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EFFECT OF SMALL DOSES OF ALCOHOL ON A SKILL RESEMBLING DRIVING

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Since the drinking of alcohol in one form or another is so common a characteristic of the social life of man in a variety of cultures, it would seem important that as much as possible should be known both of its physiological effects and of its effects on behaviour. In fact, at the present time, very little precise information is available, in spite of an extensive literature on the subject. This literature has been reviewed, more or less comprehensively, periodically since the early part of this century (Fisk, 1917 ; Darrow, 1929 ; Emerson, 1933 ; M.R.C. Alcohol Investigation Committee, 1938 ; Jellinek and McFarland, 1940 ; Drew, 1950).

The most striking feature to emerge from any such review is the marked lack of agreement between authors, amounting in many instances to direct contradiction of one another. This is especially true of the effects of smaller doses. Perhaps not surprisingly, doses of intoxicating strength have generally resulted in deterioration in efficiency in almost all aspects of behaviour tested. For doses below this level, however, the picture is not clear.

Some authors have reported deterioration in performance however small the dose, some have failed to find any effects, while several have shown actual improvements following doses of the order of one single whisky.

In part these discrepant findings reflect the unreliability of many of the results in this field, but in part they arise from the complexity of the effects of alcohol.

For moderate and intoxicating levels it has been established that the effect of alcohol is related to its concentration in the blood, and that the blood alcohol concentration obtained from a given ingested dose depends both on the body weight of the recipient and on the rate at which the alcohol is absorbed into the blood (Winton and Bayliss, 1948). The rate of absorption, in turn, has been found to be dependent on the amount, type, and dilution of alcohol, the contents of the stomach, and the drinking habits of the individual (Goldberg, 1951).

Previous reports further suggest that, apart from a slowly developed tolerance to alcohol from repeated exposure to it over a number of years, known as habituation, there is also a more rapid adaptation to each dose consumed, so that it has a greater effect when the blood alcohol level is rising than when it is falling (Mellanby, 1919 ; Miles, 1924 ; Goldberg, 1951 ; Eggleton, 1955).

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The nature of the task used is also important. Goldberg (1943) has shown that some tasks are more readily impaired by a given dose than are others. Familiar tasks, too, deteriorate less than ones that are unfamiliar (Jellinek and McFarland, 1940). The method of measuring change in performance is often of great importance. The additional stimulation provided by a new task frequently enables the subject to compensate, for a short time, for conditions which have produced an overall reduction in his efficiency. For this reason, short interpolated tests may fail altogether to measure this deterioration and may show normal or even above normal efficiency (Drew, 1942). Reasonably long-lasting tests seem necessary unless the deficiency is a gross one. Welford (1951) has stressed the importance, for the analysis of skilled behaviour, of measuring different aspects of performance, since relatively gross measures may obscure changes in the way in which different actions are integrated in the final performance.

The wide individual variations in performance in response to alcohol remaining when the above factors are taken into account have been attributed to temperamental differences, and especially to those differences related to extraversion–introversion.

Differences along this dimension have been noted in other contexts. Extraverts have been shown to be relatively less concerned with accuracy of performance (Himmelweit, 1946), to deteriorate more rapidly during continuous work (Broadbent, 1956 ; Eysenck, 1957a), and to be less consistent in performance (Venables, 1956). It has, furthermore, often been noticed, when giving depressant drugs to psychiatric patients, that a given dose has a greater effect on patients with hysterical disorders than on anxiety and depressive patients. A theory postulating a greater amount of cortical control for introverts and a greater susceptibility of extraverts to depressant drugs due to the reduction of cortical control was first put forward by McDougall (1929) and has recently been extended by Eysenck (1957b). Experimental confirmation of the greater susceptibility of extraverts to the depressant action of amylobarbitone sodium has been published by Shagass (1954, 1956).

The aims of this experiment were to investigate the effect of small doses of alcohol on a complex skill, resembling driving ; to relate any changes found to the level of blood alcohol ; to see whether individual differences in response to alcohol could be explained in terms of previous experience or of temperamental differences, when every effort had been made to minimize differences in blood alcohol level; and, finally, to investigate the accuracy with which blood alcohol level could be estimated by measuring the alcohol excreted in urine and in breath. This article is a preliminary report of the main results of the experiment which was carried out on behalf of the Road Users' Committee appointed jointly by the Medical Research Council and the Road Research Board (Department of Scientific and Industrial Research). Full details will be published later by the Medical Research Council.

Experimental Method

In deciding upon the task to be used, two considerations had to be borne in mind: that the task would need to be a continuous one of reasonably long duration, and that such a task runs the risk of becoming extremely boring for subjects. It was finally decided that an apparatus known as the "Miles motor driving trainer" provided the best compromise between a task, performance on which could be scored adequately, and one which had the motivating capacity of a real-life situation.

