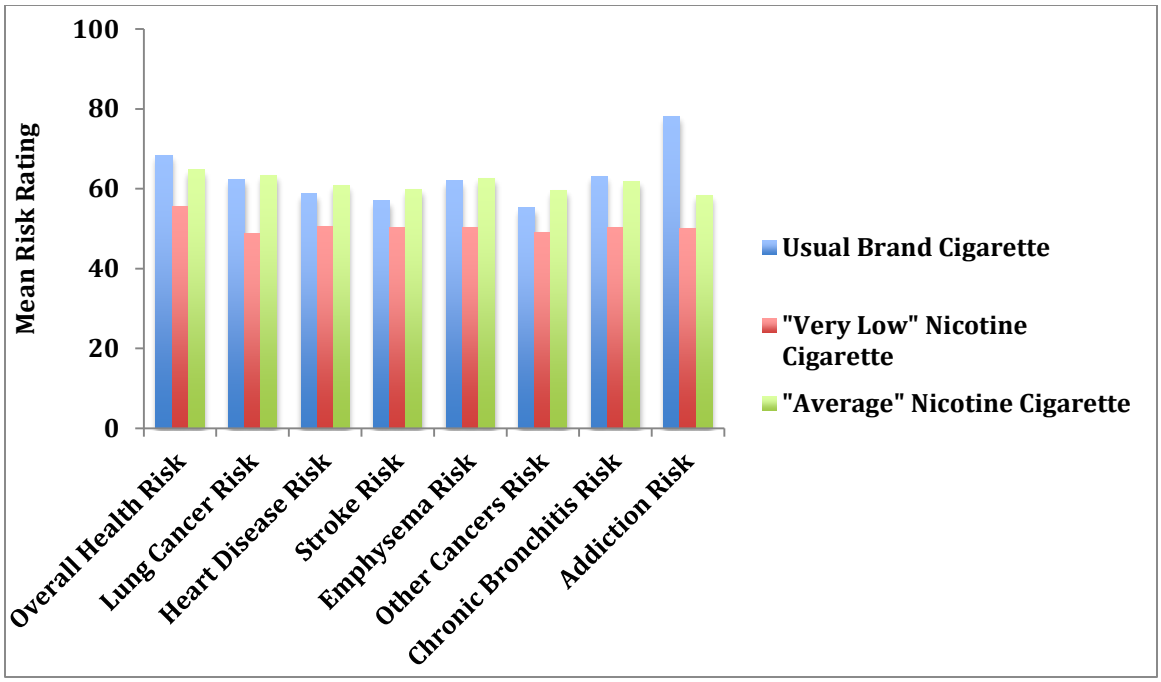


**Figure 1. Ratings for all perceived health risks for usual brand cigarette and both study cigarettes.**

*Ratings were made on a 1-100 visual analog scale. All p's<.01 except for addiction risk in which p=.01 for "very low nicotine" vs. "average" nicotine comparison. Usual brand cigarette responses are displayed for reference but were not included in analyses.*

There were no significant interactions between nicotine content expectancy and order of study conditions for any of the perceived health risks. There were no significant interactions between nicotine content expectancy and gender for any of the perceived health risks, though the interaction effect on perceived stroke risk was marginal [$F(1,66)=3.014$, $p=0.09$], such that men reported a greater difference between study cigarettes. There were no significant interactions between nicotine content expectancy and menthol status, though the interaction effect on perceived emphysema risk was marginal [$F(1,66)=3.322$, $p=0.07$)], such that menthol smokers reported a greater difference between study cigarettes. There were no significant interactions between nicotine content expectancy and impression management for any perceived health risks.

When only the data from the 47 participants who reported lower perceived nicotine content for the "very low" nicotine cigarette compared to the "average" nicotine cigarette were analyzed, the main effect of nicotine content expectancy on all health risk perceptions reported above for the full sample remained statistically significant. When only the data from the other 21 participants were analyzed, these effects were no longer significant. For these 21 individuals, the difference in means ("average" nicotine condition minus "very low" nicotine condition on a 100 point scale) was 3.63 on average (range 1.05-4.86), compared to 10.78 (range 8.27-14.66) when the full sample was analyzed.

