Bulletin of the Psychonomic Society
1979, Vol. 14 (5), 319-322

Adaptation of ethanol intoxication

WILLIAM P. BANKS, ROGER E. VOGLER, and THEODORE A. WEISSBACH
Pomona College, Claremont, California 91711

This study shows that the subjective sense of intoxication produced by ethyl alcohol exhibits classical sensory adaptation. The subjects reported a degree of intoxication that increased with the level of blood alcohol at the time of the report. However, a given level of blood alcohol produced less intoxication when it followed a high blood alcohol level than when it followed a low one. This effect of a prior level of blood alcohol on the effect of a present one implies that the mechanism that mediates alcohol intoxication adapts much as do exteroceptive sensory systems. Data on one chronic alcoholic suggest that alcohol abusers may adapt more rapidly than nonabusers.

This is a study of what could be called the "alcohol sense." The study points out an analogy between the sensation of intoxication produced by the ingestion of ethanol and the sensations produced by physical stimuli in the classical sensory modalities. Just as, for example, light energy produces sensations of brightness when applied to the retina of the eye in sufficient quantity, so does alcohol produce sensations of intoxication when present in the bloodstream in sufficient quantity.

The object of this study is to follow up a consequence of this analogy. Since the alcohol "sense"—that combination of internal cues that allows a drinker to monitor his or her own state of intoxication—depends on sensory transducers, the sense should behave in some ways like the body's other sensory systems, which also all depend on transducers for information about the world. The principle of sensory behavior of interest in this report is adaptation. This sensory principle is both amenable to investigation and of interest for theoretical and practical (clinical) reasons (cf. Solomon & Corbit, 1974, who have developed a similar analogy). The present study seeks to determine whether one's perception of a state of intoxication (from alcohol) is influenced by effects of adaptation in the same general way that perception of fundamental stimulus properties is affected in classical modalities. A number of investigators have observed what appears to be adaptation to alcohol, but none we know of has systematically observed adaptation in subjective reports of intoxication in single sessions (cf. Ekman, Frankenhauser, Goldberg, Bjerver, Jarpe, & Myrsten, 1963; Goldberg, 1943; Hurst & Bagley, 1972). We feel that subjective reports of intoxication are an important subject of investigation because they provide our closest access to the subjective cues that govern drinking behavior in a single drinking session.

We suppose that our sense of intoxication is mediated by a host of sensory and proprioceptive cues. To the extent that any of these cues comes from sensory systems that adapt, our ability to monitor our perception of our state of intoxication will be subject to adaptation effects. That is to say, the perception of the present state of intoxication will be a function of both the present and the previous levels of blood alcohol. Thus, a given level of blood alcohol may lead to a subjective sense of extreme intoxication if the preceding levels of alcohol were lower than that level, and a sense of very mild intoxication if the preceding levels were higher.

It is, as can be imagined, quite difficult to manipulate blood alcohol parametrically in the way the stimulus is manipulated in most psychophysical paradigms designed to study adaptation effects. Levels of blood alcohol cannot be raised and lowered at will, unless rather drastic and dangerous medical procedures are used. The present study therefore uses the normal time course of alcohol metabolism in the body to vary previous and present levels of blood alcohol. After ingestion of a quantity of ethanol, the blood level of alcohol rises to a maximum, from which it declines at a gradual rate to zero. The blood level of alcohol must, therefore, pass through each point in its course twice, once on the way up and once on the way down. Adaptation will be exhibited if a given level of blood alcohol produces less of a sense of intoxication "on the way down" than "on the way up."

METHOD

Procedure

Subjects ingested an alcoholic drink containing .457 g absolute alcohol per kilogram body weight in a carbonated mixer. All subjects began their session shortly after 4:00 p.m.; all had been requested to eat a normal lunch but not to eat anything during the afternoon. They were allowed 5 min to consume the drink and then reported on their states of intoxication over a period of 2 h, during which their blood alcohol concentrations were measured at regular intervals. The entire session

This research was supported partly by a Pomona College research grant and by grants from the National Science Foundation (BMS 75-20328) and the National Institute of Alcoholism and Alcohol Abuse (1 R01 AA03155-01). Requests for reprints should be sent to William P. Banks, Department of Psychology, Pomona College, Claremont, California 91711.

