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The effects of cigarette smoking on the response to stress in a driving simulator

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Summary

1. Some behavioural and physiological responses of cigarette smokers and non-smokers exposed to varying degrees of stress in a driving simulator were compared.

2. When the smokers were smoking a cigarette, some of their reaction times to light signals differed significantly from those of non-smokers, some being longer and some shorter. These differences disappeared when the smokers were not smoking.

3. Of the physiological measurements, only heart rate differed significantly between smokers and non-smokers, being higher at all levels of stress in the smokers. There were no significant differences in blood pressure, calf blood flow and respiration rate between smokers and non-smokers.

4. The results of the Cattell Sixteen Personality Factor Questionnaire showed that the smokers were significantly more extroverted and self-reliant than the non-smokers.

5. The results are discussed in relation to the pharmacology of cigarette smoking. It is concluded that the differences in reaction times and heart rates between smokers and non-smokers were a consequence of cigarette smoking.

Introduction

Smokers commonly state that the act of smoking enables them to deal more effectively with a stressful situation; this study sets out to compare some behavioural and physiological responses of cigarette smokers and non-smokers exposed to varying degrees of stress produced under controlled laboratory conditions. This was achieved by the use of a modified driving simulator as devised by Ashton, Savage, Thompson & Watson (1972) which permits human subjects to be exposed to reproducible and varying degrees of stress in a 'real life' situation created in the laboratory. Studies on the effects of smoking upon real life or analogous situations are few, although real or simulated driving tasks have been employed in testing the effects of a substantial number of other pharmacological agents on driving. The work of Heimstra, Bancroft & Dekock (1967) appears to be the only other in which the effect of smoking has been examined on a simulated driving task in which reaction time, vigilance and tracking were studied. These workers concluded that smoking did not 'tend to counteract or alleviate the effects

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of fatigue during sustained performance'. Thus, in common with most studies on driving performance (see Brown, 1967; Crawford, 1961), the major concern has been with the effects of fatigue and has largely neglected the possible effects of emotional stress which may well build up to a behavioural effect akin to that of fatigue. Consequently, the present study set out specifically to measure the effects of cigarette smoking on emotional and task stress rather than on fatigue.

Methods

Behavioural responses

A full description of the method, including the lay-out of the subject's room and the control room is published separately (Ashton *et al.*, 1972). Briefly, subjects carried out a simulated driving task in a Link Indoor Driver Trainer which had been modified so as to make it possible to measure complex motor-perceptual performance. A specially made film was projected onto a screen located on top of the car simulator and the subject was requested to 'drive' the simulator to the movements of the car in the film, using the steering wheel, brake and accelerator pedals and the traffic indicators. In addition, the subject was instructed to respond appropriately to five discrete signals in the form of coloured lights mounted on a panel above the dashboard. The lights were switched on singly and each one represented a specific command (i.e., brake, left or right steer and left or right traffic indicator). Whereas the command lights for the traffic indicator simply required the corresponding indicator to be switched on, the appearance of the brake light or one of the steering lights called for one of three possible degrees of response, namely light, medium or hard. In these instances, the only indication to the subject that the correct response had been carried out was the extinction of the appropriate light. If the subject over-responded, this was indicated by the reappearance of the particular light signal which after appropriate correction by the subject would become extinguished once again.

Inspection of the record obtained on an 8-channel Beckman 'Dynograph' recorder allowed the length of the reaction times to the light signals and also the number of corrections to be measured. The reaction times were measured as the time between the onset of the light signal and its extinction by the subject (=total reaction time).

For steering responses the total reaction time was further subdivided into response time (onset of signal to start of steering movement) and action time (start of steering movement to extinction of light by completion of correct response). It was also possible in the case of some signals to record anticipations. If the subject, acting on information obtained from the film, started to carry out the correct driving manoeuvre before the light signal appeared, his reaction time would be shorter than a previously measured 'minimum' reaction time (Ashton *et al.*, 1972). For steering responses, it was also possible to tell from the record if the steering wheel was already off the centre steer position at the time when the light signal came on. Short reaction times due to anticipations were *not* included in the mean reaction times of each subject. However, if an anticipation happened to be so far in advance of a signal that the correct manoeuvre had already been completed before the light signal came on, this would not be detected.

