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EFFECT OF CIGARETTE SMOKE  
CONCENTRATION ON HUMAN SMOKING  
CHARACTERISTICS

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THE EFFECT OF CIGARETTE SMOKE CONCENTRATION  
ON HUMAN SMOKING CHARACTERISTICS

By T.I. Wilson

SUMMARY

The smoking characteristics of humans have been investigated. The parameters measured were puff volume, velocity, duration and frequency. The manner in which subjects altered these parameters when presented with smoke at a reduced concentration was investigated in particular detail. The concentration of the smoke was reduced by using a high pressure drop (high filtration efficiency) filter on the plain cigarette.

Each individual smoker showed a reasonably small variance in his or her smoking parameters. However, the variation from one individual to another was very great. As only thirty people were used as the 'population', any average figures for the smoking parameters would be a very poor representation of the smoking population at large.

The subjects seemed to vary their smoking parameters when presented with different cigarettes. Thus, on smoking a cigarette with a high pressure drop filter, the population was found to draw harder on the cigarette in a subconscious attempt to compensate for the reduced smoke concentration caused by the high pressure drop filter. This resulted in an increase in average puff volume of 9% as well as an increase in puff duration and maximum puff velocity.

As smoking machines do not possess this inbuilt compensation, the tar figures obtained on high pressure drop filters tend to give a misleadingly low idea of how much smoke the smoker is obtaining.

The average puff volume was between 30 and 40 cc. The puff duration was between 1.7 and 2.0 seconds and the puff frequency was between 2.3 and 2.8 puffs per minute, but this latter figure was somewhat biased upwards by a number of subjects increasing their normal puff frequency under the test conditions.

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It was established that for the particular population examined, men took a larger puff of longer duration than women. No relationship could be found between the individual's smoking parameters and his or her smoking habits, such as the number of cigarettes smoked per day and number of years that the individual had been smoking.

#### INTRODUCTION

There is a fundamental need to know how people smoke. Armed with this information we will be in a better position to understand and evaluate the shortcomings of artificial smoking machines used so extensively in tobacco laboratories around the world.

Work has been carried out by R. & D.E. <sup>(1)</sup> on the measurements of breathing patterns during smoking. Brown & Williamson <sup>(2)</sup> have examined the smoking parameters of a group of individuals and observed the parameters in which men differ from women. Adams from Imperial Tobacco Co. (Bristol) <sup>(3)</sup> has presented similar work. All the investigations suffer from the problem of using a small number of people to obtain an estimate of the parameter's mean for the smoking population at large. Such a small number of people is likely to be, to some extent, atypical of the population. The present work also suffers from the same problem.

This investigation deals with the human-cigarette interaction, that is to say, the way humans vary their smoking parameters as the characteristics of the cigarette they are smoking vary . and specifically as the smoke concentration or in other words in this case, the pressure drop changes. It is thought that humans may have an inbuilt 'compensation mechanism' and when smoking a high pressure drop cigarette giving a low smoke concentration, they will involuntrarily draw more strongly on the cigarette thus increasing the puff volume. As this compensation would be a reflex action the use of a small, possibly atypical, subpopulation may not present the same problems as it would for actions which are characteristic of the individual, such as puff duration or puff frequency.

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METHOD

The drop in pressure between the mouth and the butt of the cigarette was measured by a cigarette holder pressure transducer as described by Brown and Williamson (2). These changes in pressure were recorded on a fast response recorder running at a chart speed of 1,200mm per minute. A stopwatch was started as the subject lit the cigarette and the time was subsequently recorded at each puff. Finally the butt length was measured on the completion of smoking.

The subject was supplied with reading matter during the tests which were carried out in a comfortable room especially set aside for this purpose.

Thirty subjects (twentyone men and nine women) were chosen at random from among the laboratory staff. They were required to smoke a trial cigarette first to acclimatise themselves to the environment. The next day the subject smoked the first of the test cigarettes and the second on the day following. The order in which the cigarettes were presented to the subjects was alternated to remove any possible bias caused by further acclimatisation.

Finally, twentyfive subjects smoked the same cigarette on two consecutive occasions to establish the reproducibility of the testing procedure.

RESULTS

The following measurements were made:

Puff duration from the profiles on the recorder.

Pressure, as measured at the holder. This was proportional to the peak height for maximum pressure, and peak area for the 'total pressure'.

Pressure or suction applied by the human was calculated from the peak area corrected for the effect of the cigarette pressure drop on the pressure measured in the holder.

Puff volume calculated from the square root of the peak area, since in a pneumatic system such as this, the volume equals the square root of the pressure, times a constant. The value of the constant was obtained by calibrating the peak area against puffs of known volume taken through a cigarette of known pressure drop.