0090-5054/79/110319-04$00.65/0

was conducted in the "barroom" of an alcohol research facility (described in Vogler, Weissbach, Compton, & Martin, 1977), and the subjects were encouraged to walk about the room and to talk with each other during the session so that they could more easily monitor their states of intoxication.

Subjects

Four males, ranging in age from 21 to 48 years, served as unpaid volunteers. None was either an abstainer from or an abuser of alcohol; their annual estimated consumptions ranged from 1.8 to 3.9 gallons of absolute alcohol per year (the national average is 2.6 gallons per year). The subjects served in two groups of two. The youngest subject, unfortunately, had to be dropped from the study after his data were collected. He, unlike the other subjects, had fasted since 8:00 a.m., having skipped lunch.

Measurement

The level of blood alcohol was determined by the breath-sample technique, using an Intoximeter (Intoximeters, Inc.). Fifteen minutes after consuming their drinks, subjects provided breath samples every few minutes. They were never given any information about their blood alcohol concentrations.

Assessment of state of intoxication was done with magnitude estimation instructions (Ekman et al., 1963; Stevens, 1958, 1961). The subjects were told to introspect on the feeling of intoxication when they first felt the effects of the drink, and they were to use this as a standard and assign it a numerical rating. If a later feeling of intoxication felt twice as intense, they were to assign it a number twice as large; if a later sensation was half as intense, they were to give it a number half as large. The subjects, all of whom were familiar with this general scaling procedure, expressed no doubts about their abilities to use it consistently. The numbers subjects produced were adjusted by a multiplicative constant before analysis to compensate for the different ranges of numbers subjects chose (see Stevens, 1971, for an explanation of this procedure).

RESULTS AND DISCUSSION

Figure 1 plots both blood alcohol concentration (in milligram percent) and the rating of intoxication as a function of time after the drink was finished. The func-

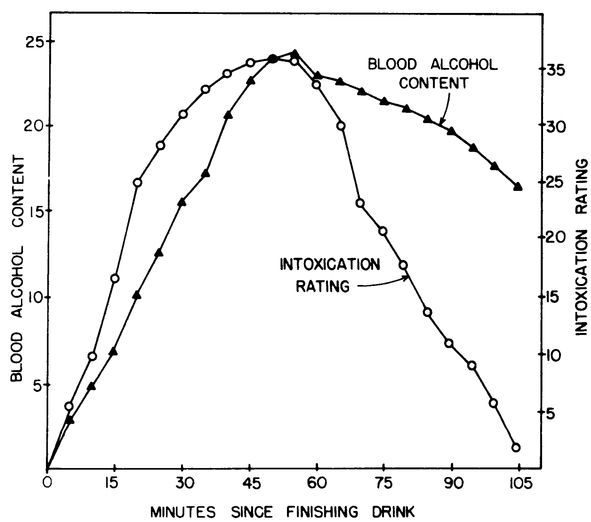

Figure 1. Blood alcohol content (milligram percent) and report of degree of intoxication (normalized magnitude estimates) plotted as a function of time after consumption of a single drink of alcohol.

tions shown in Figure 1 are the arithmetic means of the measures for the three subjects at 5-min intervals. Since the measures were not taken at 5-min intervals, the values at the 5-min intervals had to be interpolated. They were estimated separately from plots of each subject's data; interpolation was based on smooth curves fit to these plots. The averaging was justified, since the functions of the three subjects agreed closely; the times of both the peak blood alcohol content and the intoxication rating agree within 5 min for the subjects, and the absolute levels of peak blood alcohol content for the three subjects are within a ±15% range. By contrast, the excluded subject had his peak in blood alcohol 20 min earlier than the others, and the absolute level was 30% higher than their mean.

The relative time course of blood alcohol content and intoxication rating in Figure 1 confirms our expectation about adaptation in the perception of alcohol intoxication. The two functions rise together, but intoxication peaks slightly sooner than blood alcohol and levels off much more rapidly than blood alcohol. The very rapid fall-off of intoxication rating after peak indicates that a given level of blood alcohol produces a greater sense of intoxication before the peak than after. This finding is, of course, exactly what should be found in a strongly adapting sensory system, since any given postpeak level of blood alcohol is stimulating a sensory system that has been adapted by previous higher levels, whereas the same level of blood alcohol before the peak is stimulating a less completely adapted system.