In this apparatus the subject sits in a dummy car, facing a translucent screen in a darkened room. Behind the screen is a "perspex" disk with a road scene painted on it. This road scene is projected, very much magnified, on the screen by a lamp on the perspex surface. As the driver operates the accelerator and steering-wheel to change his speed and direction of movement, the car appears to progress along the road. The effect is reasonably realistic, and the task bears some resemblance to driving in that non-drivers find the machine difficult to control without considerable practice, whilst experienced drivers have little difficulty with it. Though the central task is very similar to driving, it differs from it in being completely devoid of danger and emergencies. The track used was a continuous winding circuit, the equivalent of slightly over one mile in length. Its repetitive nature was not very apparent to the subjects, and had considerable advantages for scoring in presenting the same objective task to the subjects at all stages of the trial.

The main aspects of performance to be scored were accuracy of tracking, speed of driving, and the control movements of steering-wheel, accelerator, brake, clutch, and gear lever. Of the latter, only steering-wheel and accelerator pedal movements proved worth considering. Accuracy of tracking, measured in terms of deviations from a course parallel to the left-hand kerb, and steering-wheel and accelerator pedal movements were recorded graphically, and simultaneously scored on counters, photographed once each lap. Separate recording was made of the number of collisions of the car with the side of the road; "hunting" movements of the steering-wheel too small to change the car's direction; gear changes; identification marks for lap completion and major corners; and a time mark.

The subjects were 40 volunteers from the staff of the Road Research Laboratory. Their ages ranged from 23 to 40 years, except for one subject aged 58. The mean age was 31 years. Five of the subjects were women. All were in good health and held a current driving licence. The majority reported that they took alcohol only occasionally.

The alcohol was administered orally as analar grade absolute alcohol, diluted to a 20% solution and flavoured to disguise the alcohol content. Haggard, Greenberg, and Cohen (1943) found that the toxic effect of alcohol varied considerably even within the same kind of spirit, owing, apparently, to the presence, in minute quantities, of substances related to the original distilling. They found that, after very careful distilling, absolute alcohol was less toxic than any of the other forms tried. As analar grade absolute alcohol was used in this experiment, it seems probable that the results reported here represent minimum effects for these quantities and concentrations. Equivalent amounts of alcohol taken as beer or spirits could be expected to have somewhat greater effects.

This investigation was concerned with blood alcohol concentrations of less than 100 mg. per 100 ml. of blood, since this is the figure recommended by the National Safety Council of America (1953) as the limit of "safe" and only "possibly under the influence." To achieve these concentrations, doses were given of 0.00 (placebo), 0.20, 0.35, 0.50, and 0.65 g. of alcohol per kg. of body weight. In terms of the concentrations used by Cohen, Dearnaley, and Hansel (1958) these doses represent approximately 18, 31, 44, and 57 ml. of absolute alcohol for an 11-stone (70-kg.) man. The largest dose is the approximate equivalent of three pints (1,700 ml.) of "average" beer or 5 fl. oz. (142 ml.) of whisky for an 11-stone (70-kg.) man.

In view of the expected wide individual variations, and of the difficulty of defining a "correct" performance on such a task as this, it was decided to use each subject as his own control. That is, the effect of alcohol was measured as the degree of change in performance of each subject against his own performance without alcohol. To minimize practice effects, a latin square design was used, each square containing five subjects and five doses. This square was repeated eight times with different subjects. The women subjects were assigned to one square. Each subject was tested on the same day of the week for five consecutive weeks. Thus each subject received every dose.

Subjects were given preliminary practice to familiarize them with the task, and information was obtained on body weight, age, driving experience, and drinking habits. (They were asked not to drink on the evening before a trial.) On the morning of the trial the subject took a fat-free breakfast and 2 to 2½ hours later, at 10 a.m., the first urine sample was collected to provide a check on ketones and residual alcohol and to empty the bladder. (In a subsidiary experiment, urine samples were taken with a full bladder.) He was then given his drink and requested to finish it within 10 minutes. After a further 10 minutes he entered the apparatus and was instructed to drive as he normally would in a real car, and not to stop until told to do so, unless an emergency arose. The subject drove for 20 minutes and then had a 10-minute break, during which the blood, urine, and breath samples were collected. There followed three further 20-minute periods of driving, and 10-minute rest pauses during which samples were taken. Each experimental series lasted 2½ hours.

Approximately 0.5 ml. of blood was taken from the thumb on each sampling occasion, and the blood and urine samples were analysed at the South-Western Forensic Science Laboratory, at Bristol, by the microanalytic modified Cavett method recommended by the B.M.A. Committee (Kent-Jones and Taylor, 1954). Samples taken on the alcohol-free days were usually discarded, but occasionally were used as a check on the analytic procedure. Readings from three instruments for the measurement of breath alcohol were recorded at the time of blood sampling on a number of occasions. The breath analysis instruments used were the "alcometer" (Greenberg and Keator, 1941), the "drunkometer" (Harger, Lamb, and Hulpieu, 1938), and the "breathalyser" (Borkenstein).

