

Assessing the stimulant effects of alcohol in humans

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Abstract

The stimulant effects of alcohol were assessed in humans. Twenty social drinkers were tested in dyads in the laboratory on three separate occasions, held 7 days apart. For their first session, one-third of the group consumed a dose of alcohol that was calculated to reach a target peak blood alcohol concentration (BAC) of 0.05 g/dl, one-third of the group consumed placebo-alcohol, and one-third consumed diet Sprite. For alcohol and placebo-alcohol conditions, subjects were told that they may or may not be given alcohol. For the soda condition, subjects were told they were consuming soda. Subjective stimulation, activity levels, and speech production were assessed over a 15-min period after beverage consumption (posttreatment) and compared to measurements taken prior to beverage consumption (baseline). Scores on the stimulant subscale of the Biphasic Alcohol Effects Scale (BAES) were significantly greater for the alcohol condition relative to the soda condition. There was also a trend for stimulant scores to be greater for the alcohol condition relative to the placebo-alcohol condition. Activity levels were significantly greater for the alcohol condition compared to either the placebo-alcohol or soda conditions. There were no group differences found for speech production. Subjective stimulant score and activity levels were not correlated. Peak BAC obtained in subjects who consumed alcohol was not correlated with either subjective stimulant scores or activity levels. Activity levels may provide a useful behavioral assay for assessing the stimulant effects of alcohol in humans. © 2002 Elsevier Science Inc. All rights reserved.

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1. Introduction

Although alcohol is classified as a sedative drug (Rall, 1990), it also has stimulant effects (Pohorecky, 1977; Martin et al., 1992; Earleywine, 1994). In rodents, low doses of alcohol increase locomotor activity (Friedman et al., 1980; Frye and Breese, 1981). In humans, low doses of alcohol not only induces stimulant effects on behavior, it also induces positive mood states (Pohorecky, 1977). Indeed, the stimulant subscale of the Biphasic Alcohol Effects Scale (BAES), an instrument validated to assess the biphasic subjective effects of alcohol in humans contains a stimulant subscale that is comprised of adjectives with positive valence such as “elated”, “excited”, and “up” (Martin et al., 1992). The stimulant effects of alcohol are typically experienced at relatively low blood alcohol concentrations (BACs) and on the

ascending limb of the BAC curve (de Wit et al., 1987; Martin et al., 1992). The capacity of alcohol to induce stimulant effects and positive mood is thought to play a role in alcohol's abuse liability (Koob and Weiss, 1990; Stewart et al., 1984).

The Psychomotor Stimulant Theory of Addiction purports an association between alcohol's stimulant effects on behavior, and alcohol's positive effects on mood (Wise and Bozarth, 1987). The theory posits that the common denominator of all drugs of abuse, including alcohol, is a capacity to induce psychomotor activation. The theory also suggests that the biological mechanisms underlying the induction of psychomotor activation are homologous with the biological mechanisms that underlie the positive reinforcing effects of drugs of abuse. The majority of support for this hypothesis comes from animal research that has found that drugs of abuse, which are readily self-administered by animals, also increase locomotor activity in animals (for review, see Wise and Bozarth, 1987).

Many of the methods used to assess the psychomotor stimulant effects of drugs of abuse in animals are unlikely to be useful in humans. Nevertheless, some natural parallels

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exist and may be exploited. For example, humans often choose to consume alcohol during times of celebration to enhance positive mood states associated with such events. When alcohol is consumed during social events, two behaviors frequently follow: (1) people become more talkative, and (2) they become more physically animated (Steele and Josephs, 1990). The natural tendencies for humans to talk more and move about during social functions that involve drinking alcohol may provide two behavioral measures of alcohol's stimulant effects that may be comparable to measuring locomotion in animals pretreated with alcohol. Although there have been many studies investigating the effects of alcohol intoxication on speech (Sobell and Sobell, 1972; Klingholz et al., 1988; Pisoni and Martin, 1989; Hollien and Martin, 1996), there have been no studies examining the effects of low doses of alcohol on the rate of speech production.