A psychophysical plot that is better suited than Figure 1 to showing adaptation is seen in Figure 2. Here, level of intoxication is plotted as a function of blood alcohol level, with one function drawn for alcohol levels prior to the peak alcohol level and one for levels after the peak. These two functions are labeled "upswing" and "downswing," respectively. The functions for each subject are separately plotted to illustrate the similarities and show the data without interpolation or graphical estimation procedures. The subject omitted from Figure 1 is also omitted here; his data allow plotting of only a downswing curve.

The plots of Figure 2 make clear what is implicit in Figure 1: Any given level of blood alcohol produces a higher degree of intoxication before the peak than after. Furthermore, the plots show a different functional relationship between alcohol level and intoxication during the upswing and downswing.

The upswing and downswing functions in Figure 2 exhibit what Stevens (1958) has termed "hysteresis"; that is, the effect of a given stimulus (blood alcohol, in this case) is not constant, but depends on the "path" by which one attains it. A given stimulus has less sensory effect if it comes after a stronger stimulus than if it comes after a weaker one. As Stevens has discussed, hysteresis is an indicator of adaptation, and the magnitude of adaptation can be measured by the difference between the two functions. In the case of Figure 2,

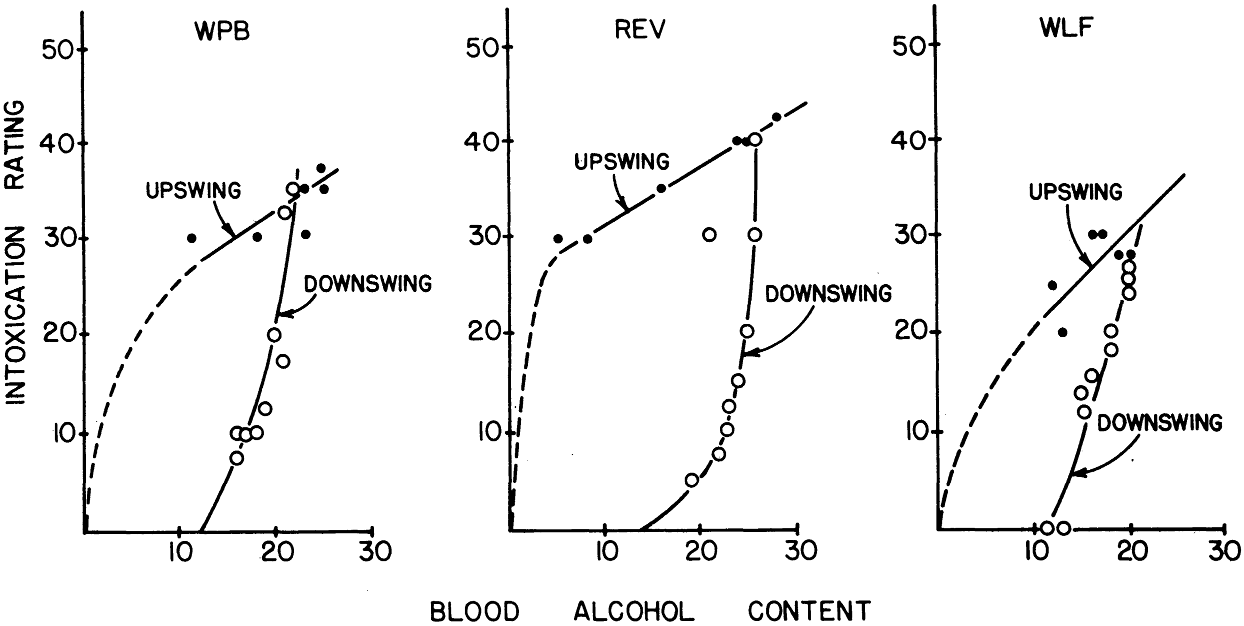

Figure 2. Degree of intoxication as a function of blood alcohol content for period prior to peak blood alcohol content ("upswing" curves) and period after peak ("downswing"), separately plotted for three subjects.

if the upswing and downswing functions had been identical, there would have been no evidence for adaptation; if the downswing function had been a vertical line at the extreme right of the plot, adaptation could be said to be total. As it is, there seems to be a very strong effect of adaptation in Figure 2, since the downswing function is very much lower than the upswing function.