The subjects were given a battery of personality tests, from which only the measures of extraversion are considered in this paper. Tests included the Minnesota Multiphasic Personality Inventory, the Maudsley Personality Inventory, and the Bernreuter Personality Inventory.

ALCOHOL CONCENTRATION

Blood Analysis.—The means and standard deviations of each dose, in mg. per 100 ml. of blood, are given in Table I. It will be observed that peak concentrations for the four doses were roughly 20, 40, 60, and 80 mg. per 100 ml. of blood. The doses used, therefore, have been effective in producing concentrations normally regarded as low or "safe." It will be seen from the standard deviations that there is relatively little overlap between the concentrations

TABLE I.—*Mean Blood Alcohol Levels, and Standard Deviations, Following Four Doses of Ingested Alcohol*

Dose	Time After Drinking in Minutes							
	30		60		90		120	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1. (0·20 g./kg.) ..	23	10	19	9	13	8	6	5
2. (0·35 g./kg.) ..	36	15	37	10	30	9	20	9
3. (0·50 g./kg.) ..	58	14	59	11	51	12	39	10
4. (0·65 g./kg.) ..	74	19	77	12	71	14	62	15

following different doses, implying that the technique of adjusting the absolute quantity of alcohol given to total body weight produces reasonably consistent blood alcohol values. The change in the mean blood alcohol values for each dose through time is shown in Fig. 1. Following each dose, blood alcohol rises steeply to a maximum, reached somewhere between 30 and 60 minutes after drinking, and then falls off in an approximately linear way. There is a tendency for the peak concentration to occur slightly later as the dose increases. That following the largest dose gives a mean time of nine minutes later than that for the smallest. For some subjects, measurements were taken up to six hours after drinking. Dose 1 fell to near zero concentration by the end of two hours, dose 2 at about four hours, dose 3 at rather over five hours, and at six hours the mean concentration following dose 4 was still 20 mg. per 100 ml. Once the peak was passed blood alcohol levels fell, on average, by approximately 10 mg. per 100 ml. per hour.

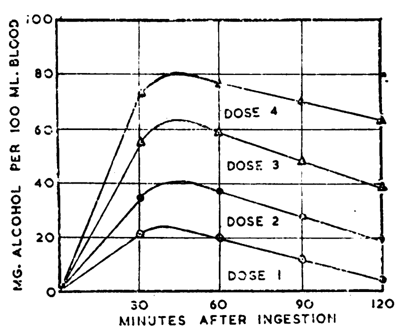

FIG. 1.—Relation between the level of alcohol in the blood and time after ingestion, for four levels of alcohol. Each point is mean of 40 subjects.

Urine Analysis.—Full details of the urine and breath analysis will be given in the main report. The concentration of alcohol in urine built up more slowly, reaching a peak concentration between 20 and 25 minutes later than that in the blood. After the peak was passed the fall-off paralleled that in the blood, the value at any given time being proportionately higher. The overall ratio of urine to blood alcohol was 1.252:1. When the samples were taken with the bladder full, values were slightly more variable, but did not differ significantly from those taken after the bladder had been emptied. Correlating the urine alcohol level with that in the blood 30 minutes earlier, to make an approximate correction for the time lag, gives a product-moment correlation of $r=+0.92$.

Breath Analysis.—Of the instruments used to analyse alcohol in expired breath, the breathalyser proved most satisfactory. It proved highly reliable and gave values corresponding closely to the blood alcohol values, having a constant error of +2 mg. per 100 ml. Some difficulties were experienced with the other instruments used. In 95% of the comparisons the breathalyser values lay within ±21 mg. per 100 ml. of the blood alcohol readings, the drunkometer within ±22 to 26 mg. per 100 ml., depending on the operating technique used, and the alcometer within ±34 mg. per 100 ml.

PERFORMANCE CHANGES

The aspects of performance measured concerned the accuracy of tracking, the speed at which the task was taken, and the operation of the controls.

The accuracy measures consisted, firstly, of tracking error (the amount of deviation across the road surface from a track parallel to the left-hand kerb) and kerb-bumpings (the more serious error of colliding with the side of the road). Secondly, two detailed accuracy measures were obtained—positioning of the car relative to the left-hand side (this was measured on a sample of 10 subjects for no-alcohol and dose 4), and consistency in car positioning at a corner in the circuit (measured, for 35 subjects, as the range of differences in negotiating the same corner on six successive occasions in the second driving period under each dose condition).

Speed was recorded as the number of seconds taken to complete one lap. The total amount of steering-wheel movement made will be the only aspect of control movements considered here.

All scores were expressed as a summed score per lap, and were then averaged over five minutes. The five-minute averages were then summed over 20 minutes. They were subjected to a variety of statistical treatments, including analysis of variance. Regression lines and coefficients of correlation are used here.

The results are presented in terms of group effects, followed by some discussion of individual differences in response to alcohol and their relationship to other personal characteristics. A table of the mean effects of alcohol for each scoring category is given in the Appendix.

