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Improvements in performance without nicotine withdrawal

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Abstract. Two tests were made of the withdrawal-relief explanation of the improvements in performance obtained with smoking. Study 1 examined the extent to which abstinence from smoking produced poorer performance in smokers in comparison with non-smokers. No evidence was obtained of differences in performance in smokers who were deprived of cigarettes for 10 h and non-smokers. Study 2 tested smokers with a standard cigarette or sham smoking after one hour and 12 h of deprivation. There was no difference in performance for the two deprivation intervals either in the sham smoking condition, or after smoking the lit cigarette. This study gave no evidence for withdrawal-relief being an explanation of the improvements in performance obtained with smoking.

Key words: Nicotine – Withdrawal – Performance

One of the most commonly given reasons for smoking is that it helps concentration. In laboratory studies, smoking prevented the decrement found in visual vigilance (Wesnes and Warburton 1978, 1983, 1984a,b) and auditory vigilance (Wesnes and Warburton 1978; Mangan 1982). In a typical study, smokers deprived for 10 h performed the task for 10 min as baseline, then had a 10-min break followed by 20 min of the task. Both speed and accuracy of performance were increased above baseline levels when a cigarette was smoked in the interval. Performance showed a marked decrement not only in the not-smoking condition but also with a nicotine-free cigarette; thus, it is likely that nicotine is the constituent of cigarette smoke causing performance improvements (Wesnes and Warburton 1983, 1984a). Improvements were also obtained with nicotine tablets (Wesnes et al. 1983; Wesnes and Warburton 1984b). More recently, there were puff-by-puff improvements in sustained attention when smokers took puffs from cigarettes during pauses in the task (Revell 1988).

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A common criticism of these studies was that the subjects in the study were deprived of nicotine for 10–12 h prior to testing. Thus, it is argued that the baseline data reflect performance under conditions of nicotine withdrawal and that the improvements in performance were due to withdrawal-relief and not due to an absolute enhancement of performance with nicotine (Snyder et al. 1989; West 1993).

In the present paper, we present the results of two studies which were designed to examine the effects on performance of nicotine abstinence in smokers compared with that of non-smokers and to test the effects of smoking after minimum deprivation, i.e. at a time before any evidence of "nicotine withdrawal" had been reported.

Experiment 1

The first study tested the hypothesis that deprived smokers go into "performance withdrawal" and that smoking only restores their performance to "normal" levels, i.e. that of non-smokers, withdrawal-relief.

Materials and methods

Subjects. Two hundred male subjects completed the study, 100 non-smokers and 100 smokers. All were students aged between 18 and 21 years (mean age 19 years). All the smokers used 15 or more non-low tar cigarettes per day. The machine-estimated yields of their usual brands ranged from 12 to 18 mg tar and 1.2 to 1.5 mg nicotine. Prior to testing the smokers were deprived of cigarettes for 10 h overnight as in the studies of Wesnes and Warburton (1978, 1983, 1984a). The study was "not disallowed" by the University Ethics Committee. Informed consent to participate was obtained prior to admission to the study.

Procedure. A version of the Rapid Visual Information-Processing (RVIP) Task was employed. Single digits between 1 and 8 were presented on a monitor at a rate of 100 per min. The same number never occurred twice in succession and within this sequence there were "targets" of three odd or three even numbers. The targets were programmed to occur eight times in each minute of the task, with four odd targets and four even targets per minute appearing in a random order and at random times within the minute. The target sequences were separated by a minimum of two digits.

The subjects were required to press a response button every time they saw a target sequence. Three measures of performance were recorded: the number of correct detections, reaction times and the number of commission errors. A response was recorded as a correct detection if it fell within 1200 ms of the onset of the third digit of a target sequence.

Design. Two training sessions were given to establish a stable level of performance. Subjects were tested for 10 min, between 8 a.m. and 11 a.m. Subjects attended the experimental sessions at the same time each morning. Subjects were required to abstain from smoking for 10 h (if smokers), from caffeine from the night before and from alcohol for 24 h before. End-tidal carbon monoxide was measured before each session to check abstinence from smoking and a cut-off point of two percent was applied. There were no violations of the abstinence restrictions.

Results

Correct detections. The mean correct detection probability for non-smokers was 0.84 versus 0.86 for smokers. An independent-sample t test revealed no significant differences ($t = 0.2464$; $P>0.58$, with $df = 198$).

Reaction time. The mean reaction times for the task were 469 ms (non-smokers) and 473 ms (smokers). An independent-sample t test revealed no significant differences ($t = 0.2355$; $P>0.40$, with $df = 198$).

