Sensorimotor and Physiological Effects of Various Alcoholic Beverages

H. Kalant1, A. E. LeBlanc, A. Wilson and S. Homatidis

The question of differences in intoxicating potency of various alcoholic beverages has been the subject of many scientific investigations. One of the main questions has been whether beer and wine are less intoxicating than distilled spirits, in doses which provide an equal amount of absolute alcohol. Several investigators (5, 9, 11-14) have reported a more rapid and higher rise in blood alcohol following the ingestion of distilled spirits than after 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 of the other beverages, consistent with the differences obtained in blood alcohol levels. Dussault et al (2) verified these results with Canadian beverages and Canadian subjects. This comparison is of special interest, in view of the finding that Canadian rye whiskey and Scotch whiskey differ substantially from bourbon with respect to the types and amounts of congeners they contain (6).

If these differences are indeed valid under ordinary conditions of use, and if differential price, by taxes or other means, can modify the patterns of consumption of different beverages in a population (1) such information could form the basis of social policy for minimizing the undesired consequences of intoxication, such as motor vehicle accidents. However, most of the experimental studies in the literature have employed 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 (2), the subjects were required to drink amounts of alcohol equivalent to eight ounces of Canadian spirits in a 25-minute period, following a 12-hour fast. The purpose of the present study, therefore, was to repeat the comparison of Canadian beverages with a rate of consumption and drinking conditions more closely comparable to those characteristic of most social (i.e., non-experimental) use of alcohol.

METHODS

Subjects

The experiments were carried out on 16 healthy male volunteers with an age range of 20-30 years (mean 25.0 years) and a weight range of 116-198 lbs. (mean weight 163.7 lbs. = 74.4 kg). Despite the range of body weights, all subjects were of essentially

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normal weight for their respective heights. All were moderate drinkers, who used alcohol, on the average, twice weekly with about 3 drinks on each occasion. More than half of them listed beer and less than a quarter listed spirits as their usual drink. Subjects were asked to refrain from taking any drugs or alcohol for 24 hours before the experimental sessions. For verification a routine drug-screening analysis was carried out on urine samples and the zero time blood sample, taken on each test day.

Procedure

One week prior to the first experimental session, each subject was given a thorough medical examination, followed by 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; no other food or beverage was provided before the test. Following this, the subjects went through the experimental procedure in pairs, in a living-room-like setting, with a minimum of direct disturbance by the experimenters. Since 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 blood alcohol level had fallen to less than 30 mg/100 ml.

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 as described below, on occasions at least one week apart. Because of these intervals between tests with the same subject, two replications of the Latin Square (8 subjects) were run as one block, and then the whole block was repeated with 8 different subjects. To minimize systematic order effect, each of the four Latin Squares was different from the others.

Beverages and Drinking Schedule

The alcoholic beverages employed were a Canadian rye whiskey, 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. The control beverage was a carbonated caffeine-free soft drink, served in a volume mid-way 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 subject on each experimental day.

The schedule of beverage consumption is indicated in Table I. This schedule was based on information derived from two sources. The first was the published work of Takala et al (13), 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. The second was the 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 shown in Table II notes that the total session consisted of a 30-minute period for baseline measures, followed by four 75-minute blocks, each consisting of a 45-minute drinking period followed by a 30-minute test period. The total beverage ration for each drinking period was given to the subject at the start of the block, and he was permitted to consume it at his own rate during the 45-minute drinking time.
TABLE I  Drinking Schedule\textsuperscript{a}

<table>
<thead>
<tr>
<th>Time</th>
<th>Absolute Alc. (ml) per 70 kg</th>
<th>Beer 5% vol ml.</th>
<th>Rye 40% vol ml.</th>
<th>Wine 11.26% vol ml.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-75 min. 0.62 ml/kg</td>
<td>43.5</td>
<td>870</td>
<td>108.75</td>
<td>386.28</td>
</tr>
<tr>
<td>105-150 min. 0.35 ml/kg</td>
<td>24.5</td>
<td>490</td>
<td>61.25</td>
<td>217.56</td>
</tr>
<tr>
<td>180-225 min. 0.32 ml/kg</td>
<td>22.5</td>
<td>450</td>
<td>56.25</td>
<td>199.8</td>
</tr>
<tr>
<td>255-300 min. 0.30 ml/kg</td>
<td>21.0</td>
<td>420</td>
<td>52.5</td>
<td>186.5</td>
</tr>
</tbody>
</table>

\textsuperscript{a} The doses used by Takala \textit{et al} (13) were lowered by 25\% to give blood levels of 100 to 120 mg/100 ml instead of original 150 mg/100 ml. The total dose of ethanol in the experiment was 1.3 g/kg.

