Psychopharmacology (1992) 107:442–446

Psychopharmacology
© Springer-Verlag 1992

Stress and arousal in sedative and stimulant cigarette smokers

S.T. O'Neill and A.C. Parrott

Department of Psychology, Polytechnic of East London, London E15 4LZ, UK

Received August 1, 1991 / Final version September 17, 1991

Abstract. Self-reported feelings of stress and arousal were assessed in 18 sedative and 9 stimulant smokers, over a typical day of smoking. Prior to each cigarette, self-ratings of stress and arousal were recorded on a brief adjective check list. These self-ratings were then repeated following cigarette smoking. These diary data were split into four blocks to represent: first cigarette of the day, second quartile cigarette, third quartile cigarette, and last cigarette of the day. Analysis of variance revealed significant effects of smoking on both stress and arousal. Self-rated feelings of stress were significantly reduced following cigarette smoking ($P<0.002$); this was found with both subject groups and across all cigarette blocks. Cigarette smoking also led to increased feelings of arousal ($P<0.01$), although these changes in arousal differed between subject groups (drug × type-of-smoker interaction: $P<0.03$). Stimulant smokers showed higher levels of arousal after smoking, across all four cigarette blocks. Sedative smokers showed a slight increase in arousal only after their first cigarette. These findings were not as predicted by the arousal modulation theory of cigarette smoking, which suggests that changes in stress and arousal are interdependent. Instead they show that smoking affects stress and arousal in quite different ways. Stress and arousal should therefore be recognised as independent dimensions within smoking/nicotine research.

Key words: Cigarette – Smoking – Nicotine – Smoking motive – Stress – Arousal – Arousal modulation theory

"The arousal modulation theory suggests that smoking is an activity which has the function of controlling arousal, i.e. the smoker smokes to increase arousal when bored or fatigued, and to reduce arousal when tense" (Mangan and Golding 1984, p 82). The arousal modulation theory represents an attempt to integrate some apparently contradictory psychological effects of smoking, namely that it can lead either to increased cortical arousal, or to reduced stress and emotional calming (Ashton and Golding 1989; Gale and Ney 1989).

There is an extensive literature showing that cigarette smoking can lead to psychophysiological changes indicative of heightened arousal (Church 1989). The EEG desynchronisation generally noted after cigarette smoking, an index of increased cortical arousal, is almost identical to the desynchronisation which follows stimulation of the Ascending Reticular Activating System (ARAS). In contrast, smoking deprivation leads to EEG changes showing reduced cortical arousal (Knott and Venables 1977). Sympathomimetic changes indicative of heightened arousal include: increased heart rate, vasoconstriction, raised blood pressure, and increased serum epinephrine (Herxheimer et al. 1967; Domino 1973; Hill and Wynder 1974). Cigarette smoking and other forms of nicotine administration, also lead to faster information processing and improved vigilance (Wesnes and Warburton 1983; Wesnes and Parrott 1991). In questionnaire studies concerned with smoking motives, many subjects report smoking for stimulation. These "stimulant" smokers tend to light up their cigarettes when they feel fatigued or bored (Frith 1971; Russell et al. 1974).

Cigarette smoking can also lead to reduced feelings of stress. In a recent review, Gilbert and Wesler (1989, p 71) concluded that: "Nicotine reduces anxiety and negative affect in chronic smokers". Heimstra (1973) monitored smokers when they were viewing a stressful film; feelings of anxiety were significantly lower when they were allowed to smoke, than when they were not allowed to smoke. When smokers give up smoking, feelings of irritability, tension, and stress, are often experienced. In a double-blind smoking cessation study (Hughes et al. 1984), subjects given nicotine chewing gum noted significantly lower feelings of tension and anger than subjects given placebo gum during the cessation period. In Russell et al'.s (1974) smoking motive study, one of the primary factors

Offprint requests to: S.T. O'Neill, Neurology Research Department, Oldchurch Hospital, Romford, Essex RM7 OBE, UK

was for "sedative" smoking, i.e. smoking for stress reduction. Around 80% of smokers report using cigarettes when they feel stressed or worried (Russell et al. 1974; Warburton 1988).

