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Effects of smoking on simple and choice reaction time

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Abstract. Twenty-nine subjects performed a reaction time task with four levels of choice-task complexity under non-smoking, sham smoking, and low, medium and high nicotine cigarette conditions. Nicotine reduced decision time, while sham smoking increased decision time. This effect was independent of subjects' habitual levels of cigarette consumption. No effect of smoking was found on movement time.

Key words: Intelligence – Decision time – Nicotine, smoking

Nicotine is a mimetic of the neurotransmitter acetylcholine at nicotinic-cholinergic receptor sites. As such it is a psychoactive drug able to act at many sites in both the central and the peripheral nervous systems. One of the clearest effects of acetylcholine within the brain is on information processing (Callaway et al. 1992), and much of the literature on nicotine has focussed on the enhancing effects of nicotine on either information processing or, more particularly, on focussed attention and vigilance.

While several researchers have established a theoretical and experimental basis for the positive effect of nicotine upon rapid information processing (Warburton and Wesnes 1979; Warburton 1992), memory (Colrain et al. 1992), and mood and personality (Mangan and Golding 1978), the purpose of the current experiment was to explore the specific effects of nicotine on a choice reaction time (RT) task previously related to intelligence (Roth 1964; Jensen 1980, 1987).

Nicotine has been shown to improve reaction time. Revell (1988), for instance, reported that smoking as few as two puffs of a cigarette improved both correct detections and reaction time on a rapid serial visual information processing (RSVIP) task both during and immediately after smoking. Smoking also appears to compensate for the retardant effects of depressants such as alcohol (Kerr, et al. 1991). Correspondingly, 24 h of abstinence from tobacco use has been shown to increase mean reaction time in smokers (Wesnes and Warburton 1983) and to elevate both variability and false positive responding on continuous performance tasks (Hughes et al. 1989). There is thus a consistent positive effect of nicotine which reverses upon withdrawal.

Recently, a more informative analysis of reaction time began to be utilised which decomposes RT into two component variables; decision time (DT), the time between onset of the imperative stimulus and commencement of the physical movement, and movement time (MT), the time to effect a response independent of decision time. Commonly this task is performed on a box providing subjects with a home key overarched by a semicircular array of stimulus lights (Jensen 1987). Beneath each light lies a response button, and the subjects' task is to respond to each stimulus by releasing the home button and moving to depress the appropriate response key.

Previous researchers have demonstrated that smoking improves both choice decision time and also decision time for a more complex reaction time task, the "odd-man-out" paradigm (Frearson et al. 1988), while Knott (1986) has shown that improvements in reaction time and speed of processing under smoking conditions correlate with increased Cz N1 amplitudes to imperative stimuli and decreased P2 amplitude in response to increasing task complexity in joint RT-EP studies.

The Knott (1986) study used two levels of choice and a distraction condition while Frearson, Barrett and Eysenck (1988) used only a single level of choice (eight lights) in their choice RT task. The present paper tests RT over a range of bits of choice and thus may cast light on the interactive effects of nicotine over a larger range of complexities than have been previously utilised. Moreover, the current study employed five nicotine doses—nonsmoking, sham smoking, low, medium, and high nicotine delivery cigarettes conditions, the non- and sham smoking conditions providing control and placebo conditions. It was expected that decision time will increase linearly with bits of choice per reaction but also that increasing doses of nicotine may decrease decision time. Using the Hick methodology, it is also possible to examine the effects of nicotine on central (DT) and peripheral (MT) processes separately. Previously it has been found that smoking influences central rather than peripheral processes (Knott 1978) and the current study allows us to examine this effect in more detail as the processing of increasing complexity is a central task which should be

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reflected in increased DT and unchanged MT as central load increases.

Materials and methods

Subjects. Twenty nine subjects 13 women (age range 17–28 years mean = 22.2) and 16 men (aged 18–32 years mean = 22.7) were recruited from a volunteer panel. All subjects were smokers and reported using between 5 and 25 cigarettes/day. Subjects were instructed not to smoke during the 2 h prior to their laboratory appointment.

The Hick apparatus was identical to that used by Jensen and Munro (1979) and described in several articles, e.g. (Jensen 1987), except that the lights were green high intensity LEDs and the buttons had been modified for easier activation by making them 1 mm proud of the surface of the box, and by increasing their diameter to 12.5 mm. The entire experiment was controlled using a Macintosh II with custom Lab VIEW II software (Bates 1992).