## 3.4 SUBJECTIVE CIGARETTE EFFECTS

When the data from all 68 participants were analyzed, smokers rated the "very low" nicotine cigarette as having reduced satisfaction [$t(67)=-3.481$, $p=0.001$], psychological reward [$t(67)=-2.330$, $p=0.023$], and enjoyment from respiratory sensations [$t(67)=-2.913$, $p=0.005$] compared to the "average nicotine cigarette" (Figure 2). There was no significant effect of nicotine content expectancy on the aversion or craving reduction factors.

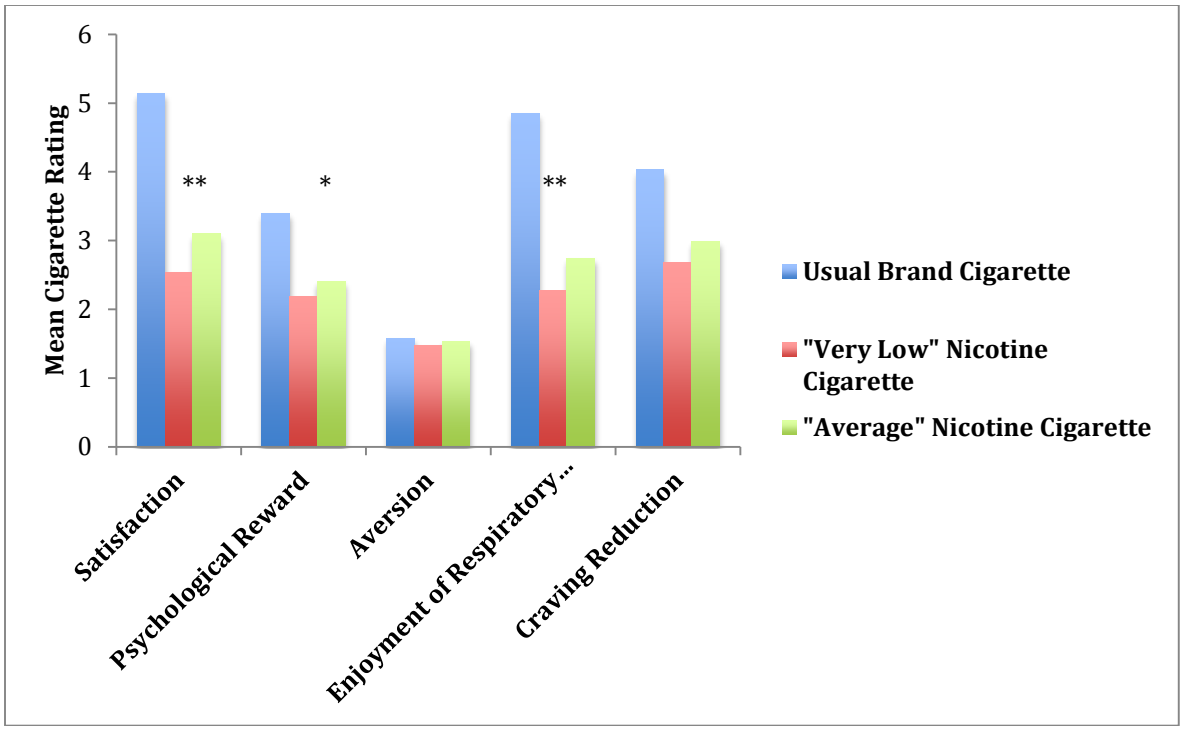


**Figure 2. Results from the five factors of the Cigarette Evaluation Scale for usual brand cigarette and both study cigarettes.**

*Ratings were made on a 1-7 Likert scale. *p<.05, **p<.01 for "very low nicotine" vs. "average nicotine" comparison. The ratings for the usual brand cigarette are displayed for reference but were not included in statistical analyses.*

There were no significant interactions between nicotine content expectancy and order of study conditions for any of the subjective effects factors. There was a significant interaction between nicotine content expectancy and gender on enjoyment of respiratory tract sensations [$F(1,66)=4.361$, $p=0.041$], such that when men were told the study cigarette contained average nicotine they reported greater enjoyment of respiratory tract sensations compared to when they were told the study cigarette contained very low nicotine and compared to women in both study conditions. A similar expectancy by gender interaction effect was marginal for psychological reward [$F(1,66)=3.234$, $p=0.08$] and craving reduction [$F(1,66)=1.492$, $p=0.07$]. There were no significant interactions between nicotine content expectancy and menthol status for any of the

subjective effects factors. There were no significant interactions between nicotine content expectancy and impression management, though the interaction effect was marginal on the craving reduction scale [$F(1,66)=3.529$, $p=0.07$] in a counterintuitive manner such that participants lower on the impression management scale reported a greater difference.