Smoking can therefore lead to increased alertness, and to decreased feelings of stress. The arousal modulation theory suggests that these psychoactive changes are inter-dependent, with cigarettes sometimes being used to increase alertness, while at other times used to reduce stress and arousal. Thus stimulant smokers tend to report the former, while sedative smokers generally experience the latter. Surawy and Cox (1987, p 33) summarised this: "Sedative smokers, who smoke under conditions of high arousal in order to decrease arousal; and stimulant smokers, who prefer to smoke under conditions of low arousal in order to increase arousal". These changes have also been explained in terms of a biphasic response to nicotine. Low doses of nicotine (e.g. shallow smoke inhalation) are said to be stimulatory, while higher doses (e.g. deep smoke inhalation) are more sedative. For a more comprehensive description of the empirical evidence behind the arousal modulation theory: see Ashton and Golding (1989), Gilbert and Wesler (1989) or Mangan and Golding (1984).

There are, however, problems with this theory. Smokers do not typically report smoking either for stimulation or relaxation, but for both. The stimulant and sedative factors of the SMQ are positively correlated, with subjects who report smoking for stimulation also stating that they smoke for sedation (Russell et al. 1974). During smoking deprivation, simultaneous increases in boredom (reduced arousal) and irritability (increased stress) have been noted (Frankenhaeuser et al. 1971; Heimstra 1973), against predictions from the arousal modulation theory. The model also has empirically unsupported implications for performance change. While performance improvements should occur when smoking for stimulation, performance *decrements* should occur when smoking for relaxation. However, the main difficulty with the theory is the absence of empirical evidence concerning the hypothesised simultaneous changes in arousal and stress (e.g. Surawy and Cox 1987).

An alternative to the arousal modulation model suggests that while increased arousal and reduced stress occur, these psychoactive changes should be seen as being independent. Thus arousal modulation is separate from stress modulation. The present study was undertaken to compare the arousal modulation model with this alternative viewpoint, by empirically assessing mood state changes while smoking. As Surawy and Cox (1987), have stated: "The role played by internal (mood)... factors as instigators of smoking remains largely untested". Self reported feelings of arousal and stress were therefore monitored over a day of smoking, using a diary method derived from Surawy and Cox (1987). Subjects completed the feeling state scales before and after cigarette smoking. According to the arousal modulation theory, changes in stress and arousal should be closely related and inter-dependent. With the alternative model being proposed here, the patterns of drug induced change to stress and arousal, will be separate and independent.

Materials and methods

Subjects

Sixty subjects volunteered to take part in the study. Of the 47 returned diaries, 2 were omitted from further analysis due to incomplete data. The remaining 45 subjects were devided into two groups using the following criteria.

Sedative smokers. SMQ sedative score of 6+, and SMQ stimulant score of 5−.

Stimulant smokers. SMQ stimulant score of 6+, and SMQ sedative score of 5− (Table 1).

The sedative group comprised 14 females and 4 males in the age range 19–48 years (mean = 29). The stimulant group comprised 4 females and 5 males in the age range 27–37 years (mean = 30). Cigarette consumption on the assessment days was similar for both groups (13.8 and 13.7 cigarettes/day, respectively). Subjects included professionals, office staff, and manual workers, recruited at a London dental surgery. None was paid for participation.

Assessment measures

The Smoking Motive Questionnaire (West and Russell 1985; based upon Russell et al. 1974) was completed by all subjects. The SMQ comprises 24 questions, loading on 7 primary factors: psychological image, hand/mouth activity, indulgent, stimulant, sedative, dependent, and automatic.