If the stimulant effects of alcohol are homologous with alcohol's positive reinforcing effects, then one would predict that low doses of alcohol would increase both subjective measures of stimulation and activity in humans. The present investigation attempted to measure the stimulant effects of alcohol using two novel behavioral measures: activity levels and speech production. The effects of a low dose of alcohol on spontaneous activity levels and speech production were examined in social drinkers and compared to their scores on the stimulant subscale of the BAES (Martin et al., 1992) and the Profile of Mood States (POMS) (McNair et al., 1992).

2. Methods

2.1. Subjects

Subjects were recruited by community postings. Eligible subjects were male and female social drinkers between the ages of 21 and 65 years who were able to bring along a friend who could also be tested for study eligibility in order to participate in the study and serve as their partner. Inclusion and exclusion criteria were applied to the initial contact subject and their friend. Exclusion criteria included: alcohol abuse problems revealed during the medical interview; > 2 positive responses on the Short Michigan Alcohol Screening test (Selzer et al., 1975); women who typically drink >3 drinks per drinking occasion and men who typically drink >4 drinks per drinking occasion; and any medical condition contraindicating the consumption of alcohol. Pregnant or breast-feeding women, and sexually active women who were not using birth control were also excluded. Eleven women and nine men were enrolled into the study (17 Caucasian, 1 Pacific Islander American, and 2 Asian American). The mean age of the group was 34 years, (range = 21–54 years). The average number of drinks per drinking occasion that was consumed by the sample was 2.6 standard drinks (S.E.M. = 0.3). Over the 90-day period leading up to study enrollment, the sample consumed

alcohol on about 20% of the 90 possible drinking days. Three of the subjects were cigarette smokers.

2.2. Test sessions

Three, 4-h test sessions were conducted between 9 AM and 8 PM on three different weekdays, each held approximately 2 weeks apart. Dyads were always tested at the same time of day. Testing took place in a 9 × 8-ft room that contained a sofa set, coffee table, stereo, and lamps. Playing cards and board games were available. The sessions were videotaped with a camera that was mounted on a tripod in the corner of the room. The research assistant monitored the dyads from a television monitor in an adjacent room.

Subjects who passed the phone screen were asked to fast from food and alcohol for 2 h prior to testing. They were encouraged to bring their favorite tapes or CDs to listen to on a stereo that would be available to them. Written informed consent was obtained from all subjects on the first day of testing, and they were also all given a breathalyzer test to ensure zero BAC prior to testing. Women provided a urine sample for pregnancy testing.

2.3. Baseline assessment

The baseline period lasted for 1 h. Prior to testing, an Actiwatch was placed on the wrist of the nondominant hand of each subject, and they were also fitted with a Logoport. They were given a restroom break, and smokers were allowed to smoke a cigarette. The baseline period began once the research assistant gave the following instructions: "You may now relax and talk to one another. Please feel free to play the stereo if you like or to play cards or any of the games on the shelf below the stereo. I'll be back in a while to give you some questionnaires. Any questions?" Thirty min into the baseline period, the subjects were asked to complete the BAES and POMS. Activity levels and speech production were recorded during the last 30 min of the baseline period.

2.4. Beverage conditions and administration

Dyads were randomly assigned to receive one of three beverages: Sutter Home White Zinfandel wine (alcohol condition), Sutter Home White Zinfandel alcohol-free wine (placebo-alcohol condition), or diet Sprite (soda condition). Beverages were poured into two Styrofoam cups. Both subjects were given the same beverage and asked not to discuss what they thought they consumed. The dose of alcohol that was administered was calculated to induce a target peak BAC of 50 mg/dl. Calculations were made using a nomogram that was based on age, gender, height, and body weight. Beverages had to be consumed within 10 min. The order of beverage administration was counterbalanced so that one-third of the group received alcohol on their first session, one-third of the group received alcohol on their second session, and so on. When subjects received alcohol

or placebo-alcohol, they were told that they may or may not be consuming alcohol. When subjects received soda, they were told that they were receiving soda and not alcohol. This balanced-placebo design was followed to control for expectancy effects (Martin and Sayette, 1993). For example, subjects receiving placebo-alcohol could display alcohol stimulant-like effects that were a result of alcohol expectancies. It is possible that these expectancy effects would result in the placebo-alcohol condition looking statistically similar to the alcohol condition. The inclusion of a soda condition allowed us to control for the possible differences between the pharmacological effects of alcohol on stimulation from that of expectancy effects on stimulation.

