Sensorimotor and physiological effects of various alcoholic beverages*

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Summary: Effects of a standard dose of alcohol (1.3 g/kg) in the form of Canadian rye whisky, Canadian beer and a sparkling table wine were compared with those of a nonalcoholic carbonated control beverage. Sixteen young male and eight female subjects, all moderate drinkers, were tested in a Latin square design. Measurements were made on the pursuit rotor and quantitative Romberg tests, and of skin temperature, heart rate, malar flush and blood alcohol concentration during the prealcohol baseline period and at regular intervals over the 4-hour drinking period.

The three alcoholic beverages produced blood alcohol curves that did not differ significantly. All three alcoholic beverages produced increasing sensorimotor impairment over time, which corresponded in degree to the increasing blood alcohol concentration. There were no significant differences between the three alcoholic beverages on either the sensorimotor or physiological measures at any blood alcohol value. The results of this study indicate that the degree of impairment after alcohol ingestion in a socially relevant manner is not dependent on the type of beverage consumed, but only on the resulting blood alcohol concentration.

Résumé: *Les effets physiologiques et sensorimoteurs de diverses boissons alcooliques*

Nous avons comparé les effets d'une dose standard d'alcool (1.3 g/kg), sous forme de rye whisky canadien, de bière canadienne et d'un vin de table mousseux, à ceux que donne une simple boisson gazeuse nonalcoolisée. Les sujets de l'étude étaient 16 jeunes hommes et 8 femmes, tous buveurs modérés. Ils ont été soumis au plan statistique du carré latin. Les mesures, obtenues des épreuves quantitatives de Romberg, de suite à la trace ("pursuit rotor"), de la température cutanée, du rythme cardiaque, de la rougeur des joues, et de l'alcoolémie, ont été faites durant la période précédant l'ingestion d'alcool et à intervalles réguliers durant le temps de la période de 4 heures d'ingestion d'alcool.

Les courbes de l'alcoolémie notées avec les trois boissons alcooliques ne différaient pas notablement. Avec le temps, les trois alcools ont produit une altération croissante des fonctions sensorielles et motrices, dont le degré était fonction du degré de l'alcoolémie. Les trois boissons alcooliques ont donné virtuellement les mêmes mesures physiologiques ou sensorimotrices, à n'importe quel degré d'alcoolémie. Il appert de cette étude que le degré d'ébriété après ingestion d'alcool, pris selon les habitudes de notre société, ne dépend pas de la nature ou du type d'alcool consommé, mais uniquement du degré de l'alcoolémie.

The question of differences in intoxicating potency of various alcoholic beverages has been the subject of folklore and scientific investigation for many years. One of the main questions has been whether beer and wine are less intoxicating than distilled spirits when the doses are such as to provide an equal amount of absolute alcohol. Various investigators[1-6] have reported a more rapid and greater increase in blood alcohol concentration after ingestion of distilled spirits than after ingestion of the same amount of alcohol in the form of beer. Various measures of intoxication have also shown greater impairment after ingestion of distilled spirits than after ingestion of the other beverages, consistent with the differences in blood alcohol values. Dussault, Burford and Chappel[7] verified these results with Canadian beverages and Canadian subjects. This comparison is of special interest in view of the finding that Canadian rye whisky and Scotch whisky differ substantially from bourbon with respect to the types and amounts of congeners they contain.[8]

If these differences are indeed valid under ordinary conditions of use there would be important implications with respect to the undesired consequences of intoxication such as motor vehicle accidents. However, most of the experimental studies in the literature have used schedules of alcohol consumption that bear little resemblance to the manner in which alcohol is generally consumed. For example, in the study by Dussault *et al*[7] the subjects were require to drink amounts of alcohol equivalent to 240 ml of Canadian spirits in a 25-minute period after a 12-hour fast. The purpose of the present study, therefore, was to repeat the comparison with Canadian beverages under drinking conditions more closely comparable to those in which alcohol is generally consumed.