Commission errors. The mean number of commission errors for the task were 0.69 (non-smokers) and 0.67 (smokers). An independent-sample t test revealed there were no significant differences ($t = 0.2653$; $P>0.30$, $df = 198$).

Discussion

It is clear that there were no differences between smokers and non-smokers on the three measures in the 10 min RVIP Task. These findings are consistent with a much smaller study of smoking during an 80-min, visual vigilance task (Wesnes and Warburton 1978), in which a comparison of 12 deprived smokers and 12 non-smokers revealed no significant difference between deprived smokers and non-smokers in their vigilance decrement. In contrast, smoking maintained the performance of smokers.

Experiment 2

The "nicotine withdrawal" syndrome of changes in performance and mood is said to be detectable after 2 or 3 h of abstinence in some smokers (American Psychiatric Association 1987). Consequently, abstinence for 3 h or less has been defined as minimal deprivation (Warburton 1990).

The second study was designed to compare the performance of smokers who were deprived for 10 h or more with 1 h deprived smokers, i.e. minimally deprived. Zero deprivation was not considered, because of the possible nauseating effects of two cigarettes in succession.

Materials and methods

Subjects. Twenty subjects completed the study, ten male and ten female. All were students aged between 18 and 21 years. All were smokers of 15 or more non-low tar cigarettes per day. The machine-estimated yields of their usual brands ranged from 12 to 18 mg total particulate matter and from 1.2 to 1.5 mg nicotine. The subjects were screened for colour blindness.

Cigarettes. A conventionally constructed, experimental cigarette was used in the present study. It had a machine-smoked yield of 1.5 mg nicotine and 14.2 mg total particulate matter. This cigarette was selected as representing the nicotine yields normally encountered by smokers of non-low tar products.

Procedure. The task was adapted from the RVIP task which was employed in experiment 1. As before, measures of both the speed and the accuracy of detection of target sequences of three odd or three even digits, but adaptation was necessary in order to enable performance to be measured while they were smoking cigarettes (Revell 1988).

After 5 min performance on the task without smoking, the numbers changed from white to red for 16 numbers (9.6 s) as a signal for the subject to light and puff from the cigarette. At the beginning of the next 8 min, i.e. minutes 7–14, 12 numbers appeared in green, over a period of 7.2 s, to signal the subject to take one puff from the cigarette. At the beginning of minute 15, 16 numbers appeared in yellow for 9.6 s, during which time the subject took the last puff and extinguished the cigarette.

The subjects were trained to perform the task continuously throughout this 10-min smoking period, regardless of the colour of the numbers. Since the act of smoking could have distracted the subjects from the task, performance during the smoking periods (when the digits appeared in colour) was not included in the analyses. The task was constrained such that there were always eight targets during the remaining 50.4 s following lighting up. Targets appeared at random during the smoking periods, in order to maintain the subjects' attention, particularly in the not-smoking condition when they only had the task to deal with. The task continued without colour changes for the last 5 min of the session.

Design. Three training sessions were given to establish a stable level of performance in the subjects. The first and third were smoking sessions and the second was a sham-smoking practice in which the subjects puffed on an unlit cigarette. There were four experimental sessions representing a complete factorial crossing of smoking/sham smoking with 1 h deprived and 12 h deprivation. Session order was counterbalanced across subjects. Sham smoking was used as a control for the tactile component of smoking.

All subjects attended the experimental sessions at the same time each morning. They were all required to abstain from alcohol and caffeine from the night before. End-tidal carbon monoxide was measured before each session to check for compliance with 12 h abstinence and 1 h deprivation. For overnight abstinence, a 2% cutpoint was applied. There were no violations of the 12 h abstinence restrictions. One subject, who had a low value in the 1 h condition, smoked his own cigarette in the laboratory and returned 1 h later for testing.

Results

The data were analyzed minute-by-minute, i.e. puff-by-puff using a factorial analysis of variance for min 6–15. The *P*-values were corrected for the possibility that the correlations among pairs of the repeated variable were not constant, using the Greenhouse-Geisser procedure (Greenhouse and Geisser 1959).

Correct detections. The mean number of correct detections were 5.24 for the sham smoking condition with 1 h of deprivation and 5.36 with 12 h of deprivation. After smoking a lit cigarette, the mean number of correct detections were 6.34 for 1 h of deprivation and 6.12 after 12 h of deprivation. A two-way, factorial analysis of variance revealed a significant effect of smoking ($F = 14.96$; $P<0.0001$ with $df = 1,19$), but no difference in the deprivation periods ($F = 3.26$; $P>0.023$, with $df = 1,19$).