2.5. Ascending limb assessment period

The assessment period for the ascending limb of the BAC curve took place over the first 15 min that followed the consumption of the beverage. The BAES and POMS were administered immediately following beverage consumption, regardless of the beverage consumed. Breathalyzer readings were taken 10 and 15 min after beverage consumption to insure that BACs were indeed rising in the subjects who had consumed alcohol. Activity levels and speech production were monitored over the entire 15-min period. After completing their third session, subjects were paid US\$150 each in compensation for the time and travel.

2.6. Assessment instruments

2.6.1. Time Line Follow Back (TLFB)

The TLFB was used to calculate the percentage of days that a subject consumed alcohol and the number of drinks per drinking days when alcohol was consumed over the previous 90 days prior to testing (Sobell et al., 1979).

2.6.2. The BAES

The BAES consists of 2 seven-item unipolar adjective rating scales that have been validated to measure the stimulant and sedative effects of alcohol in humans (Martin et al., 1992). The BAES was administered at baseline and 10 min after the ingestion of the beverage (ascending limb of the BAC curve). The stimulant subscale is comprised of items with positive valence (i.e., elated, energized, up) and is sensitive to rising BAC concentrations. The internal consistency is high for both BAES subscales on both limbs of the blood alcohol curve (Cronbach's $\alpha = 0.85\text{--}0.94$). Because we were only interested in assessing the stimulant effects of alcohol during rising BACs, we did not administer the BAES on the descending limb of the BAC curve.

2.6.3. The POMS—short version

The POMS is a 30-item scale that measures mood (McNair et al., 1992). It consists of six subscales; anger, tension, fatigue, confusion, vigor, and depression. The vigor subscale has shown utility for measuring drug-induced

euphoria in non-drug-abusing populations. The POMS was administered at baseline and 10 min after beverage ingestion.

2.6.4. Blood Alcohol Concentrations from Breath (BrACs)

BrAC was estimated from expired air using an Intoximeter breathalyzer. Breathalyzers were administered every 10 min after beverage ingestion (three times) and every 30 min following peak BAC until BrAC fell below 0.02 g/dl in subjects who had consumed alcohol. The timing of breathalyzers for the placebo-alcohol condition was approximated to the timing of breathalyzers for the alcohol condition. No readings were taken during the soda condition.

2.6.5. The Actiwatch

The Actiwatch is a lightweight motion detector developed by Mini-Mitter. It looks like a small, rectangular watch and is worn on the wrist. An accelerometer inside the Actiwatch monitors the occurrence and degree of motion in all directions. It is sensitive to both gross motor movements and more discrete movements such as hand gestures. Activity levels were obtained every 5 min during the last 30 min of baseline and for 15 min after beverage consumption.

2.6.6. Logoport

The Logoport (RIMKUS Medizintechnik) is a portable device that stores and analyses speech production at varying temporal resolution, with a measurement resolution of 8 ms. It is contained in a small ($6 \times 4 \times 2$ in.) metal container weighing 250 g. The device is carried on the body in a light canvas harness. A small sensor is attached to the throat of the subject (similar to the attachment of an EEG lead) and is connected to the device by a thin wire. Spontaneous speech production was recorded during the last 30 min of baseline and for 15 min after beverage consumption.

2.7. Behavioral measures of activity

The study was designed to measure the stimulant effects of alcohol on spontaneous activity and conversation. A pilot test, conducted previously in this laboratory, found that the Logoport required a minimum of 15 min of dialogue to detect differences in speech production. Because the Logoport has detected alcohol effects on speech production in subjects who were tested in groups and allowed spontaneous conversation (Krüger, 1989; Mundt et al., 1993), a similar strategy was employed in the present study by selecting pairs of friends and testing them in dyads. It was assumed that activity levels and speech production would occur naturally, and that the occurrence of activity levels and speech production would be relatively constant across all three sessions, with the exception of the day that alcohol was consumed.