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Methods

Subjects

The subjects in this study were 16 male and 8 female healthy volunteers. The male subjects were 20 to 30 years of age (mean, 25.0 years) and weighed from 52.7 to 90.0 kg (mean, 74.4 kg). The female subjects were 22 to 34 years of age (mean, 27.25 years) and weighed from 53.2 to 74.5 kg (mean, 61.1 kg). Despite the range of body weights, each subject had an essentially normal weight for the respective height. The men were moderate drinkers, using alcohol on the average twice weekly, with about three drinks* on each occasion. More than half of them listed beer and less than one quarter listed spirits as their usual drink. The women were light to moderate drinkers, using alcohol on the average less than once a week, with about 2½ drinks on each occasion. Subjects were asked to refrain from taking any drugs or alcohol for 24 hours before the experimental sessions. Their conformity with this request was verified by a routine drug-screening analysis of urine samples and the zero-time blood sample taken on each test day.

To minimize the variability between sessions the women were not tested for 2 days before, during and for 2 days after their menses.

Procedure

One week before the first experimental session each subject was given a thorough medical examination, then ten 1-minute practice trials on the pursuit rotor test (see below). At the beginning of each experimental session subjects received a standard light lunch consisting of a bowl of soup and a meat sandwich. No other food or beverage was provided before the test. The subjects were then carried through the experimental procedure in pairs, in a living-room-like setting, with a minimum of direct disturbance by the experimenters. Because there was only one apparatus available for each type of test procedure, the starting times were staggered by 30 minutes so that each subject would be tested at the same elapsed time after the end of each drinking period. After the end of each experimental session the subjects were escorted to the Clinical Institute of the Addiction Research Foundation, where they remained under medical supervision until the apparent effects of the alcohol had disappeared and the blood alcohol value had decreased to less than 30 mg/dl.

The basic experimental design was a 4 x 4 Latin square, in which each of four subjects was tested under the effects of placebo and three different alcoholic beverages on occasions at least 1 week apart. Because of these intervals between tests with the same subject, two replications of the Latin square design were conducted as one "block" with eight male subjects and then the whole block was repeated with the other eight male subjects. Data for the eight female subjects were analysed in a separate block. To minimize the effect of systematic order, each of the six Latin squares was different from the others.

Beverages and drinking schedule

The alcoholic beverages included a Canadian rye whisky, 40% alcohol by volume, mixed 1:1 with ginger ale; a Canadian lager beer, 5% alcohol by volume; and a sparkling rosé table wine, 11.26% alcohol by volume. These beverages were chosen on the basis of their popularity as reflected by sales figures in Ontario. The control beverage was a carbonated caffeine-free soft drink, the volume of which was midway between the respective volumes of beer and the rye and ginger ale mixture. All beverages were served chilled and the doses were adjusted according to the body weight of the subjects on each experimental day to achieve a standard alcohol dose of 1.3 g/kg.

The schedule of beverage consumption is indicated in Table I. This schedule was based on information derived from two sources: the work of Takala, Pihkanen and Markkanen,[5] in which a program of alcohol administration was set up on the basis of the observed rates at which subjects drank under *ad libitum* conditions, and unpublished observations by R.E. Popham on the patterns of consumption by tavern patrons, including a group who would be considered alcoholics by conventional clinical criteria. The experimental schedule is shown in Table II. The total session consisted of a 30-minute period for baseline measurements, then four 75-minute blocks, each consisting of a 45-minute drinking period then a 30-minute test period. The total beverage ration for each drinking period was given to the subject at the start of each block, and he was permitted to drink it *ad libitum* during the 45-minute drinking period.

