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Effects of nicotine gum on psychomotor performance in smokers and non-smokers

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Abstract. Two experiments were conducted to investigate the effects of nicotine on human performance. In the first study six smokers, who had been allowed to smoke normally prior to testing, completed a battery of psychometric tests (choice reaction time, memory scanning, tracking and flicker fusion threshold) at set points over 4 h after chewing 0, 2, or 4 mg nicotine polacrilex gum. A second study followed a similar design, but used five non-smoker volunteers who were required to chew only the 0 or 2 mg nicotine gum. Blood nicotine levels following the gum were measured in all subjects. The results indicate that additional nicotine improved both the speed and accuracy of motor activity among the smokers, but did not enhance central cognitive processes. No drug effects were found in the non-smoker study.

Key words: Nicotine – Smoking – Information processing

Several studies have claimed that nicotine facilitates information processing by promoting greater efficiency in central cognitive mechanisms (e.g. Mangan 1982; Wesnes and Warburton 1983; Parrott and Winder 1989). The majority of tests used in these investigations have been derived from vigilance measures, the selection of and response to limited amounts of information in the environment. Apparent improvements in performance after smoking or after the administration of nicotine have been interpreted as the result of increased efficiency in central cognitive mechanisms (e.g. stimulus selection) brought about by the promotion of cholinergic activity and raised electrocortical arousal (Wesnes et al. 1983). These results have been used to support the hypothesis that nicotine is used by smokers as a psychological resource which may have beneficial effects on performance.

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The methodology employed in these studies requires subjects, usually smokers, to abstain from tobacco for several hours (commonly overnight) prior to testing. After baseline assessments subjects are allowed to smoke and the assessments repeated. Significant improvements in performance are often seen, but it is not clear whether these are due to the presence of nicotine in the drug condition or the absence of everyday levels of nicotine in the placebo/baseline condition. Consequently, what has been interpreted as facilitation of performance may represent merely the recovery of normal function.

This method also seems somewhat removed from the pharmacological profile of normal smoking, where several cigarettes are smoked over the day and steady-state blood nicotine levels may be reached (Russell et al. 1976; Russell and Feyerabend 1978). Studies where subjects abstain from tobacco for several hours and are then given an acute dose of nicotine may give a good approximation of the effects of the "first cigarette of the day", but it is difficult to extrapolate the results to any effects which may be found after repeated nicotine doses, i.e. the majority of the smoker's day.

Research into the effects of steady-state nicotine levels has shown that when smokers are permitted to smoke ad libitum, smoking does not facilitate performance in any absolute sense but maintains it at a level comparable to that found in non-smokers, although there is evidence to suggest that normal smoking may help to protect performance against fatigue and circadian activity. Heimstra et al. (1967) observed that smokers who were allowed to smoke freely during testing performed equally well as non-smokers in a driving simulator and were able to maintain this level of performance over the 6-h duration of the test. Conversely, a lack of nicotine has been shown to disrupt performance significantly. Smokers who were not allowed to smoke during the Heimstra study performed significantly worse than the other two groups.

Similar results with reaction time and/or vigilance measures have been recorded by Myrsten et al. (1971),

Frankenhauser et al. (1971) and Hartley (1973). More recent deprivation studies support these findings. Both Keenan et al. (1989) and Snyder and Henningfield (1989) have observed a deterioration of performance among smokers after short-term tobacco deprivation (24 or 12 h, respectively) compared to a non-deprived baseline score.

The most pertinent studies are those which have aimed to look at the effects of acute or repeated doses of nicotine on performance which can be regarded as being free of major deprivation effects and may, a priori, be considered "normal" at baseline or under the placebo treatment. For smokers this would mean raising blood nicotine concentrations over and above preferred, self-administered levels. Morgan and Pickens (1982) showed that high nicotine yield cigarettes led to improved reaction times compared to those obtained when subjects smoked their normal brand of cigarette, although this may have been due to the novelty of the research cigarette rather than the effects of the extra nicotine.

A more controlled approach, used in the first experiment reported here, is to allow smokers to smoke normally up to the start of a test session and then to administer an acute dose of nicotine or placebo gum double-blind. This would enable a valid comparison to be made between the nicotine condition and non-deprived placebo condition in the first instance and also to monitor possible effects of nicotine deprivation across the remainder of the experimental session in both drug and placebo groups.