When only the data from the 47 participants who reported lower perceived nicotine content for the "very low" nicotine cigarette compared to the "average" nicotine cigarette were analyzed, the main effects of nicotine content expectancy on the five MCES factors reported above for the full sample remained the same. When only the data from the other 21 participants were analyzed, these effects were no longer significant. For these 21 individuals, the difference in means ("average" nicotine condition minus "very low" nicotine condition on a 7 point scale) was 0.26 for satisfaction, 0.06 for psychological reward, and 0 for enjoyment of respiratory sensations, compared to 0.56 (satisfaction), 0.23 (psychological reward), and 0.47 (enjoyment of respiratory sensations) when the full sample was analyzed.

## 3.5 PUFF TOPOGRAPHY

Only 60 participants had useable puff topography data due to eight individuals having used new equipment that was not functioning properly. Most participants followed instructions (by smoking only four puffs of the usual brand cigarette), but ten participants took five puffs and one participant took nine puffs. Paired-samples t-tests revealed no significant differences in any puff topography indices across the two study cigarettes (Table 1), though there was a marginal difference in total puff volume such that participants inhaled more from the "average" nicotine cigarette ($p=0.08$).

**Table 1. Results from puff topography for usual brand cigarette and both study cigarettes.**

| | Usual Brand Cigarette *M(SD)* | "Very Low Nicotine" Cigarette *M(SD)* | "Average Nicotine" Cigarette *M(SD)* | t value |
|---|---|---|---|---|
| **Number of Puffs** | 4.87 (.93) | 7.53 (3.74) | 8.05 (3.81) | -1.509 |
| **Total Puff Volume (mL)** | 285.44 (97.51) | 368.96 (163.5) | 397.88 (186.86) | -1.780[#] |
| **Average Puff Volume (mL)** | 59.40 (20.15) | 50.66 (14.38) | 50.48 (15.23) | .151 |
| **Puff Duration (ms)** | 2066.83 (693.96) | 1686.92 (527.31) | 1717.82 (569.67) | -.620 |
| **Inter-puff Interval (ms)** | 14658.15 (10239.97) | 14645.69 (8902.35) | 14335.74 (7335.57) | .322 |
| **Average Flow (mL/sec)** | 29.88 (7.51) | 31.53 (7.52) | 31.17 (7.74) | .693 |
| **Peak Flow (mL/sec)** | 41.81 (11.77) | 43.99 (13.58) | 43.44 (12.91) | .626 |
| **Time of Peak Flow (ms)** | 649.01 (281.13) | 582.94 (252.68) | 598.34 (253.46) | -.586 |
| **CO Boost (ppm)** | 0.5 (1.88) | 1.98 (2.32) | 1.86 (2.08) | .142 |

*N=60. [#]p<0.10. Usual brand cigarette values are displayed for reference but were not included in analyses. The number of puffs was constrained to 4 puffs for the usual brand cigarette, which also affects total puff volume.*

The results of the repeated measures ANOVA model that included order of study conditions determined that participants inhaled a significantly greater puff volume from the "average" nicotine cigarette compared to the "very low" nicotine cigarette [$F(1,58)=3.916$, $p=0.053$] and inhaled a lower puff volume from the second cigarette compared to the first cigarette [$F(1,58)=4.80$, $p=0.03$) (Figure 3). There were no other interactions between nicotine content expectancy and order of study conditions on any other puff topography indices. There were no significant interactions between nicotine content expectancy and gender on any puff topography indices, though there was a marginal interaction effect on average puff volume, such that the difference between men and women was greater when they were told the study cigarette contained average nicotine content [$F=(1,58)=2.825$, $p=0.10$]. There were no significant interactions between nicotine content expectancy and menthol status on any puff topography indices.