Test procedures

Sensorimotor tasks: The Photo Electric Rotary Pursuit apparatus (Lafayette Instrument Co., Model 2203 ET) was used as a measure of eye-hand coordination. Subjects were required to follow a moving light (30 rpm) in a square pattern with a photosensitive wand. Cumulative time on target was measured for each trial. To control for the learning effect, subjects were given 10 practice trials of 1-minute duration during the preliminary session and an additional set of 5 trials of the same duration before the baseline period of each experimental session. Each testing period throughout the experimental sessions involved five

Table I—Drinking schedule*

Time from start of test (min)	Dose of absolute alcohol per 70 kg (ml)	Volumes of beverage containing indicated doses of absolute alcohol		
		Beer (ml)	Rye whisky (ml)	Wine (ml)
30-75	43.5	870	108.8	386.3
105-150	24.5	490	61.3	217.6
180-225	22.5	450	56.3	199.8
255-300	21.0	420	52.5	186.5

*Doses were those used by Takala, Pihkanen and Markkanen,[5] lowered by 25% to give blood values of 100 to 120 mg/dl instead of 150 mg/dl.

Table II—Experimental schedule*

Time	Procedure
Arrival	Weight measured Urine sample taken 5-trial practice on pursuit rotor test Lunch
0-30 min	Baseline measures Pursuit rotor - 5 trials Romberg Skin temperature Heart rate, malar flush Blood sample
30-75 min	Drink I
75-105 min	Testing (as above)
105-150 min	Drink II
150-180 min	Testing
180-225 min	Drink III
225-255 min	Testing
255-300 min	Drink IV
300-330 min	Testing
330 min	Breathalyzer reading taken. Subject escorted to clinic for recovery.

*Each experimental session was run according to this schedule on each experimental day.

*For the purposes of this study a drink was defined as 45 ml of Ontario spirits or an equivalent volume of other beverage in terms of absolute alcohol content.

1-minute trials with a 30-second rest between trials.

The Romberg test was quantified by means of an apparatus consisting essentially of two weighted cords attached to a headband worn by the subject, passing over pulleys to pen recorders, which provided continuous records of front-to-back and lateral body sway.[9,10] Subjects were tested in three positions: feet together, eyes open; feet together, eyes closed; and feet in line, eyes open. The frequency and maximum amplitude were recorded for each direction of sway during 1 minute in each of the positions. For analysis the maximum amplitude score and the total frequency score for all three positions were obtained at each test time.

Physiological tests: Immediately after completion of the sensorimotor tasks the skin temperature, heart rate and degree of malar flush were measured. Because of equipment failure the degree of malar flush was not measured in the women. Skin temperature was measured by means of an electronic thermometer (model no. 44TA, Yellow Springs Instrument Co., Yellow Springs, Ohio) with a banjo thermister probe held to the subject's cheek. Heart rate and degree of malar flush were recorded on a physiograph (Texas Instruments Inc., Houston, Texas), using a photosensitive (red reflectance) transducer held to the cheek.

Blood alcohol measurements: Samples of fingertip capillary blood were obtained with a disposable microlancet and 50-μl capillary pipettes at the end of each test block. The samples were immediately laked and deproteinized for analysis of blood alcohol concentration by gas-liquid chromatography with n-butanol as internal standard.[11]

Results

Blood alcohol curves

Men: The blood alcohol curves for the two successive blocks of eight men were plotted separately before the results were pooled. These curves (Fig. 1), as anticipated, showed a progressive increase in blood alcohol concentration over time. They also indicated a difference between the two groups of men, which proved to be significant on analysis of variance ($F = 35.5$, df 1,14; $P < 0.01$). However, there was no significant difference between the blood alcohol curves for the various beverages among all 16 subjects, and no interaction between beverages and the two subject groups.

Women: The group of eight female subjects was analysed separately from the male groups. As had been found with the male subjects, the Latin square analysis revealed no significant effect of order and the subsequent analysis of variance for the three alcoholic beverages showed no significant difference between the various blood alcohol curves (Fig. 2).