TABLE II  Experimental Timetable\textsuperscript{a}

Arrival — Weight, Urine Sample, 5 Trial Practice on Pursuit Rotor, Lunch.

0-30 min.  
Baseline measures  

Pursuit Rotor — 5 Trials  
Romberg  
Skin Temperature  
Heart Rate and Flush  
Blood Sample  

30-75 min.  
75-105 min.  
105-150 min.  
150-180 min.  
180-225 min.  
225-255 min.  
255-300 min.  
300-330 min.  
330 min.  

Drink I  
Testing (as above)  
Drink II  
Testing  
Drink III  
Testing  
Drink IV  
Testing  
End of experimental session — breathalyzer reading taken and \( S \)'s escorted to clinic for recovery

\textsuperscript{a} Each \( S \) was run according to this schedule on each experimental day.

TEST PROCEDURES

\textit{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 photo-sensitive wand. Cumulative
time on target was measured for each trial. To control for the learning effect, subjects
were given ten 1-minute practice trials during the preliminary session and an additional
set of five 1-minute trials prior to the baseline period of each experimental session.
Each testing period throughout the experimental sessions involved five 1-minute trials
with a 30-second rest between trials.

The Romberg test was quantified by means of an apparatus which provided
continuous records of front-to-back and lateral body sway (3, 4). 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 one minute in each of the positions. For analysis, the total amplitude
score and the total frequency score for all three positions was 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. Skin temperature was measured by
means of a Yellow-Springs Electronic Thermometer (model No. 44TA) with a banjo
thermister probe held to the subject's cheek. Heart rate and degree of flush were recorded on a Texas Instruments Physiograph, using a photosensitive (red reflectance)
transducer held to the cheek.

**Blood Alcohol Measurements**

Samples of finger-tip capillary blood were obtained with a disposable microlance and
50 μl capillary pipettes at the end of each test block. The samples were immediately
laked and deproteinized for analysis of ethanol concentration by gas-liquid chroma-
tography with n-butanol as internal standard (8).

**RESULTS**

**Blood Alcohol Curves**

Since the experiment was carried out with two successive blocks of eight subjects, the
blood alcohol curves for the two blocks were plotted separately before the results were
pooled. The blood alcohol curves (Figure 1) indicated a difference between the two
groups, 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 across all 16 subjects, and no interaction between
beverages and the two subject groups. For this reason, and since each subject served as
his own control with all beverages, it was permissible to pool the various test results
for all subjects for a composite Latin Square analysis. This revealed no significant
consistent order effect, 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 (see Figure 2). The subsequent analysis was therefore confined to
an analysis of variance of the results with the three alcoholic beverages.
Physiological Effects

Figure 1  Blood Alcohol Curves in mg per 100 ml, for Blocks I and II. The points represent the mean of eight values each, for eight subjects receiving the same dose of alcohol as rye ▲, wine ■, and beer •. The largest single standard error of any point is represented by the vertical bar in each graph.

TABLE III  Summary of Statistical Analyses for Factors Other Than Alcoholic Beverage

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Analysis of variance, baseline</td>
</tr>
<tr>
<td></td>
<td>scores on four test days</td>
</tr>
<tr>
<td>Heart rate</td>
<td>Analysis of variance, effect of</td>
</tr>
<tr>
<td></td>
<td>control beverage</td>
</tr>
<tr>
<td>Flush</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Skin temperature</td>
<td>N.S.</td>
</tr>
<tr>
<td>Pursuit rotor</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Romberg frequency</td>
<td>N.S.</td>
</tr>
<tr>
<td>Romberg amplitude</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

^a N.S. indicates p < 0.05.

^b Test numbers refer to the test periods during the drinking period of each experimental session.
Figure 2  Results for the 16 subjects on the 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 at each point for the control beverage.