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Puff frequency, calculated from the time to smoke the cigarette and the number of puffs taken.

Time to smoke 50mm, calculated from the cigarette length minus the butt length and the time taken to smoke the cigarette.

No figures are shown for butt length. However, use of a holder undoubtedly alters the butt length to which people smoke, and thus any figure for butt length would be misleading.

No measurements were taken for the lighting puff as this puff was considered to be atypical.

The average figures obtained for the various smoking parameters are tabulated in Table 1. Results from a high pressure drop cigarette are compared to those from a low pressure drop cigarette to see the effect of smoke concentration on the smoking parameters of the subject.

TABLE 1.

Average smoking parameters for high and low pressure drop cigarettes

	Plain Cigarette	Plain Cigarette with filter
Cigarette pressure drop	6.0 cm	13.0 cm
Puff duration	1.73 sec	2.02 sec
Puff volume	36.8 cc	40.0 cc
Maximum peak height (pressure)	8.4 A.U.	11.1 A.U.
Maximum human suction	10.0 A.U.	11.3 A.U.
Puff frequency	2.4 sec <sup>-1</sup>	2.9 sec <sup>-1</sup>
Time to smoke 50mm	5'45"	5'28"

(A.U. = Arbitrary Units)

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The results were examined in more detail to compare the mean smoking parameters for men and women using both the low and the high pressure drop cigarettes.

TABLE 2.

Mean parameters for men and women

	Low Pressure Drop		High Pressure Drop	
	Men	Women	Men	Women
Puff duration	1.93 sec	1.26 sec	2.26 sec	1.46 sec
Puff volume	39.3 cc	31.2 cc	42.5 cc	34.2 cc
Maximum peak height (pressure)	8.5 A.U.	8.7 A.U.	11.2 A.U.	10.8 A.U.
Maximum human suction	10.0A.U.	9.6 A.U.	13.1 A.U.	12.7 A.U.
Puff frequency	2.41sec <sup>-1</sup>	2.24sec <sup>-1</sup>	2.7sec <sup>-1</sup>	3.1sec <sup>-1</sup>
Time to smoke 50mm	5'7"	6'12"	5'0"	5'8"

(A.U. = Arbitrary Units)

EXAMINATION OF INDIVIDUAL RESULTS

Individual subjects were fairly consistent in their smoking parameters. However, there was considerable variation from one subject to another. It was observed, not unexpectedly, that 'seasoned' smokers tended to be more reproduceable or constant in their smoking parameters than 'casual' smokers.

Examination of the different puff profiles showed considerable variation from individual to individual. The profiles were basically triangular or bell shaped. Some were high and narrow while others were low and broad. The maximum may occur just before or just after the mid point for the peak. Most subjects showed two maxima. The second maximum may appear only as a bump on the latter part of the profile or in the extreme case it may exemplify itself as two separate peaks.

There was little variation of the profile from puff to puff for an individual subject.

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The volume of the individual puff was seen to decrease with increasing puff number. The initial one or two puffs were generally abnormally large, whereas in the case of many subjects, the last one or two puffs were unusually small. This latter effect may be due to a subject reaching a 'satisfaction' level and thus decreasing his or her smoke intake.

The puff frequency showed no tendency to change as the cigarette was smoked.

The puff duration showed a slight tendency to decrease as the cigarette was smoked and this pattern was also observed for the maximum peak height.

#### REPRODUCEABILITY OF TESTING PROCEDURE

Although the order in which the cigarettes were presented to the subjects was alternated to remove any bias due to acclimatisation of the subjects to the testing procedure, it was still thought necessary to investigate how reproducible the results were from one test to another. The same cigarettes were presented to the subjects on two consecutive days. The mean figures for each parameter were determined from both tests and these are tabulated in Table 3.

TABLE 3.

Reproduceability of testing procedure

	Test 1	Test 2
Puff duration	1.9 sec	1.9 sec
Maximum peak height (pressure)	9.7 A.U.	9.7 A.U.
Puff frequency	2.7 sec <sup>-1</sup>	2.7 sec <sup>-1</sup>
Time to smoke 50mm	5'49"	5'47"

(A.U. = Arbitrary Units)

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DISCUSSION

It was observed from the figures in Table 1. that when a subject obtains a low concentration of smoke due to a highly efficient filter, he or she increases the intensity of the puff taken on the cigarette. This increase in intensity is shown as an increase in puff volume, duration, frequency or maximum peak height.