Test results

Because there were no significant differences between the blood alcohol curves produced by the three alcoholic beverages, and because each subject served as his own control with all beverages, it was permissible to pool the various test results for all male subjects for a composite Latin square analysis. This revealed no significant effect of order, but there was a highly significant effect of beverages, which was entirely attributable to the difference in results between the placebo and the three alcoholic beverages (Fig. 3). The subsequent analysis was therefore confined to an analysis of variance of the results with the three alcoholic beverages. The data for the female subjects were treated similarly.

Men: Analysis of variance indicated no significant change in baseline (prealcohol) measurements in the four sessions for each subject. With the nonalcoholic control beverage, the gradual decline in heart rate and skin temperature during the session was significant ($P < 0.01$ in each case). This probably indicated a gradual decrease in tension as the session continued. None of the other test results changed.

In contrast, after consumption of each of the three alcoholic beverages the heart rate did not change throughout the session. Consequently, the later values were significantly higher than those found with the control beverage ($P < 0.01$ at the last three test periods). The difference is consistent with the known tendency for ethanol to produce tachycardia. Skin temperature, however, also decreased

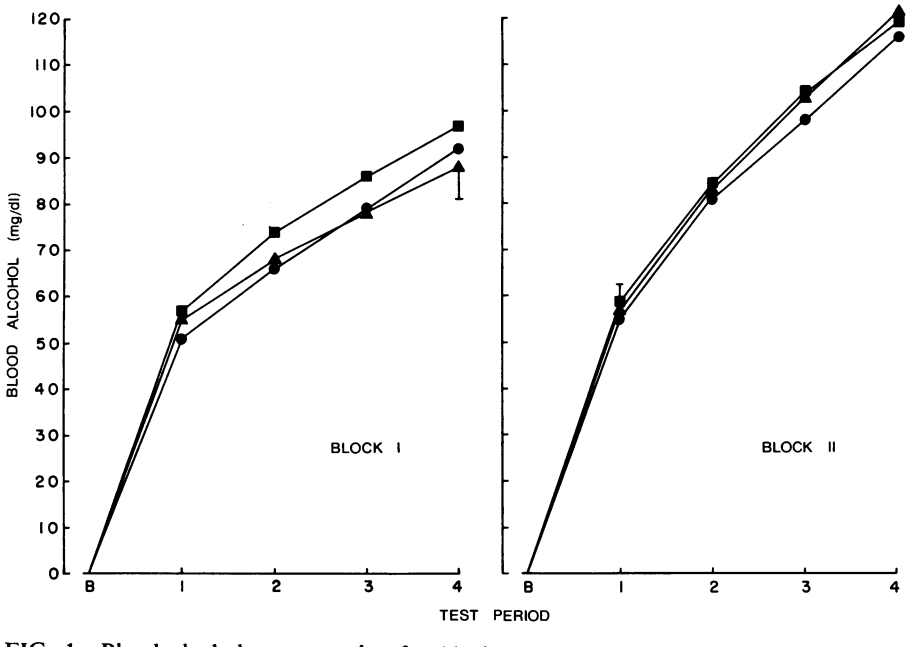

FIG. 1—Blood alcohol concentration for blocks I and II of male subjects. Points represent mean of eight values each for eight subjects receiving same dose of of alcohol as rye ▲——▲, wine ■——■ and beer ●——●. The largest single standard error of any point is represented by the vertical bar in each graph.