2.8. Data analysis

Data were analyzed by analysis of variance (ANOVA). Difference scores between measures obtained during base-

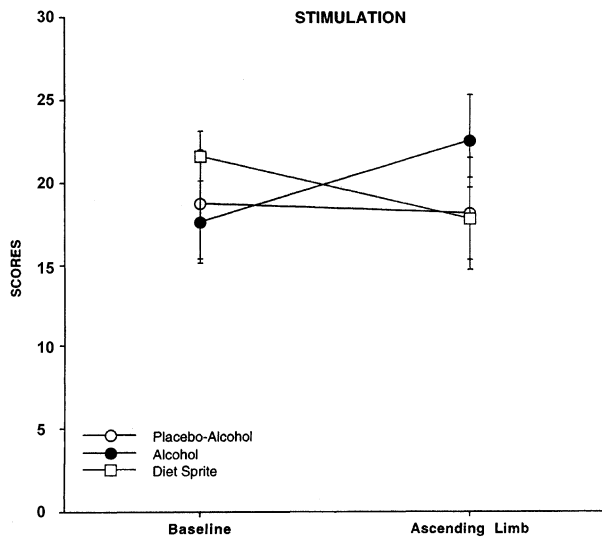


Fig. 1. Scores on the stimulant subscale of the BAES. Stimulant scores were significantly higher when subjects consumed alcohol compared to placebo-alcohol or diet Sprite. There was a trend for a slight increase in stimulant score compared to diet Sprite, when subjects consumed placebo-alcohol.

line and measured on the ascending limb of the BAC curve were calculated. The order in which the beverage was served was controlled while examining the effects of beverage type on the difference score. Post hoc tests were performed when a significant effect of beverage was found. All computations were processed by SAS version 8.1 using PROC MIXED.

3. Results

3.1. Subjects

Ten dyads were tested. The data from one subject was not included in the analysis because she vomited shortly after consuming alcohol. Therefore, the data from only 19 subjects were entered into the analyses. There were no order effects for the beverage condition, therefore, the analyses were repeated without the inclusion of an order term.

3.2. BAES: stimulant subscale

An ANOVA performed on difference scores revealed a main effect of stimulation ($F=3.57$, $P>.03$). Post hoc analyses with t tests found that stimulant scores were significantly higher when subjects consumed alcohol (5.0 ± 2.3 S.E.M.) compared to soda (-3.8 ± 2.3 S.E.M.) ($t=2.66$, $P>.005$). There was also a trend for stimulant scores to be higher when subjects received alcohol compared to the placebo-alcohol (-0.1 ± 2.4 S.E.M.) ($t=1.55$, $P>.06$). Difference scores and standard errors of the mean for stimulate scores on the BAES are displayed in Fig. 1.

3.3. Profile of Mood States

An ANOVA performed on difference scores for the six subscales of the POMS did not find any effect of beverage on mood.

3.4. Activity levels

Due to equipment failure, the activity levels for only 18 subjects were included in the analysis. An ANOVA performed on the difference scores for activity levels revealed a main effect of beverage ($F=5.27$, $P>.008$). Post hoc analysis with t tests revealed that activity levels were significantly greater when subjects consumed alcohol (82.8 ± 36 S.E.M.) compared to placebo-alcohol (-48 ± 43 S.E.M.) ($t=2.53$, $P<.007$) or soda (-73.6 ± 28) ($t=3.03$, $P>.001$). Activity levels are displayed in Fig. 2.

3.5. Speech production

An ANOVA performed on difference scores obtain on speech production data did not find any effect of beverage on speech production. Difference scores for speech production were: -10.2 ± 18.8 S.E.M. for alcohol; -3.1 ± 13.4 S.E.M. for placebo-alcohol; and -1.1 ± 14.8 S.E.M. for the soda.

3.6. Correlations

A Pearson correlation was performed to examine the association between stimulant scores on the BAES assessed on the ascending limb and activity levels. A second Pearson correlation was performed to examine the association between stimulant scores on the BAES assessed on the ascending limb and peak BAC. No significant correlations were found for either comparison ($P>.05$, one-tailed tests).