On each trial a warning tone sounded 1 s after the home key was depressed. This was followed by a random interval of 1–4 s after which the target light was illuminated. Subjects were instructed to press the target key as soon as the target was observed. DT was the time elapsing between target onset and the release of the home key. When the home key was released, all the stimuli were lit in order to mask the target. MT was measured from the release of the home key to the depression of a target key. Subjects could see how many trials were left in each condition by an on-screen indicator. Trials with a DT of less than 20 ms or more than 1 s, or on which a response error was made were discarded online and an additional trial given. Choice was manipulated by varying the number of bits of information required to be processed in order to decide on a response. Taking the simple RT condition where the stimulus position is known and fixed as 0 bits, the more complex conditions in which any one light from a set of two, four, or eight lights could appear constitute the one, two and three bit conditions, respectively.

Procedure. Nicotine was varied across five levels: no smoking, sham smoking (cigarette made from nicotine free tobacco), and smoking of cigarettes rated as providing 0.4, 0.8, and 1.2 mg nicotine (nil, sham, low, medium, and high nicotine conditions, respectively). Smoking was controlled by a recorded message which prompted subjects to "take a puff now" at 30-s intervals over a period of 3 min. Subjects then waited 1 min before beginning the RT task. In the non-smoking condition, subjects waited an equivalent amount of time but did not smoke.

The smoking conditions were performed over three sessions between 2 and 5 days apart. Subjects performed no more than two smoking conditions in a session and only one nicotine condition was given in any session. The assignment of smoking condition and of choice RT level (0,1,2, and 3 bits) presentation orders was made according to a Latin square design which ensured that the presentation of conditions and choice combinations was balanced across subjects and across orders of nicotine presentation.

On the first session subjects were introduced to the laboratory and then briefed about the RT task. In all sessions, subjects pace-smoked and then completed 32 practice trials, four trials on each of the eight lights in random order. They then completed the 0-,1-,2-, and 3-bit conditions presented in blocks consisting of 32 trials at 0 and 1 bits and 64 trials at 2 and 3 bits. More trials were given in the higher order conditions to make the numbers of trials presented at each button position roughly comparable between conditions.

Results

In order to reduce the sensitivity of RT parameters to outliers, the DT and MT data were preprocessed by first removing trials longer than 700 ms, then discarding all trials more than 2 SD above the mean of the remaining sample. DT and MT were defined as the median times from these conditioned distributions. The median was chosen because this measure has been shown to be more reliable and less sensitive to outliers than the mean (Jensen 1987).

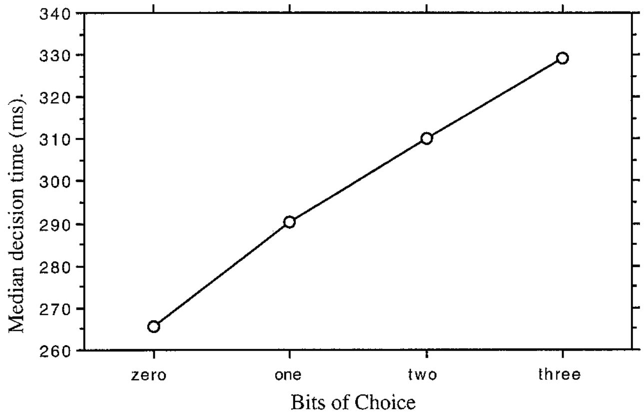

Fig. 1. Effect of bits of choice on decision time

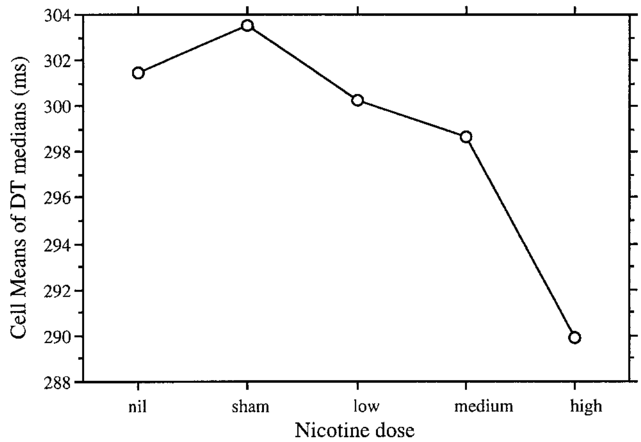

Fig. 2. The effect of nicotine and smoking on decision time

An analysis of variance using repeated measures of nicotine level and bits of choice, and a between subjects measure of fatigue were computed for both DT and MT.

Decision time was, as expected, linearly related to bits of choice with each bit adding approximately 20 ms to median DT [$F(3,28) = 181$, $P < 0.0001$] (see Fig. 1).