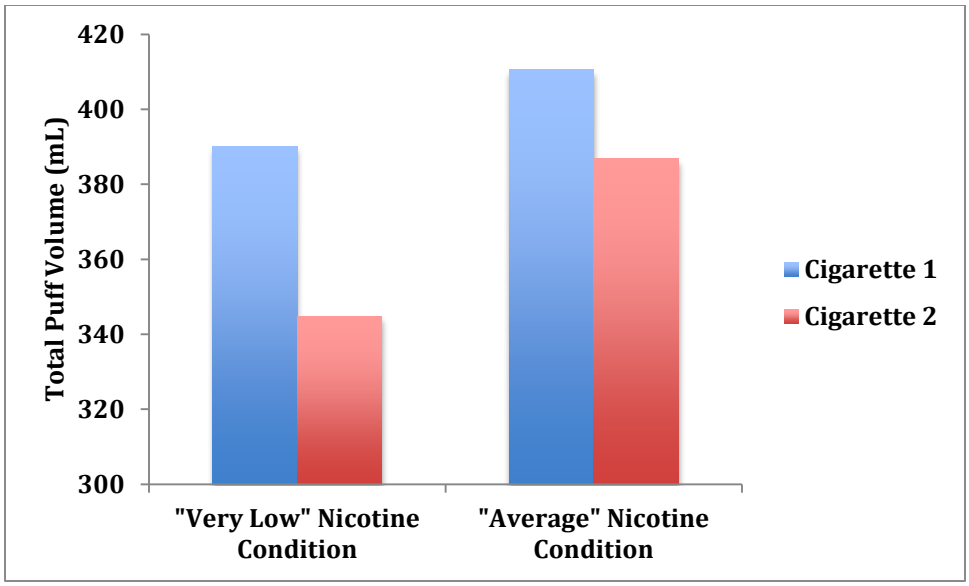


**Figure 3. Effects of nicotine content expectancy and order of experimental conditions on total puff volume.**

*Interaction effect (expectancy X order) was significant with p=0.03.*

When only the data from the 40 participants who had useable puff topography data and reported a lower perceived nicotine content for the "very low" nicotine cigarette compared to the "average" nicotine cigarette were analyzed, the main effect of nicotine content expectancy on total puff volume became significant [$F(1,38)=5.658$, $p=0.023$], such that smokers inhaled less puff volume from the "very low" nicotine cigarette, and the interaction between expectancy and order became marginal [$F(1,38)=3.233$, $p=0.08$]. When only the data from the other 21 participants were analyzed, the difference in total puff volume ("average" nicotine condition minus "very low" nicotine condition) was -5.69 mL, which was not a significant difference and was in the opposite direction compared to when the full sample was analyzed.

## 3.6 PREDICTED FUTURE SMOKING BEHAVIOR

Responses about predicted quit interest at four future time points were tested using Wilcoxon matched pairs tests because the distributions were not normal. When data from all 68 participants were analyzed, participants predicted greater interest in quitting smoking when considering exclusive availability of the "very low" nicotine cigarette compared to the "average" nicotine cigarette in 1 month (Z=-2.496, $p$=0.013), 6 months (Z=-2.442, $p$=0.015), and 1 year (Z=-2.636, $p$=0.008) (Table 2). This effect was marginal at 5 years (Z=-1.794, $p$=0.073). Furthermore, when data from all 68 participants were analyzed, McNemar's tests determined that significantly more participants predicted being abstinent in 1 year and 5 years when considering exclusive availability of the "very low" nicotine cigarette compared to the "average" nicotine cigarette (Table 3). This effect was marginally significant for the 1 month and 6 months time points (Table 3). When differences in predicted cigarettes per day (with all 0 responses removed) at the four time points were tested with a paired samples t-test, there was no significant effect of nicotine content expectancy (Table 2).