A. Group Effects

Practice effects varied in the different performance measures. Tracking error showed very little change with practice, but there was a progressive increase in speed of driving throughout the experiment. Time per lap and tracking error were negatively correlated ($r=-0.39$), but correction of error scores for increased speed makes little difference to the overall picture. Steering-wheel movement shows a pronounced practice effect in a progressive and marked reduction in the amount of movement throughout the experiment.

Effect of Alcohol on Accuracy

Accuracy of steering, in a complex task of this kind, decreases progressively as blood alcohol increases, even with the low concentrations used in this experiment. Furthermore, there is, from the group effects, no evidence of a threshold. Instead, there is a measurable increase in mean error as soon as there is a measurable quantity of alcohol in the blood. The relation between accuracy, expressed as tracking error, and blood alcohol is shown in Fig. 2. This shows the regression of error on blood alcohol. The regression is highly significant ($p<0.001$). This is confirmed by an analysis of variance, which shows a relation of error and blood alcohol significant at better than the 0.01 level of probability. The mean increase in error for the 80 mg. per 100 ml. concentration compared with no-alcohol performance is about 16%.

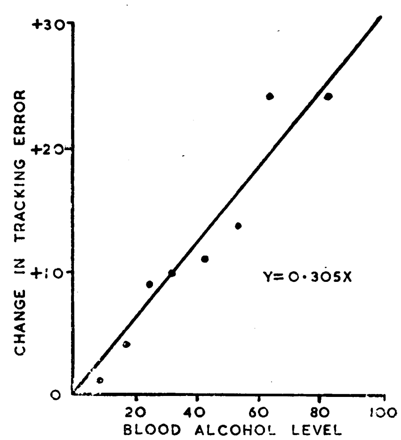

FIG. 2.—Regression of tracking error on blood alcohol level. Each point is mean of 80 paired values.

It has been noted above that blood alcohol concentration shows a characteristic change with time after drinking, showing, first, a steep rise to a maximum value, followed by a slow return to normal. Tracking error shows a very similar pattern with time after drinking. The close correspondence of the rise and fall through time of blood alcohol and tracking error is shown in Fig. 3. In this figure, tracking error scores are expressed as the mean score for each driving period. Blood alcohol concentrations have therefore been expressed in the same way. The rise and fall of urine alcohol, expressed similarly, have been included. The

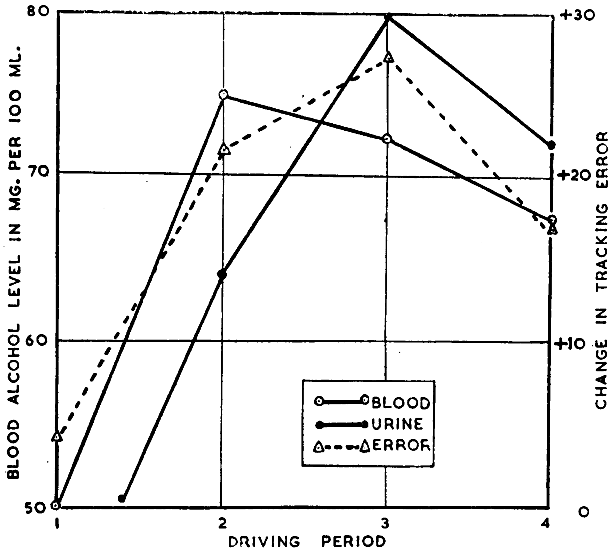

FIG. 3.—Rise and fall of blood alcohol, error score, and urine alcohol with time after drinking. (Urine alcohol levels reduced by one-fifth.) Each point is mean of 40 subjects.

figure for urine alcohol has been reduced by one-fifth (in view of the ratio of 1.252 : 1) to enable it to be presented on the same scale. Although only the largest dose has been plotted, the data for the other doses follow the same pattern.

It can be seen that urine alcohol reaches a maximum about 20 minutes later than blood alcohol. The error curve looks as though its peak would occur somewhere between the two. The calculation of lag correlations confirms this. Maximum correlations are obtained when error scores are correlated with blood values some 10 minutes earlier, and with urine values some 10 minutes later. From this it would appear that maximum error slightly lags in time behind the maximum blood alcohol and slightly precedes maximum urine alcohol.

Product–moment correlation of the rise and fall of blood alcohol and the rise and fall of error is positive and significant. The mean correlation of the four paired values, calculated separately for each individual, is $r = +0.271$, with p lying between 0.01 and 0.02. The size of this correlation, though significant, seems small. It will be seen from Fig. 3 that there is a time lag between the two variables with an inverted relationship in periods 2–3. This, and the clustering of points in the second, third, and fourth driving periods, probably have reduced the size of the correlation. When blood alcohol values at five-minute intervals, obtained by interpolation from the individual curves, are correlated with the five-minute error scores, allowing a much smaller lag than the 20-minute scores, the correlation rises to $r = +0.89$. Because the test ends before blood alcohol has dropped very markedly, it is not possible from these scores to say whether error scores recover more quickly than blood alcohol levels, though inspection of Fig. 3 shows that the slope of error scores in the last half hour is steeper than for blood alcohol. The frequency of kerb-bumping rises steeply to a maximum, for each dose, with blood alcohol, and falls almost equally steeply after the maximum has been passed.