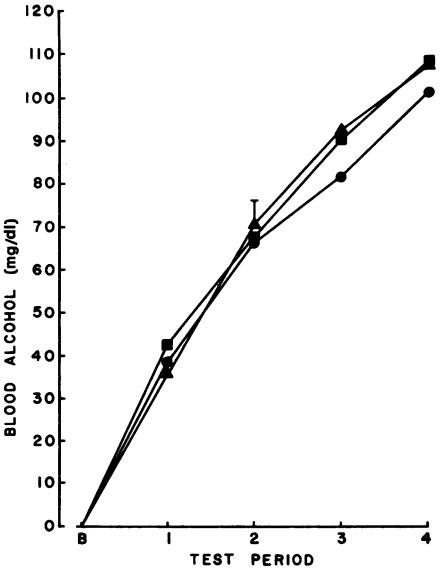

FIG. 2—Blood alcohol concentration of eight female subjects. Symbols as in Fig. 1. Largest single standard error of any point is represented by the vertical bar in the graph.

steadily through the test sessions with the alcoholic beverages just as with the control. Consequently there was no significant alcohol effect on skin temperature. There was a similar, though less clear-cut, pattern with malar flush.

All the results of motor tests showed a clear change over time (Fig. 3), which in effect corresponded to the progressive change in blood alcohol concentration. The curves were distinctly different from those obtained with the control beverage, but those for the three alcoholic beverages did not differ from each other.

Women: As with the men, there was no change in baseline readings in the four test sessions and no significant effect of order in the Latin square analysis.

With the control beverage there was again a gradual decline in heart rate during the afternoon ($P < 0.01$) but the skin temperature did not decrease appreciably. The scores for the Romberg test, both frequency and amplitude, also declined significantly during the session with the control beverage ($P < 0.05$ in each case). This suggests that the decrease in tension resulted in improved muscular coordination.

After the three alcoholic beverages the heart rate increased slightly but not significantly. However, just as for the men, the difference between the postalcohol and control values increased as the blood alcohol concentration increased ($P < 0.01$ at the last three test periods). Skin temperature again showed no significant effect of alcohol. Pursuit rotor and Romberg results showed, as with the men, a highly significant effect of alcohol, increasing steadily as the blood alcohol concentration increased but showing no difference between the three alcoholic beverages (Fig. 4).

Discussion

The difference in blood alcohol curves between the two groups of male subjects was not anticipated. However, an examination of the drinking histories revealed that the subjects in block II regularly consumed more alcohol than those in block I. The steeper blood alcohol curves for the block II subjects are, therefore, entirely consistent with the observation by Newman[12] that heavier drinkers tend to absorb the alcohol more rapidly. Consistent with this, the female subjects were the lightest drinkers and showed the slowest initial increase in blood alcohol concentration (Fig. 2). This appears to be true regardless of which beverage is involved.