**Table 2. Results from the Future Smoking Survey for usual brand cigarette and both study cigarettes.**

| | Usual Brand Cigarette | "Very Low Nicotine" Cigarette | "Average Nicotine" Cigarette |
|---|---|---|---|
| **Predicted Quit Interest** | ***Median (range)*** | ***Median (range)*** | ***Median (range)*** |
| 1 month | 14 (1-77) | 53.5 (1-100) | 50 (1-100) |
| 6 months | 20.5 (1-87) | 65 (1-100) | 52 (1-100) |
| 1 year | 27.5 (1-100) | 70 (1-100) | 60 (1-100) |
| 5 years | 41 (1-100) | 83 (1-100) | 64 (1-100) |
| **Predicted Cigarettes Per Day (0's removed)** | ***M(SD)*** | ***M(SD)*** | ***M(SD)*** |
| 1 month | 17.10 (5.67) | 14.02 (9.14) | 13.09 (7.14) |
| 6 months | 16.99 (5.88) | 13.92 (9.01) | 13.75 (6.89) |
| 1 year | 17.28 (6.88) | 13.64 (9.36) | 13.98 (7.39) |
| 5 years | 17.21 (7.11) | 13.39 (10.51) | 14.22 (7.96) |

*On the Future Smoking Survey, participants rated their predicted quit interest on a 1-100 visual analog scale. Data was not normally distributed for predicted quit interest, so median and range values are presented. Means and standard deviations are presented for predicted cigarettes per day. Usual brand cigarette values are displayed for reference but were not included in analyses.*

**Table 3. Percentage of participants that predicted abstinence (smoking zero cigarettes per day) on Future Smoking Survey for four time points for usual brand cigarettes and both study cigarettes.**

| | Usual Brand Cigarette | "Very Low Nicotine" Cigarette | "Average Nicotine" Cigarette | *Uncorrected Chi-square (VL vs. Avg)* | *Corrected Chi-square (VL vs. Avg)* |
|---|---|---|---|---|---|
| **1 month** | 0% | 14.71% | 4.41% | *4.46** | *3.27#* |
| **6 months** | 0% | 17.91% | 8.96% | *3.00#* | *2.08* |
| **1 year** | 0% | 21.88% | 12.50% | *3.60#* | *2.50* |
| **5 years** | 5.9% | 32.81% | 20.31% | *5.33** | *4.08** |

*The corrected chi-square is corrected for continuity with Yates correction, which is often too conservative; thus, the uncorrected chi-square statistic from the McNemar's test was interpreted for these analyses. *p<.05, #p<1.0 for "very low nicotine" vs. "average" nicotine comparison. Usual brand cigarette responses are displayed for reference but were not included in analyses.*

Separate Wilcoxon matched pairs tests were performed to explore whether effects of nicotine content expectancy on predicted quit interest differed by gender or menthol status. However, it should be noted that these analyses are exploratory and insignificant findings (particularly for the smaller of the dichotomous groups) could be a result of insufficient power due to dividing the sample. For males (N=38), all results mentioned above for the full sample remained the same. However, for females (N=30), none of the effects approached significance and the Z scores were significantly lower. For menthol smokers (N=45), effects remained significant except at the 5-year time point (Z=-0.65, $p$=0.52). For non-menthol smokers (N=23), the effect at 1 month was marginally significant ($p$=0.08) and the effect at 5 years was significant ($p$=0.02), while the effects at 6 months and 1 year approached marginal significance.

In addition, separate McNemar's tests were conducted to explore whether effects of nicotine content expectancy on predicted abstinence differed by gender or menthol status. Again, it should be noted that these analyses are exploratory and insignificant findings (particularly for the smaller of the dichotomous groups) could be a result of insufficient power due to dividing the sample. Significantly more men predicted being abstinent in 1 month ($p$=0.02) and 5 years

($p$=0.01) when considering exclusive availability of the "very low" nicotine cigarette, and this effect was marginal at 6 months ($p$=0.01) and 1 year ($p$=0.06). For women, this effect did not approach marginal significance for any of the four time points. Similarly, for non-menthol smokers, this effect did not approach marginal significance for any of the four time points. However, for menthol smokers, the effect was significant at 5 years ($p$=0.005), and marginal at 1 month ($p$=0.06) and 1 year ($p$=0.06)