Three levels of stress or task difficulty were employed: level 1 consisted of the light signals only; level 2 consisted of the driving film plus light signals which

always corresponded to the driving requirements of the film. Level 3, the most difficult task, consisted of the film plus signals some of which corresponded and some of which conflicted with the movements of the car in the film; the subject was instructed to drive to the film but to give precedence to the light signals.

Physiological responses

Heart rate, respiration, calf blood flow and blood pressure were recorded both during and after the tasks. Both physiological and behavioural responses were recorded on a Beckman 8-channel 'Dynograph' recorder (for details see Ashton *et al.*, 1972).

Brief outline of experimental procedure

After being seated in the simulator, each subject was first connected to the physiological recording apparatus and given a short period of instruction and practice in the use of the simulator, including the projection of a short run of film. The subject was then asked to complete the Cattell Sixteen Personality Factor Questionnaire.

The three driving task levels, each lasting 20 min, were presented to the subject in random order and were carried out consecutively by each subject with a resting period of ten minutes between each task. The total session lasted approximately 130 min for each subject.

Smokers followed the same procedure as non-smokers, except that they smoked one cigarette during the first half of each task. In addition after completing each of the three task levels, they were asked to smoke a further half cigarette (approximately) during a resting period.

Organization of experiments

The present study was carried out in three main parts:

In Experiment I a group of non-smokers was compared with a group of smokers who smoked cigarettes supplied by the Tobacco Research Council which corresponded to commercially available filter-tipped cigarettes (referred to in this paper as 'intermediate' nicotine cigarettes). The blends of tobacco and filter were such that when smoked in an analytical smoking machine with 25 ml puffs of 2 s duration smoked once a minute to a butt length of 20 mm, the tip retention efficiency for nicotine was 51% and the mainstream smoke contained 1·4 mg nicotine.

The subjects were 32 students with a mean age of 21·2 years (range 19·33–25·16) and an average of 3·2 years driving experience (range 9 months–6 years). They were divided into 17 smokers (11 male, 6 female) and 15 non-smokers (9 male, 6 female). The average daily cigarette consumption (filter-tipped) of the smokers was 14·05 (range 3–25) with an average smoking history of 3·9 years (range 4 months–12 years).

In Experiment II a group of non-smokers was compared with one group of smokers who smoked special cigarettes containing a high retention filter (low nicotine group) and with another group who smoked special cigarettes containing a low retention filter (high nicotine group). These special cigarettes, supplied by the Tobacco Research Council, contained retention filters which permitted the mainstream smoke to contain 1·0 mg nicotine for the low nicotine type and 2·1 mg nicotine for the high nicotine type.

The subjects consisted of 16 non-smokers, 16 low nicotine smokers and 19 high nicotine smokers. In the non-smoking group, there were 11 males and 5 females with a mean age of 20 years (range 17·7–22 years) with an average of 2·15 years driving experience (range 0·5–4 years). The 35 smokers consisted of 21 males and 14 females with a mean age of 22·76 years (range 19–35 years) and an average of 3·9 years driving experience (range 0·5–10 years). The average daily cigarette consumption (filter-tipped) of the smokers was 16·3 (range 3–40) with an average smoking history of 5·28 years (range 2–14 years). In this experiment, only task levels 2 and 3 (and not all three levels as in Experiment I) were used and the order alternated for subjects within the non-smoking and smoking groups.

In Experiment III an attempt was made to test the performance of smokers and non-smokers on individual components of the driving task. Thus tracking ability was tested on a pursuit rotor and reaction time to a light signal was tested on a visual reaction timer. The pursuit rotor task required the subject to track a moving light with a stylus. There were two levels of difficulty in the reaction timer task; a two choice reaction time in which the subject was required to push an appropriate button with his finger when either one of two lights came on, and a four choice reaction time in which he was required to depress an appropriate button in response to any one of four light signals. The subjects for this experiment consisted of a new group of 16 smokers and 17 non-smokers. The smokers included 11 males and 5 females, aged 17 to 32 years, who normally smoked an average of 19 cigarettes daily (range 6–39). The non-smokers included 14 males and 3 females, aged 17 to 30 years. The tests were performed on two consecutive days, the reaction timer tests being performed on one day and the pursuit rotor tests on the other, in random order. The smokers smoked a cigarette immediately before each pursuit rotor task, which lasted 5 minutes. The smokers smoked a cigarette during the performance of each reaction timer task, which lasted 10 minutes. Physiological measurements were made as for the driving simulator experiments.

