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Evaluating Nicotine as a Cognitive Enhancer

Vatsala Sachdeva
Bryson Curtis
Gayathri Srikanth
Kathryn Dudash
Emma Fritsch

Nicotine is a bicyclic chemical compound that is derived from tobacco plants. Due to its effect on the brain, nicotine is addictive and has long been used as a popular recreational drug. In numerous studies, nicotine has been shown to improve memory and reaction time performances. Some nicotine skin patch studies have exhibited characteristics of a possible treatment for cognitive impairments (Rezvani and Levin, 2001). Although many studies have shown that nicotine has cognitive-enhancing effects, there is not sufficient research conducted to examine the specific impacts of nicotine on reaction time. The aim of this study is to assess how reaction time differs before and after nicotine use for people who regularly use the drug and to test how the reaction times of non-users compares to those of regular users. This study was conducted on individuals aged 18 to 22. A Brain Gauge device and its associated software was used to collect reaction time data. Each user completed the Hardware Reaction Time test, which required the participant to press a button with their right index finger as soon as they felt the stimulus that was delivered to their right ring finger. It was found that people who did not use nicotine had faster reaction times than those who use nicotine regularly. However, regular nicotine users had slower reaction times before nicotine use as compared to after nicotine use. Although these results improve our understanding of the effects of nicotine use, there were limitations to the study. The experiment was not well-controlled as the environment of each participant was different, and the population tested consisted of mostly people in their early 20s. Further studies should be conducted with more controlled testing conditions and with a more diverse population.

Introduction

Nicotine is a stimulant that expedites message transfer between the brain and the body. After nicotine is introduced to the body, it binds to nicotinic acetylcholine receptors (nAChRs), which triggers the downstream pathways that lead to the observable effects of the drug. Areas of the brain that have medium to high densities of nAChRs include the cortical (medial-prefrontal, cingulate, orbital, piriform, frontal and rhinal cortices) and subcortical (amygdala, caudal-ventral hippocampal) structures of the brain [2]. Nicotine is commonly used in tobacco products but it is also contained in e-cigarettes, which have grown increasingly popular over the past two decades. While nicotine has varying effects on its users, some of the common effects include dizziness, weakness, and nausea in non-regular users. Regular users of nicotine bypass the short-term effects by building a tolerance to them, which results in an increased heart rate, relaxation, and increased ability to concentrate. When nicotine is used regularly over a long period of time, the user may have multiple health conditions. Similar studies have shown that nicotine has cognitive-enhancing effects, which include improved fine motor skills and both working and short-term episodic memory. The working memory was only found to be improved when the participant was an avid user of nicotine, which suggests that the baseline working memory of an avid user declines due to nicotine use. Nicotine can also increase alertness and improve the mood of its user, while decreasing stress, regardless of how regularly it is used. It is able to reduce stress due to its ability to increase “attentional focus on a benign distractor stimulus” [3]. It has also been shown that both visual and auditory reaction times of an avid smoker are lower than that of non-users. Additionally, smoking one cigarette significantly reduced the visual and auditory reaction time of non-users [4].

In this study, the effects of nicotine on reaction time will be assessed using the Brain Gauge device.

Methods

Participants for this study were recruited through Google Surveys for the purpose of completing a series of Brain Gauge tests related to the effects of nicotine on the brain's sensorimotor function and event sequencing. The survey contained questions regarding the use of nicotine products, with those participants using nicotine placed into an experimental group and those not using nicotine placed into a control group. The survey also gathered results regarding the type of nicotine used, the frequency of use, and the length of time of active use. From here, participants were given an ID number corresponding to a Brain Gauge account and were instructed to begin the assigned batteries.

The Brain Gauge device was used as a cognitive assessment tool for multiple measures of brain health. Each participant in both the control and experimental group was given the same series of tests, and the nicotine users were instructed to use nicotine immediately before taking the test. The control users did not have any nicotine in their system as they completed the assessment. Said assessment consisted of a Hardware Reaction Time test and a Timing Challenge test.