When only the data from the 47 participants who reported lower perceived nicotine content for the "very low" nicotine cigarette compared to the "average" nicotine cigarette were analyzed, the significant effects of nicotine content expectancy on predicted quit interest reported above for the full sample remained significant, and the effect at the 5 year time point became significant (Z=-2.696, $p$=0.01). When only these data were analyzed for predicted abstinence, the effect of nicotine content expectancy became significant for the 1 month time point (uncorrected chi-square= 5.444, $p$=0.02) and remained significant for the 5 year time point, but was insignificant for the 6 months and 1 year time points. When only the data from the other 21 participants were analyzed, there were no significant effects of nicotine content expectancy on predicted quit interest for any of the four time points. For these 21 individuals, the results of the Wilcoxon matched pairs test were as follows: Z=-0.659, $p$=0.51 for 1 month, Z=-0.621, $p$=0.54 for 6 months, Z=-0.769, $p$=0.44 for 1 year, and Z=-0.909, $p$=0.36 for 5 years. When only the data from these 21 participants were analyzed for predicted abstinence at the four time points, there was a significant effect at the 1 year time point (uncorrected chi-square = 12.8, $p$=0.00). For these 21 individuals, the percentages of participants that predicted abstinence in the "very low" nicotine condition were 4.8% in 1 month, 4.8% in 6 months, 9.5% in 1 year, and 19% in 5 years

compared to 4.8% in 1 month, 0% in 6 months, 0% in 1 year, and 14.3% in 5 years in the "average" nicotine condition.

## 3.7 CIGARETTE PURCHASE TASK

Similar to procedures from Chase, MacKillop, Hogarth (2003), nine individuals that responded with zero cigarettes per day when they were hypothetically free or reported they would only smoke cigarettes if they were free were excluded from analyses. This occurred six times in the "very low" nicotine condition and four times in the "average" nicotine condition. Four individuals that responded with the same value across all price increments were excluded because this violates the assumption that consumption generally decreases as price increases. Seven participants were excluded from analyses because the $R^2$ value (fit of the demand curve equation) was unacceptably low (less than 0.4). Thus, data from a total of 48 participants was analyzed. The $R^2$, intensity, and $Q_0$ parameters were normally distributed, but elasticity ($\alpha$), $O_{max}$, $P_{max}$, and breakpoint were not. Paired-samples t-tests revealed no significant differences between the two study conditions for $R^2$, intensity, or $Q_0$ (Table 4). Wilcoxon matched pairs tests revealed no significant differences between the two study conditions for elasticity ($\alpha$), $O_{max}$, $P_{max}$, or breakpoint (Table 4).

**Table 4. Results from the Cigarette Purchase Task for usual brand cigarette and both study cigarettes.**

| | Usual Brand Cigarette | "Very Low Nicotine" Cigarette | "Average Nicotine" Cigarette | | |
|---|---|---|---|---|---|
| ***Normally Distributed Variables*** | ***M(SD)*** | ***M(SD)*** | ***M(SD)*** | ***t value*** | |
| **$R^2$ (overall model fit)** | .74 (.18) | .73 (.15) | .73 (.15) | 054 | |
| **$Q_0$ (# cigarettes)** | 24.88 (13.30) | 21.33 (13.65) | 21.90 (12.50) | -.443 | |
| **Intensity-observed (# cigarettes)** | 20.88 (8.52) | 17.69 (10.45) | 17.29 (8.94) | .432 | |
| ***Non-Normally Distributed Variables*** | ***Median (range)*** | ***Median (range)*** | ***Median (range)*** | | ***Z score*** |
| **Elasticity (α)** | .01 (.00-.06) | .03 (.00-.25) | .02 (.00-.19) | | -.718 |
| **Breakpoint ($)** | 5 (.40-5) | .95 (.10-5) | .90 (.10-5) | | -.229 |
| **$O_{max}$ ($)** | 8 (1.60-45) | 4.90 (.20-25) | 6.00 (.20-25) | | -.457 |
| **$P_{max}$ ($)** | .85 (.20-5) | .40 (.05-5) | .40 (.05-5) | | -.704 |

*T values are presented for variables that were normally distributed and tested using the paired-samples t-test. Z scores are presented for variables that were not normally distributed and were tested using the Wilcoxon matched pairs test. There were no significant findings. Usual brand cigarette responses are displayed for reference but were not included in analyses.*

Repeated measures ANOVA determined no significant interactions between nicotine content expectancy and order of study conditions, gender, or menthol status for $Q_0$ or intensity. However, there was a marginal interaction between nicotine content expectancy and gender on the intensity parameter [$F(1,46)=3.33$, $p=0.07$], such that intensity was higher for men versus women in the "very low" nicotine condition. For the elasticity (α), $O_{max}$, $P_{max}$, and breakpoint parameters, separate Wilcoxon matched pairs tests were conducted to explore differences by order of study conditions, gender, and menthol status. These tests revealed similar insignificant results across all groups and parameters.