Results

1. *Experiment I* (15 non-smokers compared with 17 smokers smoking intermediate nicotine cigarettes).

Performance: task levels 1, 2 and 3.

Comparison of the reaction times obtained in the first half of the driving tasks, during which the smokers smoked one cigarette, revealed a number of significant differences between smokers and non-smokers. These differences are shown in Table 1. The smokers had significantly shorter reaction times than the non-smokers in some instances (slight steer total reaction time, task levels 2 and 3; medium steer action time, task level 1) but longer reaction times in other cases (indicator total reaction time, task level 3; medium steer response time, task levels 1 and 3; hard steer total reaction time, task level 1). The reaction times for brakes, medium steer total reaction time and hard steer response and action time showed no significant differences between the groups. The results also indicated significant differences between levels (slight steer total reaction time, medium steer action time, indicator total reaction time, hard steer total reaction time) and between subjects (slight steer total reaction time, medium steer action time and indicators).

All differences between the groups completely disappeared in the second half of the driving tasks (i.e., during the period when the smokers were not smoking) when

TABLE 1. *Analysis of variance of reaction times (in seconds) of 17 smokers and 15 non-smokers during first half of tasks*

Indicators—total reaction time

Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	1·12	1·32	1·23†	1·22
Non-smokers	1·02	1·13	1·11†	1·08
Overall task mean	1·07	1·22	1·17	1·15

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	0·3134	14·2454	<0·001
Between levels	2	0·1493	6·7863	<0·01
Interaction of groups × levels	2	0·0029	0·1318	n.s.
Subjects	30	0·0509	2·3136	<0·01
Residual	60	0·0220		

Slight steers—total reaction time

Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	1·39	1·24†	1·66‡	1·43
Non-smokers	1·50	1·50†	2·05‡	1·68
Overall task mean	1·44	1·37	1·85	1·55

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	1·5498	18·9462	<0·001
Between levels	2	2·1339	26·0867	<0·001
Interaction of groups × levels	2	0·1614	1·9731	n.s.
Subjects	30	0·1409	1·7224	<0·05
Residual	60	0·0818		

Medium steers—response time

Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	0·91‡	0·81	0·91†	0.87
Non-smokers	0·75‡	0·67	0·76†	0·72
Overall task mean	0·83	0·74	0·83	0·79

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	0·4762	15·2628	<0·001
Between levels	2	0·0959	3·0737	n.s.
Interaction of groups × levels	2	0·0019	0·0608	n.s.
Subjects	30	0·0327	1·0480	n.s.
Residual	60	0·0312		

Medium steers—action time

Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	0·37†	0·79	0·70	0·62
Non-smokers	0·60†	0·73	0·82	0·71
Overall task mean	0·48	0·76	0·76	0·66

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	0·2224	2·8045	n.s.
Between levels	2	0·8512	10·7339	<0·001
Interaction of groups × levels	2	0·1692	2·1336	n.s.
Subjects	30	0·1720	2·1689	<0·01
Residual	60	0·0793		

Hard steer—total reaction time

Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	1·84†	1·87	2·09	1·93
Non-smokers	1·65†	1·79	2·07	1·83
Overall task mean	1·74	1·83	2·08	1·88

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	0·2506	4·6151	<0·05
Between levels	2	0·9384	17·2817	<0·001
Interaction of groups × levels	2	0·0594	1·0939	n.s.
Subjects	30	0·0815	1·5009	n.s.
Residual	60	0·0543		

Only those reaction times in which there was a significant difference between smokers and non-smokers are shown in the table.

there were no significant differences in the performance of smokers and non-smokers.

Physiological measurements

The heart rate of the smokers was significantly greater than that of the non-smokers at all three task levels. This difference was apparent not only while the smokers were smoking, during the first half of the tasks, but also when they were not smoking during the second half of the tasks (Table 2). There were no significant differences between the two groups in the other physiological measurements. This applied not only to the mean measurements but also when individual and consecutive readings were compared. Significant differences between subjects were also noted.