In an attempt to interpret the increased error with increased blood alcohol, records were sampled for mean position on the road surface, amount of swing about this position, and consistency of behaviour on corners. Significant differences were found. Without alcohol, subjects tended to drive on the left-hand side of the road, to remain on that side for relatively long periods—that is, with relatively little "wobble"—and rapidly to correct swings to the right by moving back to the left once more. The effect of alcohol appears to be to produce a shift of the mean driving line from the left towards the crown of the road ($p<0.01$). With increasing dosage there is an increasing swing or "wobble" about this new, more central position ($p<0.01$), together with a tendency to tolerate swings to the right but rapidly to correct swings to the left ($p<0.01$). There was, furthermore, greater variability in the positioning of the car in negotiating a corner ($p<0.01$).

Effect of Alcohol on Speed

In this experiment there were no clear-cut group effects on speed of driving. Mean driving speeds are insignificantly different for all doses. Variability in speed around a mean shows a tendency to rise and fall through time with blood alcohol rise and fall, but this again is not significant. It is possible that the large effect of practice on speed is camouflaging any alcohol effect for the group. Changes in speed of driving after alcohol were found to be closely related to personality characteristics. These are discussed below.

Effect of Alcohol on Steering-wheel Movement

Like error, steering-wheel movement increases progressively as blood alcohol increases. The regression of amount of change of steering-wheel movement on blood alcohol is shown in Fig. 4. This regression is linear and is highly significant ($p<0.001$). There is also a decrease in the consistency of steering-wheel movement after alcohol ($p<0.01$). The decrease in consistency appears to be due to a greater variability in the timing of responses to a corner.

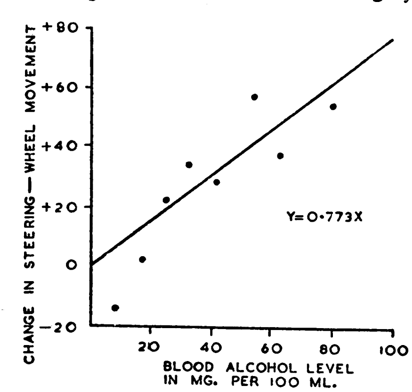

FIG. 4.—Regression of steering-wheel movement on blood alcohol level. Each point is mean of 80 paired values.

As might be expected, the amount of steering-wheel movement is related to the amount of tracking error made. The relationship is U-shaped, such that there is an optimum amount of movement for controlling the car, both less and more movement resulting in increased error. Following alcohol there is an increasing tendency to make either too little or too much movement in negotiating a particular corner, though the predominant effect is to make too much.

B. Individual Differences in Response to Alcohol

Although the latin square design used makes comparison of the performances of individuals difficult, certain features nevertheless emerge. There is undoubtedly a considerable range of individual variation in response to alcohol. This is summarized in Table II, which gives the number of subjects changing their score after alcohol by varying

TABLE II.—*Number of Subjects Showing Different Percentage Change in Scores After Alcohol (Dose 4)*

Measure	Percentage Change of Score											
	Decrease					Increase						
	−50	−40	−30	−20	−10	+10	+20	+30	+40	+50	+60	+70
Error	1	0	2	2	5	10	12	4	2	2	—	—
Steering-wheel movement ..	—	—	—	3	5	12	13	3	3	—	—	1
Time	—	—	4	5	11	13	5	2	—	—	—	—

amounts. The changes are expressed as percentage change from their own no-alcohol score. Tracking error shows a wide scatter. Though the distribution is fairly heavily skewed towards increased error after alcohol, 10 of the 40 subjects show reduced error, one as much as 50% reduction. This subject, however, showed also one of the largest reductions in speed, and achieved a high degree of accuracy by driving extremely slowly. Time scores, on the other hand, are distributed fairly normally around the "no change" position.

An attempt has been made to relate these individual differences in response to alcohol to various personal characteristics. No relationship was found between response to alcohol and differences in initial level of skill, previous driving experience, age, sex, or drinking habits. The subjects varied widely in their initial level of skill and in previous driving experience, so the lack of relationship between these variables and alcohol effect may be stated with some confidence. The range of drinking habits, however, was small, so that the comparison was between the few individuals who drank once or twice a week and those who drank very rarely. The range was therefore too small to draw conclusions on the lack of relationship.