Results from analyses of the full sample remained insignificant when the 34 participants who reported lower perceived nicotine content for the "very low" nicotine cigarette compared to

the “average” nicotine cigarette were analyzed separately. There were also no significant differences when data from the other 14 participants were analyzed separately.

## 3.8 EXPLORATORY ANALYSIS OF RELATIONSHIP BETWEEN DEPENDENT MEASURES

Since the results of puff topography and predicted future smoking behavior generally ran opposite to hypotheses, exploratory Pearson’s correlations were conducted to determine how these constructs were related to perceived health risks and subjective effects. In both the “average” nicotine and “very low” nicotine cigarette conditions, total puff volume was significantly positively related to positive subjective effects such as psychological reward, satisfaction, and enjoyment of respiratory sensations (Table 5). Similarly predicted future quit interest was significantly positively related to these positive subjective effects (Table 5). However, health risk perceptions were not significantly related to total puff volume or predicted future quit interest (Table 5).

**Table 5. Exploratory relationships between smoking behavior variables, subjective effects, and health risk perceptions for both study cigarettes.**

| | Satisfaction Factor (MCES) | Psychological Reward Factor (MCES) | Enjoyment of Respiratory Sensations (MCES) | Overall Health Risk | Addiction Risk |
|---|---|---|---|---|---|
| **"Very Low" Nicotine Cigarette** | | | | | |
| **Total Puff Volume** | 0.40** | 0.32* | 0.40** | 0.00 | 0.04 |
| **Quit Interest in 1 month** | -0.44** | -0.26* | -0.38** | 0.17 | -0.09 |
| **Quit Interest in 6 months** | -0.48** | -0.31* | -0.45** | 0.11 | -0.14 |
| **Quit Interest in 1 year** | -0.54** | -0.33** | -0.47** | 0.20 | -0.05 |
| **Quit Interest in 5 years** | -0.53** | -0.35** | -0.49** | 0.23# | 0.00 |
| **"Average" Nicotine Cigarette** | | | | | |
| **Total Puff Volume** | 0.57** | 0.47** | 0.53** | 0.14 | 0.08 |
| **Quit Interest in 1 month** | -0.62** | -0.42** | -0.52** | 0.15 | -0.03 |
| **Quit Interest in 6 months** | -0.61** | -0.40** | -0.51** | 0.17 | -0.02 |
| **Quit Interest in 1 year** | -0.58** | -0.41** | -0.49** | 0.21 | 0.01 |
| **Quit Interest in 5 years** | -0.54** | -0.39** | -0.46** | 0.23 | 0.03 |

*Values presented are r values from Pearson's correlations. **p<.01, *p<.05, #p<1.0.*

# 4.0 DISCUSSION

The results from the present study were expected in some aspects but somewhat surprising in others. The hypotheses that drove this study stemmed primarily from previous survey literature highlighting smokers' misconceptions about the harms of nicotine as well as previous literature on "light" cigarettes that demonstrated compensatory smoking and decreased interest in quitting when smokers assumed lower harm from these products. Thus, it was expected that if risk perceptions of cigarette smoking were reduced due to a very low nicotine content expectancy, short-term and predicted long-term future smoking behavior would simultaneously increase. The data confirmed that when smokers are given a VLNC cigarette and are aware of the very low nicotine content, they believe it is safer than an identical cigarette that they are told has average nicotine content. This finding was consistent across a range of disease types so it appears to be a general misconception, not just about one particular health problem. However, smokers interestingly reported that they would be more interested in quitting smoking in the future if only the "very low" nicotine cigarette was available to them, compared to if only the "average" nicotine cigarette was available to them, even though they perceived the "very low" nicotine cigarette to be less risky to their health. Additionally, there was some evidence that smokers inhaled less total puff volume from a VLNC cigarette when they knew it contained very low nicotine content. At the same time, when smokers were aware that the study cigarette contained very low nicotine they reported significantly fewer desirable subjective effects than

when they believed it contained average nicotine. Though this study did not set out to specifically explore mechanisms, one possible interpretation of the data is that the more proximal positive effects of smoking (i.e. desirable subjective effects) may drive smoking behavior more than distal negative health consequences. In fact, an exploratory analysis determined that total puff volume was positively correlated with desirable subjective smoking effects, but unrelated to health risk perceptions. Similarly, predicted future quit interest was negatively correlated with desirable subjective smoking effects, but generally unrelated to health risk perceptions. Future studies will be important to clarify the mechanisms underlying smokers' short-term and predicted long-term future smoking behavior.