The Hardware Reaction Time test evaluated sensorimotor functions; participants pressed a button on the brain gauge once they felt a stimulus, allowing for the documentation of stimulus perception in regards to creation of a motor response. The test records participant fatigue, or the speed at which the brain tires of repetitive tests or events, which nicotine is believed to decrease. This test also eliminates systematic delays, increasing both accuracy and precision of results.

The Timing Challenge test evaluated the brain's ability to sequence events and communicate and coordinate amongst itself. In this test, the subject received two asynchronous stimuli through the Brain Gauge in rapid succession, then determined which came first through pressing the correct corresponding tip on the Brain Gauge. This test also relates to short-term memory, which nicotine is believed to improve.

Results

Figure 1 compares various reaction time metrics in non-nicotine users and nicotine users both before and after using nicotine. Results taken before nicotine use occurred following a full day of abstinence, while results taken after use occurred less than fifteen minutes after use of a nicotine product. Lower values for averages indicate improvements in the speed of reaction time, while lower values for standard deviations indicate greater uniformity in reaction time results.

Subject Type	Average Reaction Time (ms)	Average Reaction Time Percentile	Reaction Time Standard Deviation (ms)	Reaction Time Percentile Standard Deviation
Non-nicotine Users	239.883	38%	49.36388261	0.2458272452
Nicotine Users - Before Nicotine	291.500	59%	59.60144294	0.2059530691
Nicotine Users - After Nicotine	259.779	45%	69.67811372	0.2661431264

Figure 1. ***Comparison of data between nicotine and non-nicotine users.***

Figure 2 compares average reaction time variability and average reaction time variability percentile in non-nicotine users and nicotine users both before and after using nicotine. Results taken before nicotine use occurred following a full day of abstinence, while results taken after use occurred less than fifteen minutes after use of a nicotine product. Lower values indicate smaller variability in reaction time results.

Subject Type	Average Reaction Time Variation (ms)	Average Reaction Time Variation Percentile
Non-nicotine Users	9.805516443	22.94%
Nicotine Users - Before Nicotine	25.53333333	53.33%
Nicotine Users - After Nicotine	17.08947368	43.00%

Figure 2. *Comparison of reaction time variability across nicotine and non-nicotine users.*

Figure 3 is a graphical comparison of data and shows that reaction time is slower for nicotine users, and Figure 4 displays the differences in reaction time variability between the cohorts.