A low smoke concentration from a high pressure drop cigarette causes some people to increase their puff frequency while leaving their puff volume the same, while others tend to increase the puff volume, smoking at a similar frequency. Similarly some people show an increase in puff duration and the same maximum peak height while others show an increase in maximum peak height or puff velocity, while keeping the puff duration much the same. Another sub-group shows an increase in both puff duration and maximum peak height.

STATISTICAL SIGNIFICANCE OF RESULTS

The high variation between individuals in their average figures for the various parameters makes statistical analyses difficult, as this variance tends to cover the effect of the change caused by the difference in smoke concentration from the two cigarettes. Thus if we apply the T test to a comparison of the means, none of the parameters show significant difference between the high and low pressure drop cigarettes. On the other hand, there are significant differences between the mean parameters of cigarettes of different pressure drops when measured by the Chi square distribution test. This test only examines the variance between the two cigarettes and does not allow for a variance within the subjects themselves on the one cigarette.

With results such as those obtained in this project, the Chi-square test is the more applicable of the two. From this test we find there is a significant difference in the volume, puff duration and maximum peak height registered by the subjects smoking the two cigarettes. The difference in the frequency is not significant even though it is nearly significant by the comparison of means method. The time taken to smoke 50mm does not show a significant difference by either statistical methods.

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The wide variation of individual subject's results should be reduced if the subjects could be grouped into a number of sub-groups. The problem involved is to establish a satisfactory criterion for division. The most obvious division is into male and female smokers. If the results summarised in Table 2. are examined statistically, it is found that men take a significantly larger volume than women, and the puff duration of males is just significantly greater than that of females. In other respects such as puff frequency, maximum peak height, time to smoke 50mm etc. there is no significant difference between men and women.

In an attempt to take this sub-grouping further, the subjects were asked to fill out a questionnaire and from the data they supplied they were divided up into a number of sub-groups depending on the length of time they had been smoking and the number of cigarettes per day which they smoked. Statistical examination of the results showed no pattern of difference that could be associated with either the length of time a smoker had been smoking or how heavy a smoker he happened to be.

As mentioned earlier, the use of a cigarette holder, and the fact that the subject knows he is undergoing a test, does produce an artificial atmosphere in which smokers may be expected to change their smoking pattern. It is felt that this effect has influenced the results for the puff frequency giving an abnormally high result. Observations on some subjects smoking under normal conditions show them to take a lower puff frequency. The effect of this is hard to estimate and does vary from individual to individual as some people were able to overcome the test atmosphere, concentrating only on the reading matter, and thus smoking in their normal manner, while others could not seem to attain this.

Table 3. shows the reproduceability of the testing procedure. The agreement between the two tests was surprisingly close. These results are, of course, the mean of twentyfive subjects. Each subject did show variation between the two tests but it would appear that twentyfive subjects are sufficient to obtain reproduceable results.

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These results then are an accurate representation of the smoking characteristics of this particular population. However they could not be used to draw conclusions about the smoking population as a whole. To obtain information about the smoking population at large would require examination of the smoking characteristics of a much greater population than could be handled in this laboratory.

#### CONCLUSIONS

The experiment has demonstrated the fact that humans have an inbuilt compensation mechanism which they use when they are presented with a cigarette having a filter of high pressure drop. This, no doubt, is not an effect of the pressure drop, per se, but rather it is caused by the human reacting to the reduced amount of smoke that he receives through a cigarette with a highly efficient filter such as the one used in this test. The smoker will then draw harder on the cigarette to increase the smoke yield towards a point which gives sufficient satisfaction.

It is not known which component the smoker is trying to obtain in sufficient amounts, whether it is nicotine or associated compounds. It seems probable that it is not any one compound but the total smoke which the smoker requires at a certain level and if he obtains it at a level below this, due to an efficient filter or the like, he will by reflex, draw harder on the cigarette to compensate. The compensation in terms of volume obtained from this experiment, is only about 9%. This of course, would not compensate for the considerably reduced amount of smoke issuing from this high filtration efficiency filter. However, the difference is significant, and it does mean that T.P.M. figures produced from a smoking machine are not a fair representation, even relatively, of the amount of smoke the human will obtain from a given cigarette.

This work has shown there to be a difference, for this population at least, between men and women in regard to the volume of the puff they take and its duration.

From the results obtained, it would appear that the smoking regime used in this laboratory is a fair representation of the manner in which humans smoke. The puff frequency is two to three times greater than that used in the regime but it is felt that this is an artifact of the experimental conditions.

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The human compensation mechanism demonstrated in this experiment would, no doubt, apply to smoking population at large. However, the differences between men and women in their smoking parameters and the mean figures of the parameters obtained in this experiment may have to be modified if the experiment were to be carried out on a large population which was intended to represent in some way the smoking population at large.

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