The mood state questionnaire was derived from the Short Adjective Check List (SACL; Mackay et al. 1978). Two questions were taken from the SACL stress factor (questions 1, 2), while two were taken from the SACL arousal factor (questions 3, 4). These four questions were chosen for their high loadings on the respective factors. The biploar scales were as follows:

TENSE– strongly, slightly, neither, slightly, strongly –RELAXED
NERVOUS– strongly, slightly, neither, slightly, strongly –CALM
ENERGETIC– strongly, slightly, neither, slightly, strongly –TIRED
ALERT– strongly, slightly, neither, slightly, strongly –DROWSY

The tenseness question was scored as follows: strongly tense 50, slightly tense 40, neither 30, slightly relaxed 20, strongly relaxed 10. The other three scales were scored similarly. The overall stress score was obtained by combining the tense-relaxed and nervous-calm scores. The overall arousal score was similarly obtained by combining the energetic-tired and alert-drowsy scores. Thus the stress and arousal scores each ranged from 100 to 20.

Procedure

Volunteers agreed to complete the mood state questionnaire, before each cigarette, and after each cigarette, over 1 normal day of smoking, when they would not be consuming alcohol. Subjects

Table 1. Smoking motive questionnaire subscale scores, and cigarette consumption (mean ± standard deviation), for the two smoker groups

Subject group	*N*	Smoking motive questionnaire		
		Cigarette consumption	Sedative subscale	Stimulant subscale
Stimulant smokers	9	13.8 ± 4.7	4.3 ± 0.8	7.9 ± 1.0
Sedative smokers	18	13.7 ± 4.9	7.8 ± 1.1	3.0 ± 1.6

Table 2. ANOVA F values and probability levels (2-tail) for the two mood state variables

	Stress		Arousal	
	F value	P level	F value	P level
Drug condition (pre/post-cigarette)	9.99	<0.002	6.23	<0.01
Time (cigarette block: 1, 2, 3, 4)	23.89	<0.001	40.00	<0.001
Type of smoker (sedative/stimulant)	0.94	ns	0.13	ns
Drug × type	1.46	ns	4.67	<0.03
time × type	3.7	<0.01	2.00	ns
Drug × time	0.13	ns	2.96	<0.03
Drug × time × type	0.14	ns	0.31	ns

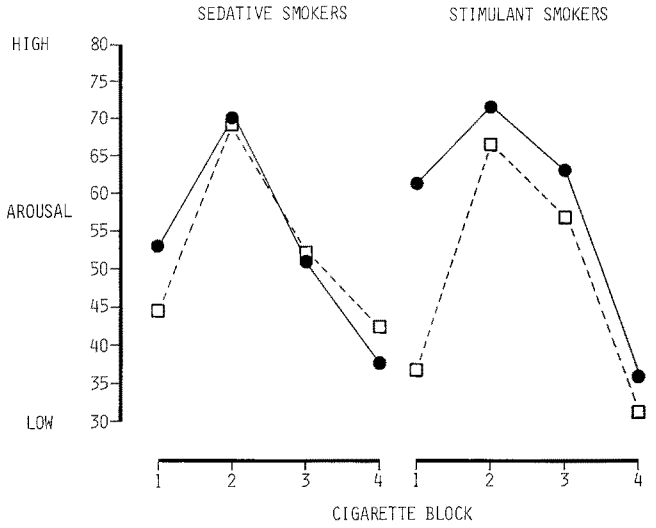

Fig. 1. Self-rated feelings of arousal in sedative and stimulant smokers, before (–□–) and after (–●–) cigarette smoking