2. *Experiment II* (a new group of 16 non-smokers compared with 16 smokers smoking low nicotine cigarettes and 19 smokers smoking high nicotine cigarettes).

Performance: task levels 2 and 3 only.

As shown in Table 3, during the first half of the task levels, some of the reaction times of the smokers were slower than those of the non-smokers (indicator total reaction time, brakes total reaction time, slight steer total reaction time, hard steer response time). These differences were sometimes between low nicotine smokers and non-smokers and sometimes between high nicotine smokers and non-smokers. All the differences occurred in the level 2 task. There were also significant differences between subjects for indicators and brakes. There was no significant difference between the performance of the low nicotine as compared with the high

TABLE 2. *Analysis of variance of heart rates of* 14 *smokers and* 15 *non-smokers during first and second halves of task levels* 1, 2 *and* 3

Heart rate (beats/min)	**First half of task: during smoking**			
Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	94·74‡	97·39‡	95·10†	95·74
Non-smokers	81·73‡	84·36‡	84·90†	83·66
Overall task mean	88·23	90·87	90·00	89·70
Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	3,170·6251	109·9422	<0·001
Between levels	2	52·9328	1·8354	n.s.
Interaction of groups × levels	2	19·0697	0·6612	n.s.
Subjects	27	364·5991	12·6425	<0·001
Residual	54	28·8390		
Heart rate (beats/min)	**Second half of task: after smoking**			
Means	Level 1	Level 2	Level 3	Overall
Groups				
Smokers	94·25‡	95·07‡	92·50†	93·94
Non-smokers	82·10‡	83·50‡	83·80†	83·13
Overall task mean	88·17	89·28	88·15	88·53
Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	1	2,536·2129	198·1772	<0·001
Between levels	2	11·7403	0·9173	n.s.
Interaction of groups × levels	2	24·6553	1·9265	n.s.
Subjects	27	325·7855	25·4565	<0·001
Residual	54	12·7977		

TABLE 3. *Analysis of variance of reaction times (in seconds) of* 16 *non-smokers,* 19 *smokers of high nicotine cigarettes and* 16 *smokers of low nicotine cigarettes during the first half of task levels* 2 *and* 3

Indicators—total reaction time

Means	Level 2		Level 3	Overall
Groups				
Non-smokers	1·17†		1·22	1·19
Low nicotine smokers	1·28†		1·28	1·28
High nicotine smokers	1·29		1·33	1·31
Overall task mean	1·24		1·27	1·26

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	2	0·1294	6·0467	<0·01
Between levels	1	0·0206	0·9626	n.s.
Interaction of groups × levels	2	0·0059	0·2757	n.s.
Subjects	48	0·0675	3·1542	<0·001
Residual	48	0·0214		

Brakes—total reaction time

Means	Level 2		Level 3	Overall
Groups				
Non-smokers	1·10†		1·29	1·19
Low nicotine smokers	1·30†		1·30	1·30
High nicotine smokers	1·18		1·32	1·25
Overall task mean	1·19		1·30	1·24

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	2	0·0871	2·9726	n.s.
Between levels	1	0·3084	10·5255	<0·01
Interaction of groups × levels	2	0·0699	2·3856	n.s.
Subjects	48	0·0693	2·3651	<0·01
Residual	48	0·0293		

Slight steers—total reaction time

Means	Level 2		Level 3	Overall
Groups				
Non-smokers	1·32†‡		1·84	1·58
Low nicotine smokers	1·52†		1·84	1·68
High nicotine smokers	1·59‡		1·78	1·68
Overall task mean	1·47		1·82	1·64

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	2	0·1066	1·8129	n.s.
Between levels	1	2·8166	47·9013	<0·001
Interaction of groups × levels	2	0·2424	4·1156	<0·05
Subjects	48	0·0747	1·2704	n.s.
Residual	48	0·0588		

Hard steers—response time

Means	Level 2		Level 3	Overall
Groups				
Non-smokers	0·67†		0·79	0·73
Low nicotine smokers	0·66		0·84	0·75
High nicotine smokers	0·71†		0·83	0·77
Overall task mean	0·68		0·82	0·75

Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	2	0·0143	0·5478	n.s.
Between levels	1	0·5267	20·1800	<0·001
Interaction of groups × levels	2	0·0096	0·3678	n.s.
Subjects	48	0·0335	1·2835	n.s.
Residual	48	0·0261		

Only those reaction times in which there was a significant difference between smokers and non-smokers are shown in the table.

nicotine cigarette smokers. In the second half of the task levels, there was no difference in the reaction times of smokers and non-smokers.