TABLE IV  Analysis of Variance for Changes in Test Scores During Alcohol Drinking Sessions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect of beverage(^a)</th>
<th>Effect of cumulative dose(^b)</th>
<th>Interaction beverage x dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood alcohol level</td>
<td>N.S.(^c)</td>
<td>p&lt;0.01</td>
<td>N.S.</td>
</tr>
<tr>
<td>Heart rate</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>Malar flush</td>
<td>N.S.</td>
<td>p&lt;0.01</td>
<td>N.S.</td>
</tr>
<tr>
<td>Skin temperature</td>
<td>N.S.</td>
<td>p&lt;0.01</td>
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<td>Romberg frequency</td>
<td>N.S.</td>
<td>p&lt;0.01</td>
<td>N.S.</td>
</tr>
<tr>
<td>Romberg amplitude</td>
<td>N.S.</td>
<td>p&lt;0.01</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

\(^a\) This refers to effect of whisky vs. wine vs. beer.

\(^b\) Refers to change of scores over successive test periods within the same session, in response to continued drinking.

\(^c\) N.S. indicates p < 0.05.
Test Results

Analysis of variance (Table III) indicated that there was no significant difference with respect to any of the variables measured, during the pre-drink baseline measurements on the same subjects on different test days. With the exception of heart rate, all of the tests showed a clear change over time (Figure 2) which in effect corresponded to a progressive change in blood alcohol level. The significance of changes in test scores, as revealed by the analysis of variance, is summarized in Table IV. Despite the evidence of a marked alcohol effect on five of the six tests, there was no significant difference among the three alcoholic beverages on any of them.

DISCUSSION

The difference in blood alcohol curves between the two groups of eight subjects was not anticipated. When it was found, an examination of the drinking histories revealed that group 2 regularly consumed more alcohol than group 1. The steeper blood alcohol curves for the group 2 subjects are therefore entirely consistent with the observation by Newman (10, p. 9) that heavier drinkers tend to absorb the alcohol more rapidly. This appears to be true independently of which beverage is involved.

This would have introduced a serious problem for interpretation of studies based on group comparisons, in which different groups of subjects received different beverages. In contrast, 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 present results reinforce the importance of the negative finding with respect to such difference.

The results in Figure 2 indicate a more clear-cut and consistent alcohol effect upon the psychomotor performance tests than on the autonomic measures. The reason for the difference is not entirely evident from the present work, but two or three possible explanations may be suggested. One is that homeostatic changes are considerably more rapid for autonomic functions, especially those affecting heart rate, than for purely central nervous system functions. Therefore, the alcohol effects 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 beverage effect, so that the absence of the latter 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 psychomotor performance measures. 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 differences among the three alcoholic beverages, at the same dose of ethanol, with respect to 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 (2). The explanation is probably a very simple one, resting on well established facts of alcohol physiology. The absorption of ethanol from
the gastrointestinal tract proceeds by a process of simple physical diffusion (7) so that the rate of absorption is markedly 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.

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 rise of blood alcohol level. This is the situation in the study by Dussault et al (2). In contrast, the ingestion of alcohol in divided doses spaced over time, and following food intake, would minimize the importance of the concentration gradients as in the present study. In real life, even alcoholics show a drinking pattern which is much closer to the second than to the first type. It is noteworthy that the reported difference between beverages in the study by Dussault et al (2) was evident only during the first 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 levels to each other, the effects of the alcohol also became relatively independent of the beverage type.

The importance of the present findings can be expressed in both medical and social policy contexts. In a medical sense, it is worth pointing out that the undesired effects of acute intoxication, such as behavioral disturbances, motor vehicle accidents and other consequences of CNS impairment, are most unlikely to be significantly 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 which affect the CNS, such as antihistaminics, minor tranquillizers and barbiturates.

With respect to social policy the present findings suggest that any attempt to promote the use of one beverage in preference to another, by such means as differential taxation, must rest entirely on economic or political grounds because it is not defensible on medical or pharmacological grounds.

SUMMARY

Sensorimotor and physiological effects of equivalent doses of alcohol in the form of Canadian rye whiskey (diluted 1:1 with ginger ale), Canadian beer and a sparkling table wine were compared with those of a non-alcoholic carbonated control beverage. A total alcohol dose of 1.3 g/kg was consumed over four hours, beginning one hour after a standard light meal. Sixteen male subjects aged 20-35 years, all moderate drinkers, were tested in pairs in a replicated 4 x 4 Latin Square design. Pre-drinking base line measurements were made on the pursuit rotor, quantitative Romberg tests, skin temperature, heart rate, facial flush and blood alcohol level. The same measures were repeated at regular intervals over the 4-hr. drinking period.

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