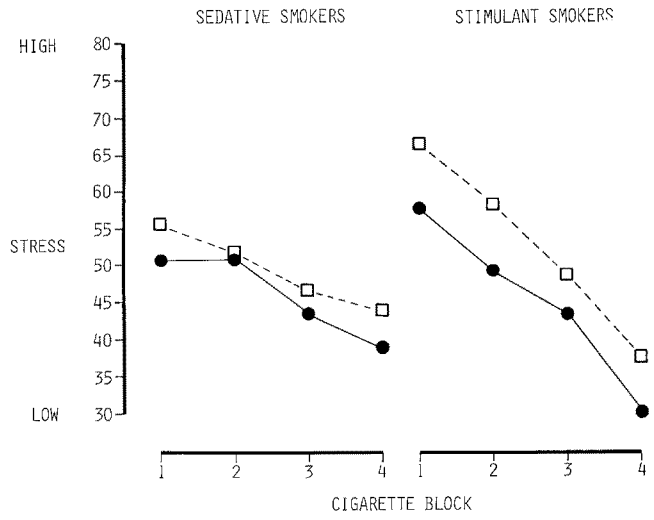

Fig. 2. Self-rated feelings of stress in sedative and stimulant smokers, before (–□–) and after (–●–) cigarette smoking

smoked their usual brand of cigarette and completed the diary during the course of their usual activities. Written instruction booklets were given out, while subjects were debriefed on completion.

The feeling state scores were split into four time blocks. The score for the first cigarette of the day represented block 1, while the last cigarette of the day represented block 4. The remaining cigarettes were then divided into two groups by median-split, with the means for these two groups representing blocks 2 and 3. Thus the data comprised pre-cigarette and post-cigarette scores, on stress and arousal, for each of four cigarette time blocks.

Design

The design comprised a split-plot ANOVA, with one between-subjects factor: type of smoker (sedative/stimulant), and two within-subjects factors: drug (pre-and post-cigarette), and time (four cigarette blocks).

Results

Group mean arousal and stress scores are shown in Figs. 1 and 2, while statistical significance levels are presented in Table 2. With arousal, significant ANOVA main effects were found for time ($P<0.001$), and drug ($P<0.01$). Self-rated feelings of arousal therefore differed across the cigarette blocks, and were sigificantly higher following cigarette smoking. The significant drug × type interaction ($P<0.03$) showed that smoking affected the arousal of the two subject groups in different ways (Fig. 1). The significant drug × time interaction ($P<0.03$) indicated that the drug effect differed across the four time blocks. All other ANOVA effects were non-significant (Table 2).

With self-ratings of stress, significant ANOVA main effects were found with time ($P=0.001$), and drug ($P<0.002$). Self-rated feelings of stress therefore differed over the four time blocks, while feelings of stress were also higher pre-cigarette then post-cigarette (Fig. 2). The significant time × type interaction ($P<0.01$) showed that the pattern of stress across the day differed between the two subject groups (Fig. 2). All other ANOVA effects were non-significant (Table 2).

Discussion

Cigarette smoking significantly affected feelings of both stress and arousal. However, these changes varied in complex ways, being influenced by type of smoker, and time block over the day. Self-rated levels of arousal will be examined first. They were significantly affected by: drug, time, drug × type of smoker, and drug × time (Table 2). Feelings of arousal were significantly higher following cigarette smoking. However, the significant drug × type interaction showed that this drug effect dif-

fered between subject groups. Stimulant smokers showed consistently higher arousal after smoking, across all four cigarette blocks (Fig. 1). This increase was particularly marked following the first cigarette of the day, when pre-cigarette arousal was low. Sedative smokers also showed an increased in arousal following the first cigarette of the day, while a small reduction in arousal was evident following the last cigarette block (Fig. 1). The significant drug × time interaction reflected the less pronounced drug-induced changes in arousal, as the day progressed (Fig. 1; Table 2).

These findings with stimulant smokers provide support for Frith (1971), who noted that stimulant smokers smoke under conditions of low arousal in order to increase arousal. Golding and Mangan (1982) also found that smoking led to an increase in EEG indices of arousal, during a boring low-interest situation. The significant drug × type interaction also agreed with previous studies (Frith 1971; Russell et al. 1974; Surawy and Cox 1987), which showed differences between sedative and stimulant smokers in their feelings of arousal while smoking. Thus sedative smokers generally reported little change in arousal following smoking, although they did note increased arousal following their first cigarette of the day (Fig. 1).