The data presented here may be beneficial for policymakers in the event that the FDA enacted a low nicotine product standard for cigarettes. The results from this study suggest that making smokers aware of the low nicotine content of VLNC cigarettes could possibly have both detrimental and positive consequences. Policymakers should certainly consider the reduced risk perceptions, and any information about these cigarettes that conveys low nicotine content should be accompanied by communication that VLNC cigarettes are not necessarily safer and still lead to the same smoking-related diseases. However, it seems that explicit awareness of the low nicotine content decreases smokers' enjoyment of VLNC cigarettes, which may result in at least two possible consequences. One possibility is that smokers may desire these cigarettes less, which could promote increased quitting. This consequence would clearly be a benefit and its potential is generally supported by the data presented here. Conversely, another possibility is that smokers may believe that they need to smoke more VLNC cigarettes per day to get the effects that they desire, which would increase their harm from smoking. This issue was generally not

supported by the data presented here, but it should still be surveyed closely to prevent unintended consequences of a low nicotine product standard.

An interesting finding was that the effects of a very low nicotine content expectancy on risk perception, subjective cigarette effects, and smoking behavior were generally nonexistent in the minority of participants that rated the nicotine content of the study cigarettes after they tried them in a way that was inconsistent with the manipulation (i.e. rated the nicotine content of the cigarettes equally or reported that the "average" nicotine cigarette contained less nicotine than the "very low" nicotine cigarette). This may suggest that labeling of the nicotine content of VLNC cigarettes may not be particularly salient for some smokers who may pay more attention to their own subjective smoking experience. This may also suggest that for some smokers, even perceived nicotine content may not be particularly important for risk perception, subjective smoking experience, or smoking behavior. However, it is possible that these analyses were not powered enough to determine significant effects, so future studies with larger sample sizes would be important to replicate these findings and explore the mechanisms underlying the differences.

Furthermore, this study was a brief single-session experiment with several limitations, so future studies would be beneficial to further explore the effects of a very low nicotine content expectancy on smoker's perceptions and behaviors. First, this study explored the effects on objective smoking behavior in a limited way by only measuring puff topography; a longitudinal study exploring cigarettes smoked per day over time would provide a much richer dataset to make conclusions from. Moreover, because participants were only able to sample the study cigarettes through the puff topography device, this was not a natural smoking experience and could have influenced ratings of the cigarettes. Secondly, it is possible that the effects of a very low nicotine content expectancy on perceptions are short-lived, so it would be helpful for future

studies to measure all dependent variables in this study repeatedly over an extended time period as perceptions may change with repeated exposure to the products. Third, participants were asked to predict their future behavior over the next five years, and people may not be very accurate while doing this. Fourth, the same-day, single session design of the study was not ideal. This could have lead to reduced desire to smoke the second study cigarette, especially after having already tried the first study cigarette and not liking it as much as the usual brand cigarette. Either a within-subjects design with two separate study sessions or a between-subjects design with more participants might be a better way to explore these research questions. Lastly, the participants in this study were not in a nicotine deprived state, so it would be important for future studies to explore the impact of deprivation on the measures described here, as effects of a very low nicotine content expectancy may be more pronounced.

In conclusion, the present study suggests that labeling of the nicotine content of VLNC cigarettes could make an impact on some smokers and should be considered carefully. The possible consequences appear to be fairly complicated and future studies will be important to replicate and extend the present findings. Previous literature suggests that a very low nicotine cigarette standard could have a large beneficial public health impact, and it will be important for policymakers to determine how to maximize this benefit without causing unintended harm. Labeling and marketing of VLNC cigarettes is one aspect that could potentially moderate the effects of such a product standard.

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## 6.0 DECLARATION OF INTERESTS

The author has no competing interests to declare.

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