In this experiment, the number of anticipations and corrections made by the subjects responding to the light signals during the driving were also measured. Although no significant differences between the groups were detected, there was a consistent tendency for the smokers to anticipate more signals than the non-smokers during both halves of both the level 2 and the level 3 driving tasks.

Physiological measurements

As in the first experiment, the heart rate of the smokers was significantly higher at all task levels and during both halves of the tasks than that of the non-smokers. There were also significant differences between the heart rates of high and low nicotine smokers. These results are shown in Table 4. No significant differences were found in calf blood flow, blood pressure or respiration rate between the smokers and non-smokers.

3. *Experiment III* (17 non-smokers compared with 16 smokers smoking intermediate nicotine cigarettes).

Performance in pursuit rotor and simple reaction timer tasks

The differences in performance between smokers and non-smokers observed during the relatively complex driving tasks were not reflected in the simpler tasks,

TABLE 4. *Analysis of variance of heart rates of* 16 *non-smokers and* 15 *low nicotine and* 18 *high nicotine smokers during first and second halves of task levels* 2 *and* 3

Heart rate (beats/min)	**First half of task: during smoking**			
Means	Level 2		Level 3	Overall
Groups				
Non-smokers	83·65*†		82·65*	83·15
Low nicotine smokers	107·60*		107·86*	107·73
High nicotine smokers	92·41†		90·08	91·24
Overall task mean	94·55		93·53	94·04
Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	2	4,840·6843	115·0708	<0·001
Between levels	1	29·7551	0·7073	n.s.
Interaction of groups × levels	2	13·8891	0·3301	n.s.
Subjects	48	213·7934	5·0822	<0·001
Residual	48	42·0670		
Heart rate (beats/min)	**Second half of task: after smoking**			
Means	Level 2		Level 3	Overall
Groups				
Non-smokers	81·50*†		79·73†‡	80·61
Low nicotine smokers	103·63*		105·93†	104·78
High nicotine smokers	88·38†		87·69‡	88·03
Overall task mean	91·17		91·11	91·14
Variance source	Degrees of freedom	Mean square variance	F	*P*
Between groups	2	4,729·0297	315·1446	<0·001
Between levels	1	0·4011	0·0267	n.s.
Interaction of groups × levels	2	34·2944	2·2853	n.s.
Subjects	48	194·4929	12·9610	<0·001
Residual	48	15·0059		

Key to symbols used in Tables 1, 2, 3 and 4: *t* test—† indicates a significant difference between smokers and non-smokers, $P<0·05$; ‡, $P<0·01$; *, $P<0·001$.

for there was no significant difference in performance between smokers and non-smokers in the pursuit rotor and reaction timer tasks.

Physiological measures

The physiological measurements only showed significant changes in the smokers while they were smoking during the performance of the reaction timer tasks. These changes consisted of a higher heart rate ($P<0{\cdot}05$) and higher systolic ($P<0{\cdot}01$) and diastolic ($P<0{\cdot}05$) blood pressures.

4. *Personality characteristics of smokers and non-smokers*

The results of the Cattell Sixteen Personality Factor Questionnaire for all subjects taking part in experiments I and II (a total of 52 smokers and 31 non-smokers) showed that the smokers were significantly more extroverted and more self-reliant than non-smokers, but did not differ in other personality characteristics.

Discussion

These results show that there are definite differences between the performances in a car simulator of smokers and non-smokers. All the changes in performance were confined to the first half of the driving task, which was the period when the smokers were actually smoking a cigarette and disappeared in the second half, when they were no longer smoking. Thus it seems likely that the changes were not due to inherent differences, such as the observed differences in personality characteristics between the smokers and non-smokers, but were due in some way to the smoking itself. It is unlikely that the motor effects of holding a cigarette significantly inhibited performance, since some of the reaction times were actually faster in the smokers, and in any case the brake reaction times involved movements of the foot. The differences in performance between smokers and non-smokers did not appear to be consistently related to any particular stress level.