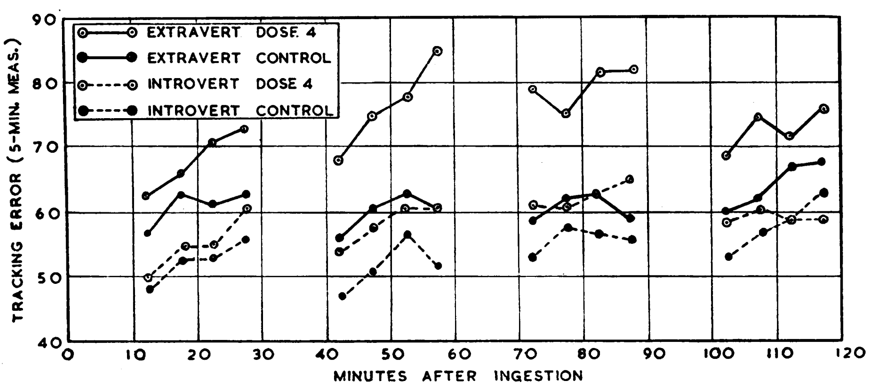

FIG. 5.—Comparison of the tracking error of extraverts and introverts under no alcohol and dose 4 conditions. Extraverts $n=7$; introverts $n=9$.

Scores obtained, for 35 subjects, on the extraversion scale of the Maudsley Personality Inventory were well distributed. The mean was 10.24 (sigma 4.53) as compared with the standard norm of 10.94 (sigma 4.74). Performance scores were compared for a group of subjects scoring high in extraversion and a group scoring low. Fig. 5 shows the mean differences in tracking performance between the resulting seven extraverts and nine introverts. The extravert group made more error ($p<0.05$), were less consistent in car positioning ($p<0.05$), and showed a bigger increase in error during each period of driving ($p<0.01$). The effect of alcohol on error was greater for the extravert group ($p<0.05$), the extraverts having an average increase of 23% and the introverts of 6%.

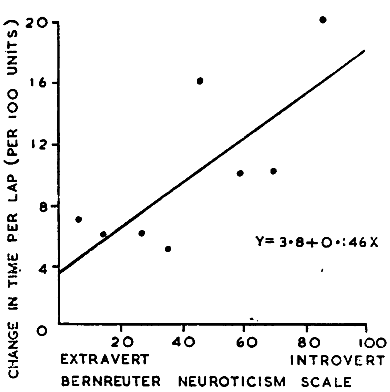

FIG. 6.—Regression of change of speed after alcohol on extravert–introvert score. Each point plotted is mean of five subjects.

The extraverts responded to alcohol in a similar manner, but the introverts showed more varied responses. For example, the extraverts all increased their tracking error after alcohol, whereas two of the introverts made less error. This is especially clearly shown in the effect of alcohol on speed of driving. The extraverts showed very little change of speed after alcohol, but the introverts changed considerably. The nearer the introvert end of the scale they were, the more speed changed. They subdivided, however, into two distinct groups, one of which speeded up very considerably, and the other slowed down. It has not so far been possible to relate this to any personal characteristics. Fig. 6 shows the regression of change of speed on extraversion–introversion as measured by the Bernreuter Neurotic Inventory. This regression is linear and is significant at the 5% level. Comparing those scoring more than 50 on the Bernreuter with those scoring less than this in terms of whether they change speed by more or less than 8 units gives a χ^2 significant at better than 0.01. It would appear that personality characteristics—at least those of the extravert–introvert dimension—are related to the effects of alcohol.

DISCUSSION

It is now generally agreed that a relationship exists between the concentration of alcohol in the blood and the appearance of clinical signs of intoxication. The definition of intoxication based on clinical evidence is, however, a variable one. Liljestrand (1940) gives evidence of a considerable variation in diagnoses made by different clinicians on people who all had blood alcohol concentrations between 100 and 150 mg. per 100 ml. Moreover, the range of blood alcohol concentrations at which people are judged intoxicated is very wide. Goldberg (1951) has shown that the level at which 50% of people are judged clinically to be intoxicated varies with the legal definition in different countries. In America it has been defined by the National Safety Council as 150 mg. per 100 ml., in Sweden it is 100–120 mg. per 100 ml., and in Denmark and Norway 80 mg. per 100 ml.

The level of alcohol in the blood at which people are diagnosed clinically to be intoxicated, besides being variable, tends to be high in comparison with the concentrations used here. This is not surprising, since an estimate of impaired behaviour is made in the absence of any criterion of normal behaviour for that individual, so that the impairment must be obvious before it is detected, and since it is known that people can compensate for their reduced efficiency over the short periods of time during which they are examined. It does not follow, however, that, because no impairment is found in clinical tests, more complex skills, like driving, will also be unaffected.

The present study shows that performance begins to deteriorate with very low blood alcohol concentrations, certainly of the order of 20–30 mg. per 100 ml., and that the deterioration is progressive and linearly related to blood alcohol level. There is, in this study, no evidence of a threshold effect.