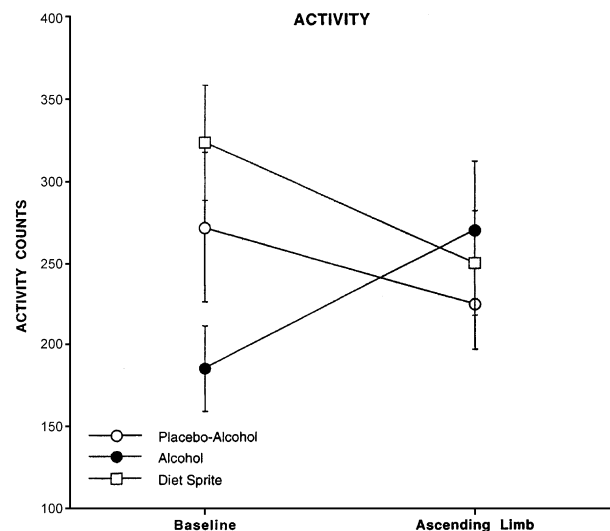


Fig. 2. Activity levels measured by the Actiwatch. Activity levels were significantly higher when subjects consumed alcohol compared to placebo-alcohol or diet Sprite.

4. Discussion

The Psychomotor Stimulant Theory of Addiction postulates that increases in psychomotor activation induced by drugs of abuse are homologous with the biological mechanisms that mediate positive reinforcement (Wise and Bozarth, 1987). In other words, all drugs of abuse induce positive reinforcing effects that are experienced as rewarding and stimulate activity. The heuristic value of the theory is that it predicts that drug-induced increases activity may serve as a useful behavioral assay of the abuse liability of a drug. Conversely, medications thought to decrease drug-taking behavior by blocking the positive reinforcing effects of a drug would also be expected to block drug-induced increases in activity (Kosten and Kosten, 1991; Littleton and Little, 1994; Anton, 1996). Thus, the measurement of activity levels could be added to the battery of screening methods used to assess new pharmacotherapies for treating drug abuse.

Surrogate measures of the positive reinforcing effects of drugs of abuse are of particular utility in animal models because of the inability to directly assess subjective mood effects. In humans, however, there have been inconsistencies reported by researchers using paradigms that assess subjective measures of positive reinforcing drug effects, and the propensity to self-administer the drug when it is made available in the same experiment (de Wit and Griffiths, 1991). Thus, a surrogate measure of positive reinforcing drug effects may also be of value in human research.

We attempted to measure the stimulant effects of a low dose of alcohol on two innovative behavioral measures of stimulation: activity levels and speech production. Activity levels and speech production were compared to subjective stimulation measured by the stimulant subscale of the BAES (Martin et al., 1992) and to mood assessed by the POMS (McNair et al., 1992).

Stimulant scores on the BAES were significantly higher following the consumption of a relatively low dose of alcohol compared to the soda condition. Although stimulant effects were also higher in subjects that consumed alcohol compared to placebo-alcohol, the difference fell just short of statistical significance. Presumably, placebo-alcohol induced expectancy effects of stimulation that were similar, although of a smaller magnitude, to the stimulant effects induced by alcohol. Expectancy effects were not observed when subjects consumed soda (Martin and Sayette, 1993). Thus, the stimulant subscale of the BAES was sensitive to both the stimulant effects assessed in subjects who had ingested alcohol or who had thought they ingested alcohol.

Although many investigators have found stimulant effects of alcohol at the low dose of alcohol administered in this experiment (Pohorecky, 1977; Martin et al., 1992; Earleywine, 1994), some investigators have not. Holdstock and de Wit (1998) examined the effects of three doses of alcohol on sedative-like and stimulant-like subjective and behavioral effects in social drinkers. They did not find stimulant effects of a moderate dose of alcohol (0.4 g/kg),

which was similar to the dose of alcohol that was administered in the present study. The difference between their findings and the data presented in this study is likely due to the different instruments used to assess subjective stimulant effects. Holdstock and de Wit (1998) did not use the BAES, which is validated for assessing the subjective biphasic effects of alcohol. The BAES has also assessed stimulant effects following low doses of alcohol that was administered intravenously (Davidson et al., 1997).