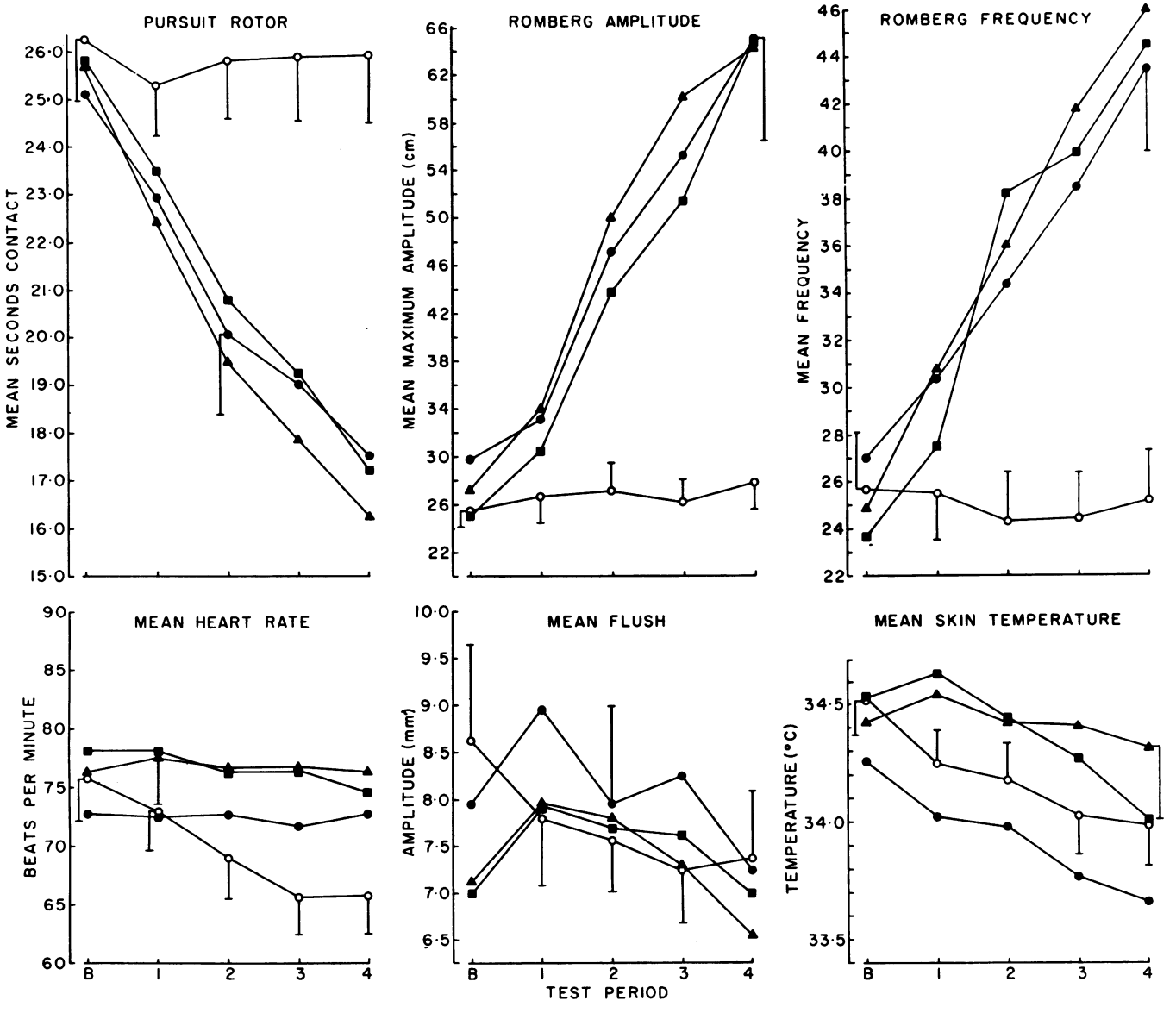

FIG. 3—Results for 16 male subjects on tests as labelled at various times after drinking rye ▲——▲, wine ■——■, beer ●——● and the control beverage ○——○. The largest single standard error is shown for the alcoholic beverages and the standard error is shown for each point on the control beverage curve.

This would have introduced a serious problem for interpretation of results of studies based on comparisons of groups of subjects who received different beverages. But it is of no importance in a Latin square design, in which each subject receives all treatments and serves as his own control. For this reason the Latin square design maximizes the chances of showing a difference between beverages if there is one, and therefore the absence of such a difference in the present results is all the more striking.

The results in Figs. 3 and 4 indicate a more clear-cut and consistent effect of alcohol on the tests of psychomotor performance than on the autonomic measures. The reason for the difference is not entirely evident, but two or three possible explanations may be suggested. One is that homeostatic changes take place much more rapidly for autonomic functions, especially those affecting heart rate, than for purely central nervous system functions. Therefore, the effects of alcohol may have been more rapidly corrected or more variable over time. A second factor is that the different alcoholic beverages were adjusted to provide the same dose of ethanol, but differed substantially in the total fluid volume. This factor might have introduced variability in the cardiovascular measures, tending to obscure any common effect of ethanol. On the other hand, this might have caused an apparent difference among the various beverages, so that the absence of such a difference is even more striking. A third possible explanation is that differences in emotional tension connected with the test situation would introduce greater variability in the autonomic measures than in the measures of psychomotor performance. Although the test situation was a comfortable one. and the novelty was lost on repeated sessions with the same subjects, it is impossible to exclude this factor completely.