Self-reported feelings of stress were significantly affected by cigarette smoking (Table 2). Reduced feelings of nervousness and tenseness were found with both subject groups, and across all cigarette blocks (Fig. 2). This decrease in nervousness and tenseness following cigarette smoking is in accord with previous research, since many studies have shown that smoking can lead to reduced feelings of stress (McKennell 1970; Frith 1971; Ikard and Tomkins 1973; Kleinke et al. 1983; Surawy and Cox 1987; Warburton 1988; Gilbert and Wesler 1989). It should, however, be emphasised that the lower feelings of stress post-cigarette, mean that there were significantly higher feelings of stress prior to each cigarette. These data therefore describe a pattern of constantly vacillating feelings of stress: reduced after a cigarette, but heightened before the next is lit. The literature on mood and smoking tends to concentrate upon the reduction in stress following cigarette smoking (e.g. Fig. 2*b* in Ashton and Golding 1989; Gilbert and Wesler 1989). It should also point out the increased stress that smokers feel before their next cigarette is lit (due possibly to acute withdrawal).

The altered levels of arousal over cigarette blocks was consistent with research on circadian rhythms (Fig. 1). Self-rated arousal levels typically increase during the morning, remain at a maximum until late afternoon, then reduce over the evening (Folkard et al. 1978). The present data were, however, defined by cigarette number, rather than time of day, so caution must be exercised in extrapolating these findings to the circadian literature. There was an intriguing time effect with self-reported feelings of stress, which reduced significantly as the day progressed (Fig. 2). The significant time × type interaction also showed that stimulant smokers demonstrated a comparatively steeper reduction in stress over the day (Fig. 2). This circadian decrease in stress was independent of drug status, since it was evident both before and after each cigarette (Fig. 2). However, it may be that it reflects the accumulation of nicotine over the day. This hypothesis is currently being investigated, in a study where circadian patterns of self-reported stress are being monitored in smokers and non-smokers. It is hypothesised that stress levels with non-smokers will remain constant over time, while those for smokers will decrease.

The present study has shown that cigarette smoking can affect arousal and stress in independent ways. Stimulant smokers demonstrated increased arousal and reduced stress post-smoking throughout the day. Sedative smokers reported a consistent reduction in stress, while feelings of arousal were generally less affected. Arousal and stress did not co-vary in the way predicted by the arousal modulation theory. Altered feelings of stress and arousal seem therefore to be largely independent (Figs. 1, 2). These findings raise serious questions for the arousal modulation theory of smoking, which has been summarised in the following terms: "Smoking can be used either to arouse the individual or to sedate and tranquilize", also: "Smoking is arousing in some situations and for some people, and dearousing for others" (Gale and Ney 1989, p 7). See also: Mangan and Golding (1984, pp 82–84), or Ashton and Golding (1989, pp 38–43). One essential aspect of the arousal modulation theory is the equation of high stress with high arousal, and low tension/nervousness with low arousal. This was not, however, confirmed by the present findings (Figs. 1, 2; Table 2).

The present study provides empirical support for the alternative viewpoint: that stress and arousal are separate dimensions (Surawy and Cox 1987; Ashton and Golding 1989). This conclusion also equates with factor-analyses of mood state questionnaires, where arousal and stress emerge as orthogonal factors (Mackay et al. 1978). Ashton and Golding (1989) have also criticised the arousal modulation theory for being too simplistic, and failing to account for the many disparate psychological changes which occur during smoking. They recently wrote: "Nicotine and smoking affect simultaneously all the major functional systems governing behaviour – those for reward/punishment, for arousal, and for learning and memory" (Ashton and Golding 1989, p 42). Furthermore: "The motives discussed in the preceding pages operate together at all times in any smoker, although the weightings between different motivations may vary between and within individuals, over time, and in different circumstances" (p 43). The present findings confirm this viewpoint. They further suggest that arousal modulation should be seen as separate from stress modulation. Both occur, but in separate and largely independent ways.

Acknowledgements. The authors would like to thank Messrs. E.L. and A.G. Pigot for allowing the use of their dental surgery to recruit subjects. This study comprised part fulfillment for a BSc (Hons) Psychology degree by S.T. O'Neill.