The subjective sensation of stimulation experienced by humans consuming alcohol is not a novel observation (Pohorecky, 1977; Martin et al., 1992; Earleywine, 1994). A novel observation was the finding that a dose of alcohol that induced subjective sensations of stimulation on the BAES also increased activity levels. Activity levels were significantly greater when subjects consumed alcohol relative to soda. Activity levels were also increased when subjects consumed placebo-alcohol relative to soda. The increase in activity suggests that expectancies of stimulation detected by the BAES in placebo-alcohol-treated subjects was also detected by the Actiwatch. Unlike stimulant effects measured on the BAES between alcohol- and placebo-alcohol-treated subjects, however, activity levels measured by the Actiwatch were statistically significant. Surprisingly, there was no correlation between alcohol-induced stimulation assessed by the BAES and peak BAC. There was also no correlation between alcohol-induced stimulation assessed by the BAES and activity levels.

The POMS did not detect any effects of alcohol on any subscale. This was unexpected because the POMS has been shown to be sensitive to drug and alcohol effects on mood. Experiments that have found alcohol effects on the subscales of the POMS have generally tested higher doses of alcohol than were administered in this study. The subscales of the POMS may have been insensitive to the effects of low doses of alcohol administered in this study, or the sample size tested may have been too small to detect differences.

We did not find increases in speech production for subjects who had received alcohol. The lack of effect of the low dose of alcohol on speech production could be explained in several ways. First, the sample size was small in light of the large individual differences that were observed in the rate of speech production. Second, although, spontaneous speech was encouraged by choosing two friends to serve as subjects in each test session, the laboratory setting may have been too artificial to promote and sustain consistent dialogue through the testing period. Finally, speech production might provide a better measure of stimulation if it were used in a group setting where there would be more individuals to contribute to the conversation. Mundt et al. (1993), for example, were able to measure increases in speech production with the Logoport in groups of individuals who consumed a small dose of alcohol.

One of the limitations of this study was the differences in baseline levels of stimulation, activity levels, and speech production measured on the three different test sessions.

Unexpectedly, stimulation, whether assessed by the BAES or the Actiwatch, was always the greatest for the baseline soda condition. Because the experiment used a within-subjects design and the order of the administration of beverage condition was counterbalanced across the subjects, it is difficult to determine what accounted for the greater levels of stimulation during the baseline period of the soda condition. Therefore, despite the use of difference scores in the analyses to control for differences in baseline measures, it is possible that the intermediate levels of stimulation observed for the placebo-alcohol condition were not the result of expectancies, but rather an artifact resulting from decreases from baseline. In other words, the activity levels observed at baseline for the soda condition may have diminished by the time behavior was reassessed after the ingestion of soda. One possible explanation for this observation may be that enthusiasm for the experiment may have diminished in the subjects once they realized that they would not receive alcohol that day.

A second limitation of the study stems from testing subjects in dyads. Anytime two or more human subjects are tested together, there is the possibility of the behavior of one subject affecting another (Caudill and Liscomb, 1980; Caudill and Marlatt, 1975). Thus, the behavior assessed in this study that was attributed to alcohol may, in fact, be contaminated to some extent by the behavior of another. One subject in a dyad, for example, could be exquisitely sensitive to the stimulant effects of alcohol, whereas the other is not. The alcohol-stimulant-insensitive partner, may have increased their activity levels because of the influence of their partner and not because of the stimulant effect of the alcohol. These modeling effects, if present, did not appear to affect speech production. Nevertheless, increases in subjective stimulant effects and activity levels observed in this study must be said to be due in part to the effects of alcohol and to some unknown interaction between the subjects such as modeling.

In summary, alcohol-induced stimulant effects measured on self-report questionnaires may also increase activity levels. These data did not, however, find a correlation between alcohol-induced subjective stimulant effects and activity levels, or between either measure of stimulation and positive mood states measured by the POMS. Score on the stimulant subscale of the BAES and activity levels were also not correlated with peak BAC.

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