The impairment of performance was shown most clearly in the operation of the controls. As the aim of the task was primarily to track, it is perhaps not surprising that in attempting to retain a level of accuracy the operation of the steering-wheel should be most affected. Efficiency in using the steering-wheel is indicated by the amount of tracking error which results. With practice the amount of steering-wheel movement made goes down without a reduction in the accuracy of tracking, whereas after alcohol tracking error increases despite an increase in steering-wheel movement. This suggests that timing of the steering-wheel movements was upset. The decrease in consistency of the movements required to negotiate a corner supports this view. The importance of timing of control movements in a complex skill has been stressed previously by Bartlett (1943), and adverse conditions such as fatigue have been shown to have a marked effect on timing (Drew, 1942 ; Russell Davis, 1948).

The work of Cohen *et al.* (1958) is interesting additional evidence. While the task used in this present study reasonably reflects the tracking aspect of driving, it is almost completely free of hazard and risk-taking. These authors have shown that an amount of alcohol not much larger than the biggest dose used in this experiment produced a significant increase in the hazards in which drivers became involved. From the two studies it is reasonable to assume that not only will drivers become involved in greater hazards with this amount of alcohol but they will be less efficient in dealing with them.

It is suggested, furthermore, that the results reported here show that the level of alcohol in the blood is a good indicator of the extent of impairment of performance. It may be pointed out that the blood alcohol levels reported by Cohen *et al.* (1958) seem surprisingly low. Assuming their drivers to weigh rather more than 11 stone (70 kg.), on average, their two doses correspond fairly closely to the smallest and biggest used here. Their blood samples, however, would appear to have been taken almost two hours after subjects began to drink. If this is so, the blood alcohol levels correspond very closely to those found here. They report a concentration of 4 mg. and 58 mg. per 100 ml. for the two doses. At two hours comparable figures in this experiment were 6 mg. and 62 mg. per 100 ml.

While this in no way affects the conclusions reached by these authors about the effect of such doses on performance, it does affect their discussion about "safe" levels of blood alcohol. At the time of the tests the blood alcohol levels in their drivers would almost certainly be at least 10–20 mg. per 100 ml. higher than those reported. Even so, their experiments, and these, suggest a marked impairment of performance on such tasks with blood alcohol levels of 60 to 80 mg. per 100 ml.

In view of the known difficulty of clinical estimates of impairment in such situations, and of the individual's capacity, if he is capable of realizing that he is under test, to compensate temporarily for loss of efficiency, estimation of blood alcohol level would seem the most direct way of assessing impairment. Estimation of the alcohol excreted in urine and in breath allows a close approximation to blood alcohol. In these experiments, urine alcohol agreed very closely with blood alcohol. Breath analysis, which has enormous administrative advantages over both blood and urine analysis, can, from these results, given a suitable instrument, also give a very close approximation.

It would seem fairly clear, from these results, that the efficiency with which a task like driving is performed is likely to decrease progressively as blood alcohol rises. At some point the loss of efficiency is likely to be large enough to constitute a danger in a practical driving situation. As this experiment has been carried out in a laboratory, necessarily free of the hazards and many of the motivating features of a real-life situation, it is not possible, from these results, to say at what level of blood alcohol the increased risk of accident would become unacceptable. Some evidence on this is available from the experience of the U.S.A., Denmark, Norway, and Sweden, where rather different cut-off levels are used.

Individual differences in response to alcohol appear to be related, at least in part, to personality characteristics, especially those of extraversion–introversion. Eysenck (1953) has collected the evidence for the existence of this dimension of personality and has postulated (Eysenck, 1957a) that extraverts would be more susceptible to the effects of depressant drugs like alcohol. The extraverts in this experiment behaved as a group, and tend to confirm Eysenck's hypothesis. The introverts do not behave as a group. It is of interest that all the scales used agreed on the extravert end but did not agree on the introverts. It is possible that the almost bimodal effect noted on change of speed for introverts reflects the intrusion of some other personality characteristic not tested in this experiment. The test which showed this bimodal effect most clearly was the Bernreuter, which uses a more "neurotic" criterion of introversion than the Maudsley.

In this experiment extraverts appear not to be bothered by the extra stress imposed by alcohol. They drive at much the same speed as before, make very little additional corrective movements, but make much greater error, are less consistent, and deteriorate more rapidly during 20-minute driving periods. Introverts, on the other hand, appear to be striving to compensate for the alcohol effect, and to be anxious to demonstrate their efficiency. They over-react to the situation, make more corrective movements of the steering-wheel, and change their speed markedly. Some slow right down, presumably in an attempt to achieve accuracy, though they do not necessarily do so, while others appear to be attempting to demonstrate how quickly they can drive, again not always with a proportionate loss of efficiency.

SUMMARY

An experiment has been carried out to investigate the effects of small doses of alcohol on a complex skill.

Four alcohol doses and a placebo dose were used. The peak blood alcohol concentrations from the doses were approximately 20, 40, 60, and 80 mg./100 ml. of blood.

Urine and breath analyses were compared with direct blood analysis. Urine alcohol peaked later and higher than blood, but breath alcohol followed blood alcohol in time. The ratio of urine alcohol to blood alcohol was 1.252 : 1.