The presence of shorter reaction times in some instances amongst the smokers, coupled with the tendency for smokers to anticipate signals more than non-smokers, raises the possibility that smoking had a stimulating or alerting effect, tending to increase the speed of response in the smokers. Even the apparently longer reaction times could be a result of the smokers making more anticipations, since the measured reaction time depended on how soon before the appearance of a light signal an anticipation occurred. If the light signal came on just as a correct anticipation was occurring or was about to occur, the observed reaction time would be short. If, however, an anticipation had been completed and therefore the correct manoeuvre already executed when the light signal appeared, the subject might be less ready to respond again and the observed reaction time to the signal would be long. Thus both short and long reaction times in the simulator could theoretically be explained by an alerting action of smoking. Unfortunately, it was not possible to tell with certainty from the records whether this explanation is correct.

The lack of difference in performance between smokers and non-smokers in the simpler and less stressful pursuit rotor and reaction timer tests would seem to indicate that the effects of smoking are subtle and may be more important in complex situations associated with higher degrees of stress. This possibility could

perhaps be tested by progressively increasing the complexity of the pursuit rotor or reaction timer tasks.

The stimulant effects of small doses of nicotine in animals are well known (Armitage, Hall & Morrison, 1968 ; Hall, 1970) and it is possible that the nicotine from the cigarettes contributed such an effect in the present experiments. The lack of difference in performance between the high and low nicotine cigarette smokers would be expected from the finding already reported (Ashton & Watson, 1970) that these two groups extracted substantially the same amount of nicotine from the two types of cigarette by altering the puffing rate, the low nicotine smokers puffing faster than the high nicotine smokers.

Larger doses of nicotine have been shown in animals to have a central depressant effect (Armitage *et al.*, 1968 ; Hall, 1970) and it is also possible that such an effect could account for some of the longer reaction times observed among smokers. This, however, seems less likely since the smokers were instructed to smoke ' naturally ' and were not pressed to take more nicotine than they required. The increased intake of nicotine during a relaxed situation after a period of relative stress in a driving simulator has been noted by Ashton & Watson (1970). It is possible, however, that in the complex situation of the driving tasks both stimulant and depressant effects of nicotine may have occurred and the resultant reaction times represented the interaction of these two effects. Raised carboxyhaemoglobin levels in the smokers as a result of smoking may also have affected their performance ; this possibility is being further investigated.

Of the physiological measurements, it was perhaps surprising that only heart rate showed significant differences between smokers and non-smokers in the driving experiments. Cigarette smoking is well known to increase the heart rate but it is perhaps noteworthy that the increased heart rate among smokers persisted into the second half of the tasks, up to 10 min after finishing the cigarette and that it was still significantly higher in the smokers during a non-smoking resting period after the tasks, 20–30 min after finishing the cigarette. It suggests that under these conditions cigarette smoking has a long-lasting effect on the heart rate. The difference in heart rate between low and high nicotine smokers observed in the present investigation may be partly due to the fact that the low nicotine group took more puffs per cigarette than the high nicotine smokers (Ashton & Watson, 1970) and therefore presumably had a higher level of carboxyhaemoglobin.

Of the other physiological measurements, calf blood flow tended to be lower in the smokers than the non-smokers, but the differences did not reach statistical significance, and blood pressure showed a rise from resting values during the driving tasks in both smokers and non-smokers alike, presumably due to the stress of the tasks themselves. This effect may have masked any separate effects of smoking on the blood pressure ; it is also possible that rapid changes in blood pressure occurred but escaped detection because blood pressure could only be measured when the subject was relatively immobile (see **Methods**, Ashton *et al.*, 1972).

The findings on the personality characteristics of smokers and non-smokers agree with those of Cattell & Krug (1967) and Smith (1967) who found significant positive correlations between smoking and extroversion. These results are also consistent with those of Eysenck, Tarrant, Woolf & England (1960) and Eysenck (1963, 1965). Our results also agree with these authors in showing that the overall level of anxiety or neuroticism is not greater in smokers than in non-smokers.

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