Experiment 1

Materials and methods

Subjects. Six female smokers were studied. All had smoked for a minimum of 5 years immediately prior to the start of the study. The subjects were in good health and underwent a full medical examination before they were accepted as volunteers. The subjects were paid expenses.

Medication. Three doses (0 mg, 2 mg and 4 mg) of nicotine polacrilex gum (Nicorette) were used. One drop of red pepper (Tabasco) sauce was added to the gum to disguise the presence of nicotine. Subjects were required to chew the gum slowly and steadily for 20 min. Benowitz et al. (1987) estimate systemic doses of between 0.38 mg and 1.40 mg (2 mg gum) and 0.85 mg and 1.92 mg (4 mg gum) based on this procedure.

Blood analysis. To check that subjects had complied with treatment demands, an objective measure of systemic nicotine was provided by serum analysis of 10 ml blood samples taken immediately after subjects had finished chewing the gum.

Critical flicker fusion threshold (CFFT). CFFT has been used as a means of measuring the ability to distinguish discrete sensory data and is taken as an index of overall central nervous system activity (Hindmarch 1982). The subject is required to discriminate flicker fusion in a set of four light emitting diodes held in foveal fixation at 1 m. Individual thresholds are determined by the psychophysical method of limits on three ascending and three descending scales. Larson et al. (1950) studied the effects of smoking on the CFFT of both deprived and non-deprived smokers. The first cigarette of the day, taken at any time of the day by subjects who had abstained overnight, led to a temporary lowering of the threshold. No effect, however, was found when subjects were allowed to smoke normally before testing.

Choice reaction time (CRT). CRT (Frewer and Hindmarch 1988) is used as a measure of sensori-motor performance. The subject is required to extinguish one of six red lights illuminated at random by touching the appropriate response button. Recognition (time required to see the light and to remove the finger from its start position) and motor (time taken to reach the correct response button) components of the total reaction time may be obtained by subtraction. Total reaction time was recorded as the mean latency for 20 stimulus presentations. Myrsten et al. (1971) found that smokers who were allowed to smoke before each test period showed significantly reduced response times in a choice reaction time task compared to when the smokers performed the task without access to cigarettes. There was, however, no evidence to suggest that this was an absolute improvement since the experiment did not include a non-deprived placebo control group.

Tracking. In this task subjects are required to use a joystick to keep a cursor in alignment with a moving target while simultaneously responding to visual stimuli presented at random intervals in the peripheral field of vision. Two performance measures are recorded; tracking accuracy measured as the root-mean squared deviation of movements of the subject controlled cursor from the target track and the mean reaction time to the peripheral stimuli (Hindmarch et al. 1983). This test bears similarities to that used by Tarriere and Hartemann (1964). They observed that non-smokers and smokers who were allowed to smoke normally performed a sustained 2.5-h tracking and peripheral vision task equally well, but smokers who were not allowed to smoke performed significantly worse than both other groups.

Memory scanning. High speed scanning and retrieval from short term memory were assessed using a technique based upon the reaction time method pioneered by Sternberg (1966, 1975). The subject is required to judge whether a test digit is contained within a short memorised sequence of 4 digits which were presented sequentially for 1.2 s each. The test digit appeared 1 s later and the time taken for the subject to react recorded. Twenty-four such presentations were made at each assessment. The mean reaction time for correct responses was used in the subsequent analysis. It has been suggested that the cholinergic system may be involved in certain aspects of human memory (Squire and Davies 1981) and that nicotine may impinge upon this activity. Mangan and Golding (1983) found superior recall, compared to non-smokers, of paired associates after 1 month in smokers who had been minimally deprived (1 h) prior to smoking in the learning session. Similarly, Peters and McGee (1982) produced evidence for state-dependent learning with nicotine among deprived smokers, although Warburton et al. (1986), using a similar procedure, were unable to identify which of the many processes involved in memory were responsible for this effect.

Apparatus. Measures of CFFT and CRT were made using the Leeds Psychomotor Tester. The tracking and memory scanning tasks were presented and responses recorded on a BBC model B microcomputer. All tests were conducted in laboratory rooms where temperature, noise and illumination levels remained constant.

Procedure. Each subject attended the laboratory for seven sessions, one session per day. All sessions lasted approximately 5 h. Smokers were permitted to smoke freely up to the start of testing (10 a.m.) but were required to abstain until all tests were completed for that test day (3 p.m.). Consumption of alcohol- or caffeine-containing beverages was not permitted throughout the study. The first session was a practice session to familiarise subjects with the tasks