Three kinds of breath-testing apparatus were used. Best results were obtained from the "breathalyser." The others either showed high constant errors or were unreliable. The results from the breathalyser were good enough to warrant its consideration from a practical point of view.

Mean error showed an increase with increase in blood alcohol, amounting to about 16% deterioration with a blood alcohol concentration of some 80 mg./100 ml. Part at least of the increase in error is to be explained by a significant tendency for subjects to move towards the right-hand side of the road after alcohol and also by less consistent positioning. Error scores and control movement scores also showed a variation in time, rising and falling in a way similar to that of blood alcohol.

Mean speed showed no significant change, but marked individual differences in speed after alcohol were found.

Control movements, as measured by steering-wheel movement, showed significant increases and a significant reduction in consistency.

Age, sex, previous driving experience, and previous drinking habits, within the limits available, showed no relation to individual differences in response to alcohol.

Personality ratings, especially those relating to extraversion–introversion, showed a definite relation to behaviour changes. Extraverts did not change either speed or control movements very much, though they were less consistent in control movements, but showed large increases in error. Introverts changed speed considerably, though it is not possible to differentiate between those who slowed down and those who speeded up. Control movements also increased, but were relatively consistent. Error may or may not increase, but the mean error score was significantly less than that for extraverts.

APPENDIX

Average Scores For Various Aspects of the Tracking Task, After Each Alcohol Dose

Performance Variable	Dose 0	Dose 1	Dose 2	Dose 3	Dose 4
Tracking error	227	230	235	246	246
Kerb bumpings	209	255	350	260	359
Inconsistency in tracking ..	4·82	5·08	5·63	5·78	5·53
Time per lap	403	390	386	393	398
Steering-wheel movement ..	674	673	690	708	764
Inconsistency in steering-wheel movement	3·61	3·51	3·61	4·03	4·15

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The World Health Organization has published its eighth annual volume of vital statistics of various countries for the year 1955 (699 pp., £3). The number of subjects has been increased in order to make possible a more thorough analysis of the factors influencing public health. In some 700 pages the report includes, in addition to the subjects usually covered, detailed specific death rates, by sex and by age, for the main sites of malignant neoplasms (lungs, digestive organs, breast and genital organs, lymphatic and haematopoietic tissues). It also presents for the first time a type of information previously unobtainable—namely, the distribution of cases of communicable disease by sex and by age. Among some other statistics not previously included are the numbers of health personnel in various countries, hospital establishments, and numbers vaccinated against certain communicable diseases in 1955.

SIMPLE CLINICAL HEARING-TESTS FOR VERY YOUNG OR MENTALLY RETARDED CHILDREN

BY

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In the course of an inquiry into problems of deaf and partially deaf children in mental deficiency hospitals and occupation centres carried out during 1955, it became apparent that there was need for a series of graded clinical hearing-tests, suitable for routine application by medical officers and psychologists concerned with official ascertainment of handicapped children, which could be repeated at intervals by different examiners and recorded in some standard fashion. Originally, with the intention of obtaining results as precise as possible, some form of instrumental testing was envisaged, and numerous trials were laboriously carried out with drums, whistles, pitch-pipes, tuning-forks, and, in a few cases, with pure-tone audiometers; but it was soon obvious that the difficulties of routine testing of mentally handicapped children with what were, to them, completely meaningless sounds were insurmountable. Since, in any case, the aim was primarily *to obtain reliable information concerning the child's capacity to hear with comprehension in everyday situations*, it became clear that the tests should be based on his reactions to familiar homely sounds and particularly to "live" speech. It is hoped to give in detail elsewhere the reasons for employing each individual item in the present series.

This paper is intended only to describe the general principles underlying the tests, the materials used, the procedure which was eventually decided upon, and the responses which may be expected. In order to establish comparative developmental standards, it was found necessary to keep checking the performance of mentally handicapped children against that of young normal children attending day nurseries and infant schools, and in the process it was discovered that in these groups, also, the tests could usefully be employed for sorting out children with difficulties of hearing and speech. The tests can be carried out in any quiet room, and the material required is easily obtainable. They are simple enough in content to be readily grasped by young children, but when correctly applied provide clear-cut evidence regarding capacity for auditory discrimination. Since it is essential for adequate assessment to observe *how* the child responds, the tests should be carried out personally by the medical examiner (or psychologist) or in his presence. They are not intended at this stage for large-scale application by ancillary personnel. Suitable techniques are already available for this purpose (Ewing, 1957).

Categories of Hearing-tests

The hearing-tests for children at present in use fall into two broad categories: (1) those which are designed as preliminary *screening devices*, first to sort out as quickly and effectively as possible children whose speech and hearing is below the normal for their age and who therefore require further investigation, and then to provide a means of recording results for future reference; and (2) those more precise *diagnostic procedures* which seek to define more accurately the nature and extent of the speech and hearing disability.