Interactions. Figure 1 shows that more correct detections were made when smoking either cigarette than with sham-smoking from min 8, the third puff, through to the end of the session. Planned comparisons confirmed this observation with the difference between cigarette and sham-smoking being significant at every minute from min 9 onwards for the 1-h deprivation, with the exception of min 16 and for min 11, 14, 17, 18 and 20 for 12-h deprivation.

Reaction times. The mean reaction times were 442 ms for the sham smoking condition with one hour of deprivation and 452 ms with 12 h of deprivation. After smoking, the reaction times were 424 ms for 1 h of deprivation and 422 ms with 12 h of deprivation. A two-way, factorial analysis of variance revealed a significant effect of smoking ($F = 17.88$; $P<0.0001$ with $df = 1,19$), but no difference in the deprivation periods ($F = 0.51$; $P>0.05$ with $df = 1,19$).

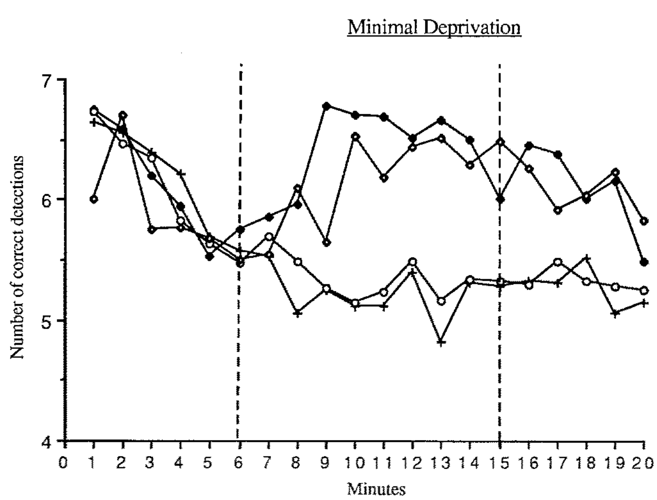

Fig. 1. The number of correct detections made minute by minute. Smoking commenced at min 6 with a puff every minute until min 15. The *upper* two plots shows the effect of a lit cigarette after either 1- or 12-h deprivation versus sham smoking after either 1- or 12-h deprivation.

Reaction times increased from minutes 1 to 3 and then stabilised. They then varied between 410 and 460 ms in the sham-smoking controls. Reaction times in the two smoking conditions improved, i.e. shortened, from around min 5 to min 9 and then varied between about 390 and 440 ms, i.e. were quicker in the smoking conditions than in the control conditions from min 8 or 9 onwards. Analyses at each minute confirmed the interpretation of the data, with reaction times being significantly shorter in the smoking conditions from min 9 onwards with the exception of minutes 13 and 16 with 1 h of deprivation, and min 11, 14 and 16 with 12 h deprivation.

Commission errors. The average number of commission errors were less than one per condition and those errors were not analyzed.

Discussion

In this study, improvements in performance with cigarette smoking were demonstrated from puff 1 to puff 2, both in terms of correct detections and reaction times. After two or three puffs, performance in terms of both measures is raised above the sham-smoking level and maintained through to beyond the end of smoking. The improvement of performance with smoking does not increase in proportion to plasma nicotine levels, which reach a maximum at the end of smoking. From this experiment and that of Revell (1988), it seems that as little as 15–20 ng per ml are required for maximum improvements in performance both in terms of the speed and accuracy of performance.

This improvement cannot be due to relief from withdrawal, because there were no significant differences between one hour deprived (minimal deprivation) and 12 h deprived, in terms of correct detections and reaction times in the sham smoking condition, nor while smoking a cigarette.

This finding is in accord with a sizeable body of evidence involving testing nicotine or smoking with non-deprived smokers. Smoking by non-deprived smokers increased reaction times in the "odd man out" task (Frearson et al. 1988) and the continuous performance task (Pritchard et al. 1992), as well as improved choice reaction time (Frearson et al. 1988; Landers et al. 1990). Nicotine gum also increased reaction times in non-deprived smokers (Hindmarch et al. 1990; Sherwood et al. 1990a, 1991b; Kerr et al. 1991) as well as improve tracking in a simulated driving task (Hindmarch et al. 1990; Sherwood et al. 1992; Kerr et al. 1991). Sherwood et al. (1990b) and Kerr et al. (1991) also reported that nicotine gum speeded memory scanning in the Sternberg paradigm in non-deprived smokers.

Previous results with non-smokers given nicotine tablets (Wesnes and Warburton 1984b) indicate there can be an improvement in performance caused by nicotine, without nicotine withdrawal. In a test of the effects of nicotine on Stroop performance of both 10 h deprived smokers and non-smokers, no differences were found between the baselines of the deprived smokers and non-smokers or in the amount of improvement produced by nicotine (Wesnes and Warburton 1978).