An interesting feature of plots like those in Figure 2 is that information is lost about the time at which each observation is taken. Thus, in Figure 1 we can read off the point in time in the session at which each blood alcohol and intoxication level was attained, but we cannot in Figure 2. The advantage of plots like those of Figure 2 is precisely that they do lose the temporal information and isolate the "pure" functional relations for the upswing and downswing periods. The hysteresis plots are therefore the appropriate plots to use in an experimental separation of the effect of adaptation per se and other variables, such as rate of increase or decrease of the adapting stimulus. Suppose, for example, that we wished to disentangle effects of amount of time in session from blood alcohol level, two variables that are confounded in our data. It might be argued that our intoxication function falls off as it does after the peak blood alcohol level because people simply expect drinks to wear off about then, or because boredom or restlessness, setting in after about 1 h in the situation, cause the subjects to lose their subjective feelings attributable to drinking alcohol. One way to test such alternative hypotheses would be to vary the rate of increase or decrease of blood alcohol level by breaking up the dose of alcohol into several small doses and administering them at intervals calculated to attain the same maximum blood alcohol level, but at different rates. If the hysteresis plots were the same for the different rates, then it would be clear that prior blood alcohol level was the sole determiner of the effect of a present level. To the extent that the hysteresis function differed, then elapsed time in session or rate of blood alcohol change would be implicated as additional variables influencing intoxication.

The apparent finding in this study of adaptation to ethanol in moderate drinkers led us to suspect that abusive drinkers may adapt to the effects of alcohol even more quickly and thoroughly than moderate drinkers do. We suspect this because alcohol abusers sometimes report they "don't feel" alcoholic drinks when they have quite high blood alcohol levels. We speculate that increased adaptation rather than reduced overall sensitivity to alcohol may be responsible for these reports because many alcoholics seem to respond normally to a drink taken at a blood alcohol level of zero. The hypothesis of increased adaptation in alcoholics is also attractive as an explanation of alcoholic "binge" drinking: Because of adaptation, the alcoholic must drink more and more, must actually drink at an accelerating rate, in order to maintain the subjective effect of the alcohol. We note also that rapid rates of adaptation by abusers is predicted by the Solomon and Corbit (1974) analysis of addiction.

As a preliminary check on the possibility that alcohol abusers do adapt more rapidly than normals, we had one long-term abuser perform in the same procedure as our normal subjects in this study. This subject was female, weighed 160 lbs, and was 47 years of age. She had a history of alcohol abuse, and during the most recent 18-month period she had drunk at a rate estimated at 12.4 gallons of absolute alcohol per year. Her intoxication rating rose at about the same rate as that of the normals after she consumed the drink, but did not go as high and reached its peak 19 min after the drink (rather than the mean of 50 min for the normals). The drop-off of intoxication after the peak was very much steeper than that of the normals: Only 6 min after the peak, she reported that her intoxication had returned to a level of "10," while the normals took a mean of 45 min to return to this point. If other alcohol abusers turn out to have the same adaptation pattern as this subject, then adaptation differences might be used to distinguish abusers or potential abusers from normals.

REFERENCES

Ekman, G., Frankenhaeuser, M., Goldberg, L., Bjerver, K., Jarpe, G., & Myrsten, A. Effects of alcohol intake on subjective and objective variables over a five-hour period. *Psychopharmacologia*, 1963, **4**, 28-38.

Goldberg, L. Quantitative studies on alcohol tolerance in man. *Acta Physiologica Scandinavica*, 1943, **5**, 1-128.

Hurst, P. M., & Bagley, S. K. Acute adaptation to the effects of alcohol. *Quarterly Journal on Studies of Alcohol*, 1972, **33**, 358-378.

Solomon, R. L., & Corbit, J. D. An opponent-process theory of motivation: I. Temporal dynamics of affect. *Psychological Review*, 1974, **81**, 119-145.

Stevens, S. S. Problems and methods of psychophysics. *Psychological Bulletin*, 1958, **55**, 177-196.

Stevens, S. S. The psychophysics of sensory function. In W. A. Rosenblith (Ed.), *Sensory communication*. Cambridge, Mass: M.I.T. Press, 1961.

Stevens, S. S. Issues in psychological measurement. *Psychological Review*, 1971, **78**, 426-450.

Vogler, R. E., Weissbach, T. A., Compton, J. V., & Martin, G. T. Integrated behavior change techniques for problem drinkers in the community. *Journal of Consulting and Clinical Psychology*, 1977, **45**, 207-279.

(Received for publication July 25, 1979.)