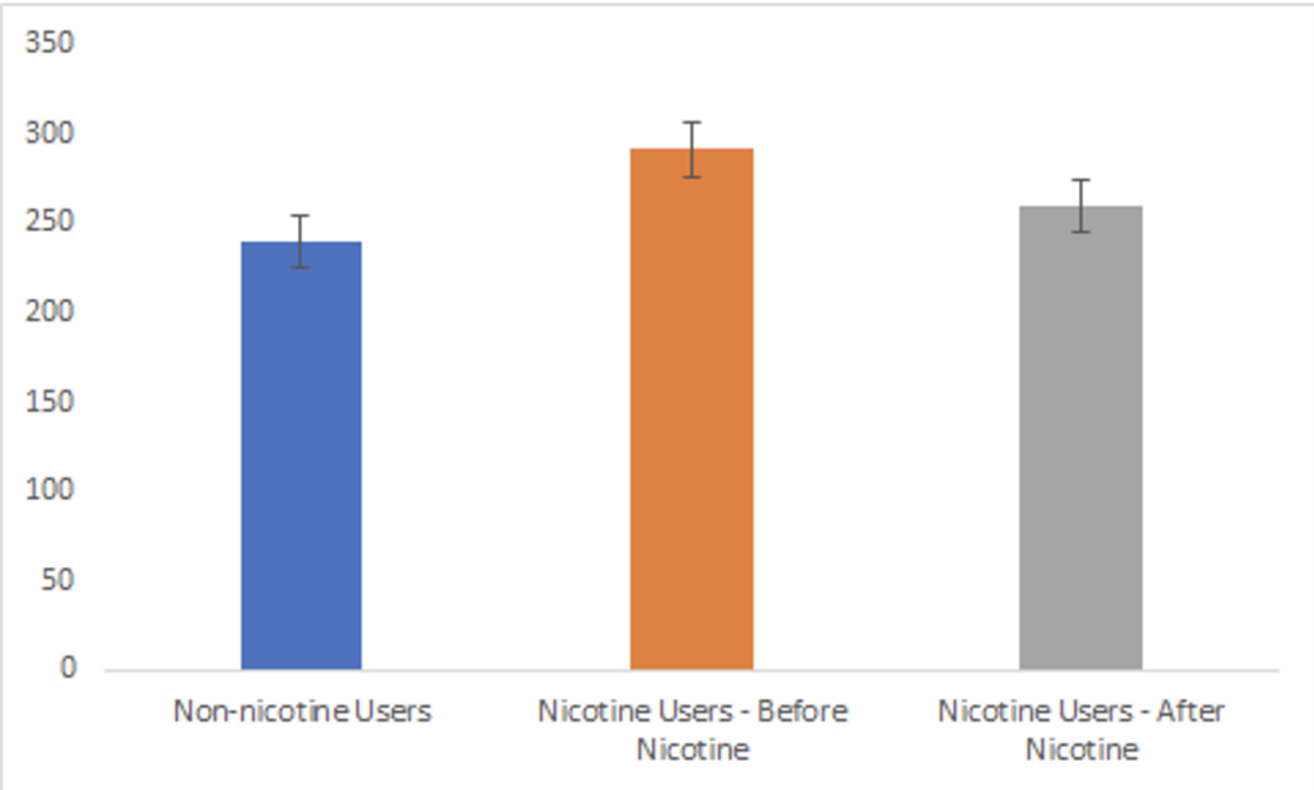

Figure 3. *Graphical comparison of reaction time in non-nicotine users and nicotine users before and after the immediate use of nicotine.*