In addition, no difference was found in the effects of nicotine in regular and occasional smokers on a vigilance task (Wesnes, and Warburton 1978; Wesnes et al. 1983) and memory scanning in the Sternberg paradigm (West and Hack 1991). Similarly, subcutaneous nicotine produced identical attentional improvements in both smoking and non-smoking Alzheimer patients (Jones et al. 1992).

More compelling evidence against the nicotine withdrawal-relief hypothesis comes from the results of animal studies with nicotine, reviewed by Clarke (1987) and Levin (1992). It has been found that attentional performance (e.g. Nelsen and Goldstein 1972), discrimination performance (e.g. Geller et al. 1971) and memory are improved by nicotine (e.g. Bättig 1970). Obviously, animals have had little exposure to nicotine and the improvements in their performance could not have been due to the reversal of nicotine withdrawal.

References

Bättig K (1970) The effect of pre- and post-trial application of nicotine on the 12 problems of the Hebb-Williams test in the rat. Psychopharmacologia 18: 68–76

Clarke PBS (1987) Nicotine and smoking: a perspective from animal studies. Psychopharmacology 92: 135–143

Frearson W, Barrett P, Eysenck HJ (1988) Evidence of more rapid stimulus evaluation following cigarette smoking. Addict Behav 10: 113–126

Geller I, Hartmann R, Blum, K (1971) Effects of nicotine, nicotine monomethiodide, lobeline, chlordiazepoxide, meprobamate and caffeine on a discrimination task in laboratory rats. Psychopharmacologia 20: 355–365

Greenhouse SW, Geisser S (1959) On methods of analysing profile data. Psychometrika 24: 95–112

Hindmarch I, Kerr JS, Sherwood N (1990) Effects of nicotine gum on psychomotor performance in smokers and non-smokers. Psychopharmacology 100: 535–541

Kerr JS, Sherwood N, Hindmarch I (1991) Separate and combined effects of the social drugs on psychomotor performance. Psychopharmacology 104: 113–119

Jones GMM, Sahakian BJ, Levy R, Warburton DM, Gray JA (1992) Effects of acute subcutaneous nicotine on attention, information processing and short-term memory in Alzheimer's disease. Psychopharmacology 108: 485–494

Landers DM, Lindholm E, Crews DJ, Koriath JJ (1990) Cigarette smoking and smokeless tobacco facilitate information processing and performance. Psychophysiology 27: S47

Levin ED (1992) Nicotinic systems and cognitive function. Psychopharmacology 108: 417–431

Nelsen JM, Goldstein L (1972) Improvement of performance on an attention task with chronic nicotine treatment in rats. Psychopharmacologia 26: 347–360

Pritchard WS, Robinson JH, Guy TD (1992) Enhancement of continuous performance task reaction time by smoking in non-deprived smokers. Psychopharmacology 108: 437–442

Revell AD (1988) Smoking and performance – a puff-by-puff analysis. Psychopharmacology 96: 563–565

Sherwood N, Kerr JS, Hindmarch I (1990a) Effects of nicotine on short-term memory. In: Adlkofer F, Thurau K (eds) Effects of nicotine on biological systems, Birkhauser, Basel, pp 531–535

Sherwood N, Kerr JS Hindmarch I (1990b) No differences in the psychomotor response of heavy, light and non-smokers to the acute administration of nicotine. Med Sci Res 18: 839-840

Sherwood N, Kerr JS, Hindmarch I (1992) Psychomotor performance in smokers following single and repeated doses of nicotine gum, Psychopharmacology 108: 432–436

Wesnes K, Warburton DM (1978) The effect of cigarette smoking and nicotine tablets upon human attention. In: Thornton RE (ed) Smoking behaviour: physiological and psychological influences. Churchill-Livingstone, London, pp 131–147

Wesnes K, Warburton DM, Matz B (1983) The effects of nicotine on stimulus sensitivity and response bias in a visual vigilance task. Neuropsychobiology 9: 41–44

Wesnes K, Warburton DM (1983) The effects of smoking on rapid information processing performance. Neuropsychobiology 9: 223–229

Wesnes K, Warburton DM (1984a) Effects of scopolamine and nicotine on human rapid information processing performance. Psychopharmacology 82: 147–150

Wesnes K, Warburton, DM (1984b) The effects of cigarettes of varying yield on rapid information processing performance. Psychopharmacology 82: 338–342

West R (1993) Beneficial effect of nicotine: fact or fiction? (Editorial). Addiction 88: 589–590

West R, Hack S (1991) Effects of cigarettes on memory search and subjective ratings. Pharmacol Biochem Behav 38: 281–286