References

Ashton H, Golding JF (1989). Smoking: motivation and models. In: Ney T, Gale A (eds) Smoking and human behaviour. Wiley, Chichester

Church RE (1989) Smoking and the human EEG. In: Ney T, Gale A (eds) Smoking and human behaviour. Wiley, Chichester

Domino EG (1973) Neuropsychopharmacology of nicotine and tobacco smoking. In: Dunn WL (ed) Smoking behaviour: motives and incentives. Winston, Washington DC

Frankenhaeuser M, Myrsten A, Post B, Johansson G (1971) Behavioural and physiological effects of cigarette smoking in a monotonous situation. Psychopharmacologia 22:1–7

Folkard S, Monk TH, Lobban MC (1978) Short and long term. adjustments of circadian rhythms in "permanent" night-nurses. Ergonomics 21:785–799

Frith CD (1971) Smoking behaviour and its relation to the smokers immediate experience. Br J Social Clin Psychol 10:73–78

Gale A, Ney T (1989) Introduction: the key questions about smoking behaviour. In: Ney T, Gale A (eds) Smoking and human behaviour. Wiley, Chichester

Gilbert DG, Wesler R (1989) Emotion, anxiety and smoking. In: Ney T, Gale A (eds) Smoking and human behaviour. Wiley, Chichester

Golding J, Mangan GL (1982) Arousing and de-arousing effects of cigarette smoking under conditions of stress and mild sensory isolation. Psychophysiology 19:449–456

Heimstra NW (1973) The effects of smoking on mood change. In: Dunn WL (ed) Smoking behaviour: motives and incentives. Winston, Washington, DC

Herxheimer A, Griffiths RL, Hamilton B, Wakefeild M (1967) Circulatory effects of nicotine aerosal inhalations and cigarette smoking in man. Lancet ii:754–755

Hill P, Wynder EL (1974) Smoking and cardiovascular disease: effect of nicotine on the serum epinephrine and corticoids. Am Heart J 87:491–496

Hughes JR, Hatsukami DK, Pickens RW, Krahn D, Malin S, Luknic A (1984) Effect of nicotine on the tobacco withdrawal syndrome. Psychopharmacology 83:82–87

Ikard FF, Tomkins S (1973) The experience of affect as a determinant of smoking behaviour: a series of validity studies. Abnorm Psychol 81:172–181

Kleinke CL, Staneski RA, Meeker FB (1983) Attribution for smoking behaviour: comparing smokers with nonsmokers and predicting cigarette consumption. J Res Personal 17:242–255

Knott VJ, Venables PH (1977) EEG alpha correlates of nonsmokers, smoking smokers, and smoking deprivation. Psychophysiology 14:150–156

Mackay CJ, Cox T, Burrows G, Lazzerini T (1978) An inventory for the measurement of self-reported stress and arousal. Br J Soc Clin Psychol 17:283–284

Mangan GL, Golding JF (1984) The psychopharmacology of smoking. Cambridge University Press, Cambridge

McKennel AC (1970) Smoking motivation factors. Br J Soc Clin Psychol 9:8–22

Russell MAH, Peto J, Patel VA (1974) The classification of smoking by a factorial structure of motives. J R Statist Soc 137:313–346

Surawy CJ, Cox T (1987) Smoking under natural conditions: a diary study. Personality and Individual Differences 8:33–41

Warburton DM (1988) The puzzle of nicotine use. In: Lader M (ed) The psychopharmacology of addiction. Oxford University Press, Oxford

Wesnes K, Parrott AC (1991) Smoking and human performance. In: Smith A, Jones D (eds) Factors affecting human performance, vol II. Academic Press, London

Wesnes K, Warburton DM (1983) Smoking, nicotine and human performance. Pharmacol Ther 21:189–208

West RJ, Russell MAH (1985) Pre-abstinence smoke intake and smoking motivation as predictors of severity of cigarette withdrawal symptoms. Psychopharmacology 87:334–336