The effect of nicotine on DT was also significant [$F(4,28) = 2.56$, $P = 0.04$]. Sham smoking increased DT from NS levels, a post-hoc contrast indicating that this effect was significant ($P = < 0.02$). Nicotine, however, decreased DT, with increasing doses of nicotine having greater effects (see Fig. 2). A planned contrast between the non-smoking and high nicotine decision times was significant at 0.0001 [$F = (1,28) = 29.37$].

Movement times were not significantly affected by smoking condition [$F(5,28) = 0.81$]. Movement time was,

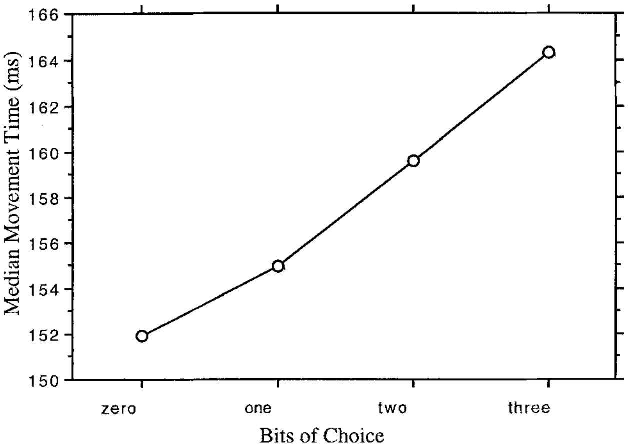

Fig. 3. Bits of choice and movement time

however, significantly related to bits of choice (see Fig. 3) with longer MTs being recorded to the harder choices [$F(3,28) = 13.7$, $P = 0.0001$].

Discussion

While previous studies have shown that nicotine can decrease RT on certain tasks, the present study separated MT and DT components of RT and studied the effect over multiple bit and nicotine dose levels. There were two main benefits to this new methodology. Firstly, it was possible to differentiate between peripheral and central processes for the dose dependent effects of nicotine. Secondly, we could integrate our psychopharmacological findings with a large body of research on psychometric performance.

While nicotine undoubtedly has localised peripheral effects, on pulse pressure for instance (Cryer et al. 1976), the fact that nicotine decreased decision time without affecting movement time argues for a central rather than a peripheral locus for the enhancement effects of nicotine on performance. Given that the decrease in decision time does not appear to be decellerating, it would be interesting to further explore the dose-response surface of this effect by increasing nicotine levels beyond the current moderate levels.

Movement time, while being unaffected by nicotine, was significantly influenced by bits of choice. The mean data in this study indicate an increase of 4 ms per bit of choice. While this is small compared to the 22-ms increment in DT per bit, it is certainly larger than the more commonly reported slight relationship with perhaps 2–3 ms increase in MT per bit of choice (Jensen 1987). Indeed, in some studies MT has actually decreased on the larger choices. An obvious question which arises is which process is responsible for the 4 ms/bit increase in MT? The increase is so small that the finger is probably still moving ballistically towards its target, i.e. feedback does not explain the increase in MT. Perhaps the simplest explanation is that subjects are less certain about their response at high levels of uncertainty, and that this translates into a weaker efferent volley to the musculature. Certainly this seems more likely than the alternative hypothesis that subjects are still deciding which target to hit during the rapid descent of the finger towards its target.

Given that decision time has been shown previously to correlate moderately with IQ (Jensen 1987; Bates and Eysenck 1993a) it is natural for curiosity to be piqued by the possibility that the nicotine mediated decrease in DT has its basis in the same biological mechanism as underlies the RT-IQ relationship. While the absolute level of the IQ-DT correlation (of the order of 0.3) implies that most of the RT variance is controlled by variables other than IQ, it is possible that the decrease in decision time caused by nicotine increases the biological processing efficiency factor (Bates and Eysenck 1993b) which is indexed by the RT-IQ correlation. One method of examining this possibility is to replicate this study using a different biological indicator of IQ/brain efficiency such as inspection time (Nettlebeck and Lally 1976) and to determine whether or not nicotine affects the same variance in both RT and inspection time. A negative result would indicate that nicotine is not affecting a process common to both IT and RT and is therefore unlikely to be affecting intelligence.

A second possible mechanism for the effect on nicotine on DT involves attention. Nicotine has previously been shown to improve attention and, more specifically, focussed attention (see Callaway et al. 1992 for a recent review). Improved focussed attention may function to improve Hick paradigm performance due to the well demonstrated inverted "U" relationship of attention to behavioral efficiency. These attention effects can be demonstrated both the level of psychophysiological process (Papanicolau et al. 1987; Bates and Eysenck 1993a) and also at the level of the single cell neural recordings (Spitzer et al. 1988). An obvious extension of the present findings is to examine the effects of nicotine at these levels.

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