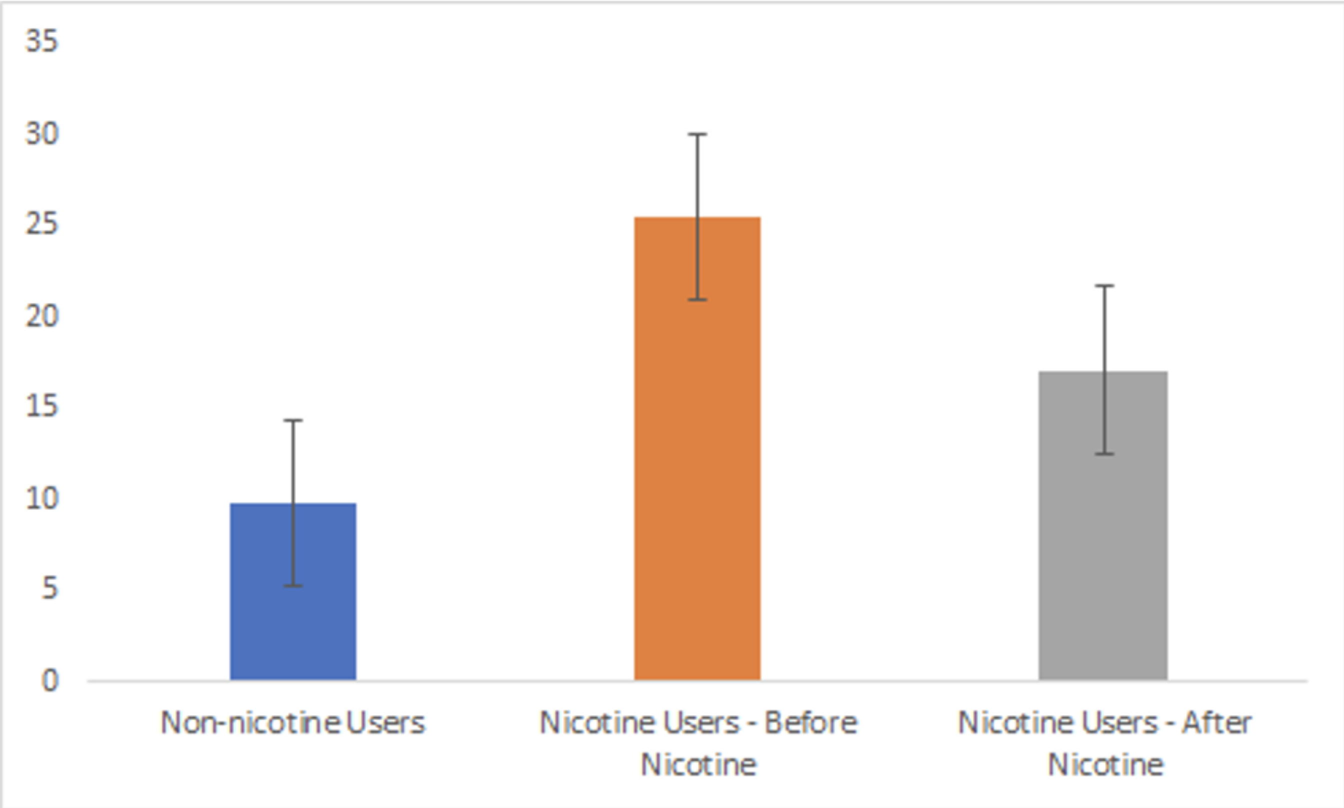

Figure 4. *Graphical comparison of reaction time variability in non-nicotine users and nicotine users after abstinence from nicotine and after the immediate use of nicotine.*

Discussion

Overall, the average difference between a participant who used nicotine immediately before the test and after was 32 msec of improvement. This means the percentile of reaction time improved from 59% to 45%. Select participants in this study demonstrated improvements in their Brain Gauge results when completing the exam with nicotine. Out of the six participants who took the test before and after nicotine, five showed improvement in reaction time as demonstrated in the chart above. The greatest improvements in reaction time (measured in msec) came from participants who used nicotine several times a day. One participant went from the 40th percentile to the 25th percentile before and after using nicotine, respectively. Additionally, another participant went from the 30th percentile to the 10th percentile; this participant reported feeling jittery and more focused during their second trial after using nicotine. This particular participant is a 21-year-old female who has been using nicotine several times a day, specifically e-cigarettes, for several years. Their improvements may be attributed to the cognitive enhancing properties of nicotine discussed earlier in the paper. The reaction times of these participants exhibited improvement after using nicotine, so it may aid in their ability to process and respond to stimuli.

Interestingly enough, the results revealed that non-nicotine users, on average, performed better than nicotine users (both before and after using nicotine on the test) in the reaction time test. Further exploration of these results through more testing should be done. Furthermore, these results may demonstrate that while nicotine may be thought of as a cognitive enhancer, its long term usage is actually detrimental in completing cognitive tasks. As a result, non-nicotine users tend to have a faster reaction time when compared to the range of reaction time data obtained from nicotine users. When focusing on nicotine users, the data show that nicotine improves their reaction time when they are regular users. It may be deduced that nicotine has properties of a cognitive enhancer when the participant regularly uses nicotine.

In completing this study, there were many limitations that shall be addressed here. First, the testing size was limited to classmates and fellow peers willing to take the brain gauge test using or not using nicotine. More test results could have validated the results found in the initial study and increased the efficacy of our results. Secondly, we were not able to control continuity in nicotine usage. Some participants used cigarettes, while others used electronic cigarettes or nicotine gum. Ideally, if this experiment were to be done in the lab, a rat model would have been used as every rat could be administered the same amount and form of nicotine. Furthermore, this addresses the drawback of remote testing as participants took the brain gauge test off site in their own respective, differing environments. Ideally, the test would have been given in a quiet room with no distractions. The participants may have also been affected by the time of day that they took the brain gauge test because they could have varying levels of sleep. Possible sleep deprivation could have changed reaction time as well. In addition, the results of this experiment could have been affected by other substances if participants were actively using something other than nicotine as well. Participants may have taken prescription drugs or used recreational drugs surrounding the time that they took the brain gauge test. These confounding variables have impacted the results of our experiment because reaction time can be influenced by a variety of factors. In order to improve the accuracy of the data, the experiment must be done at the same time of day, in the same environment, with no other substances and with consistent amounts and forms of nicotine.

Author Contributions

BC, EF, GS, KD, and VS designed the experiment. GS and KD wrote the abstract and introduction. BC and VS wrote the methods. BC wrote the results and created the figures/tables. The discussion was written by GS and VS.

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