By far the most important finding of this study is the absence of any significant difference between the three alcoholic beverages, at the same dose of ethanol, in either the blood alcohol curves or the observed effects. It is therefore necessary to account for the difference between these findings and those of other investigators such as Dussault *et al.*[7] The explanation is probably a very simple one, resting on well established physiological facts. Ethanol is absorbed from the gastrointestinal tract by simple physical diffusion,[13] so that the rate of absorption is dependent on the concentration gradient of ethanol between the content of the lumen and the blood perfusing the submucosal capillary network. In addition, the diffusion proceeds more rapidly through the thinner mucosa of the small intestine than through the gastric mucosa. Therefore, absorption proceeds more rapidly when gastric emptying time is shorter; delayed gastric emptying, resulting from gastric

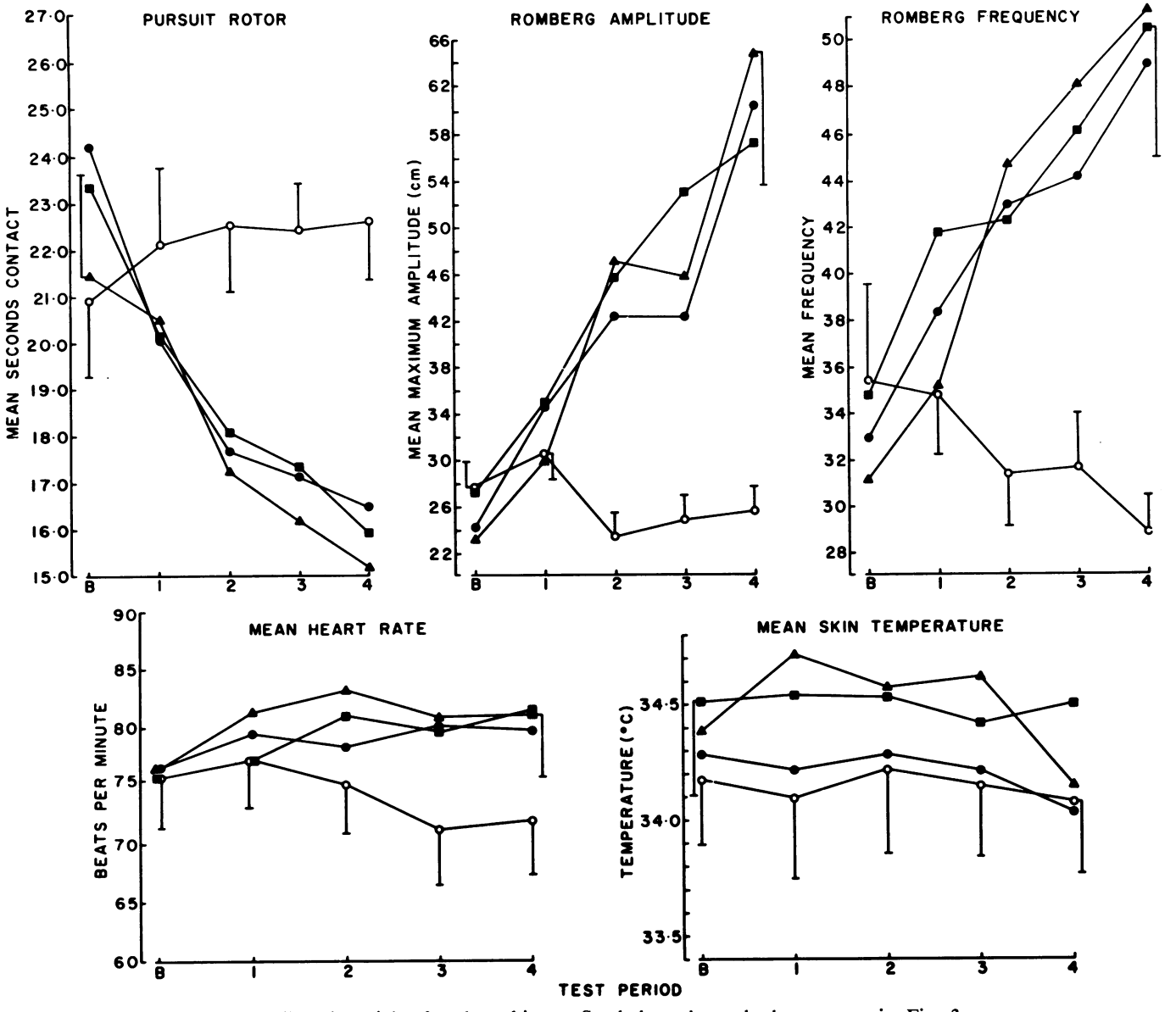

FIG. 4—Test results as labelled for eight female subjects. Symbols and standard errors as in Fig. 3.

irritation, seems the most probable explanation for the slower increase in blood alcohol concentration in the less experienced drinkers (Figs. 1 and 2).

For these reasons, the ingestion of the entire amount of alcohol as a single large dose, taken on an empty stomach, would maximize the importance of the concentration gradient as a determinant of the rate of increase in blood alcohol concentration. This is the situation in the study by Dussault *et al.*[7] In contrast, the ingestion of alcohol in divided doses over a period of time, and following food intake, would minimize the importance of the concentration gradient, as in the present study. In real life, even alcoholics show a drinking pattern much closer to that used in this experiment. The reported difference between beverages in the study by Dussault *et al*[7] was evident only during the 1st half hour. After this time the differences in concentration gradient across the intestinal mucosa would have become minimal, and with the increasing approximation of the blood values to each other, the effects of the alcohol also became relatively independent of the beverage type.

The present findings suggest that the undesired effects of acute intoxication, such as behavioural disturbances, motor vehicle accidents and other consequences of central nervous system impairment, are unlikely in most instances to be greatly influenced by the choice of alcoholic beverage, but heavily dependent on the amount and rate of ethanol consumption. The same would hold true for undesired interactions between ethanol and other drugs that affect the central nervous system, such as antihistaminics, minor tranquillizers and barbiturates.

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Retrospect

Preventive medicine

The greatest advance in all time, in preventive medicine, arose from the study of fermentation in wine which was shown to be due to bacteria and the question arose, if fermentation was due to bacterial growth, why not also putrefaction, and perhaps all disease.

The discovery of the germ cause of disease by Louis Pasteur more than fifty years ago, and the success of the preventive inoculation against anthrax slowly unravelled the mystery of infection and prophylaxis, and made possible the advance of hygiene, and modern sanitary science. As the causal germs of contagious disease have been discovered and understood, one by one diseases have been conquered by preventive treatment. Diphtheria has been robbed of its terrors within living memory, and typhoid practically banished.

The facts concerning germ infection, discovered by Pasteur, were afterwards applied by Lister in the prevention of wound infection and later, the same principle of germ infection was applied to prevent the spread of so-called "hospital diseases" such as gangrene and erysipelas.

A later and more modern development is the science of hygienic habits based on our knowledge of the germ cause of disease, which is being taught in our schools to-day. The danger of contact with sick persons; the danger of eating contaminated food; precautions as to what goes into the mouth, food, finger, or what not, and what comes out, cough, expectoration, or sneeze, all these common every day channels for the dissemination of disease are now popular knowledge. Though "foolproof" protection can be bestowed by vaccine and inoculation against many serious diseases prevalent in this zone, yet, for protection against other diseases such as tuberculosis, we must depend upon intelligent application of sanitary measures, and careful personal habits. This class of protection cannot be given — it must be learned. — Ferguson RG: Medical examination of school children. Can Med Assoc J *15: 397, 1925*