Ingested Ethanol and Binocular Rivalry

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**Purpose.** An early study claimed that ethanol ingestion can attenuate binocular rivalry and, in some cases, may produce the phenomenal fusion of normally rivalrous stimuli. The current study examined those claims in an experiment incorporating key controls that were lacking in the earlier study.

**Methods.** There were two conditions, one in which observers consumed ethanol and the other in which they consumed a placebo. Observers reported the course of binocular rivalry for several hours after drink consumption using two types of rivalry stimuli, one consisting of a continuously illuminated set of stimuli, the other consisting of dichoptic afterimages.

**Results.** Ingestion of ethanol resulted in a decrease in rivalry alternation rates, although there was no evidence of phenomenal fusion. Results were essentially identical for both stimulus types.

**Conclusion.** It is suggested that this effect is not caused by ethanol-induced changes in oculomotor mechanisms but may be caused by ethanol-induced decreases in contrast sensitivity. Invest Ophthalmol Vis Sci. 1995;36:1548-1554.

Binocular rivalry occurs when dissimilar images stimulate corresponding retinal areas of the two eyes. During rivalry, the image in one eye disappears from awareness (i.e., suppressed), whereas the other eye’s image remains phenomenally present (i.e., dominant). Phases of suppression and dominance alternate between eyes: first, one eye’s view is suppressed and the other’s is dominant; a moment later, the second eye’s view is suppressed and the first eye’s view dominates. Such reversals can continue indefinitely with prolonged viewing.

Binocular rivalry is thought to be a kind of “default setting” of sensory mechanisms responsible for fusion. In this view, when fusional mechanisms fail to achieve binocular fusion and both eyes’ stimuli are on the horopter, the outcome is binocular rivalry. Several theories have been proposed to account for binocular rivalry. Such theories generally propose that the increased thresholds that occur during periods of rivalry suppression are the result of some type of cortical inhibition.

It has been reported that ethanol can reduce alternation rate and may in some cases eliminate rivalry suppression altogether, producing phenomenal fusion of the two eyes’ views. This is an intriguing finding, in part because it raises the possibility that ethanol may affect the inhibitory cortical mechanisms that normally prevent fusion under such conditions. Unfortunately, this finding must be treated as tentative because the original report was methodologically flawed and possibly confounded. In particular, many oculomotor mechanisms that serve to modify the retinal image in normal vision (e.g., accommodation, vergence, pupillary responses, and eye movements) may also affect stimulus strength and, therefore, might influence the relative dominance of each eye’s image during binocular rivalry. For example, small changes in accommodation can lead to a blurred retinal image, which has been shown to reduce the strength of binocular rivalry.

The experimental investigation of the role of oculomotor mechanisms in binocular rivalry has a long history. Lack used a number of experimental manipulations (e.g., artificial pupils, afterimages, and various mydriatics and cycloplegics) to investigate the influence of oculomotor mechanisms on the control of rivalry alternations. He concluded that these mecha-
nisms played a minor role in his subjects' ability to control binocular rivalry.

Because ethanol has been shown to affect some oculomotor mechanisms, the changes in binocular rivalry reported by these researchers may have been indirect consequences of ethanol-induced changes in these mechanisms.7–10 Although this would be an interesting result, their procedure provided no means for differentiating oculomotor mechanisms from neurophysiological ones as mediators of this effect. Thus, the results of Lack's investigations have some bearing on the current experiments: oculomotor mechanisms can influence the course of rivalry alternations, if only a little, and thus must be removed as a potential confounding factor. We accomplished this by using rivalrous positive afterimages. Positive afterimages generated by brief but intense photic stimuli arise because of photoadaptation of light-sensitive pigments in the retina. Therefore, once produced, they are unaffected by oculomotor mechanisms. The use of positive afterimages is an effective control for these mechanisms as the possible source of any effect of ethanol on rivalry. Rivalrous positive afterimages have been used by other researchers to control for the influences of these mechanisms on stimulus strength.6,11,12

Our study had two principal objectives, both relating to the above criticisms. The first was to replicate the original results, with a cleaner design. The second objective was to examine the possible role of oculomotor mechanisms in the effect by using positive rivalrous afterimages as stimuli. We asked subjects to track the dominance of each of two rivalry stimuli at the same time, which allowed them to signal alternations as well as simultaneous dominance (i.e., phenomenal fusion) if it occurred. Simultaneous dominance phase duration (the total time both eye's views were dominant simultaneously) was assessed to determine if phenomenal fusion occurred with high blood alcohol concentration (BAC).

METHODS

Experimental Subjects

Subjects were nine men (age range, 21 to 29 years) in good health, who reported no current or prior drinking problems, no genetic or familial history of alcohol abuse, and no personal history of seizures. All were within 10% of desirable mean weight for their height.15 The sample was limited to men to avoid gender differences in the absorption and metabolism of ethanol, partly mediated by the menstrual cycle.14–16 All were moderate drinkers, as defined by a Quantity-Frequency Adjusted (QFA) Index in the range of 0.25 to 1.5 oz ethanol/day using the alcohol consumption questionnaire of Armor and Polich.17 All subjects gave their informed written consent to participate after the nature of the procedures had been explained fully. The human use protocol conformed to the Declaration of Helsinki and was approved by the institutional Review Board of Washington State University. Each subject received $50 for his participation.

Candidates were screened for general visual functioning, had fine stereopsis within normal limits (able to resolve crossed disparity ≤ 43 seconds of arc), and had no history of serious vision disease. All had uncorrected or corrected far acuity of 1.0 or better with no measurable vertical phoria, nor any lateral phoria outside the following ranges: +3.33 prism dioptries (PD) eso to −2.66 PD exo (far); +3.0 PD eso to −10.5 PD exo (near).

Materials

Blood alcohol concentration was estimated with an Intoximeter (Mark IV; Intoximeter, St. Louis, MO). This instrument uses gas chromatography to estimate BAC from deep-lung air samples.

Subjects viewed the stimuli in a modified Lyle Major Amblyoscope, the unmodified version of which has been described.19 The subject's chair and the amblyoscope were adjusted to each individual's eye height, chin height, and interpupillary distance. The amblyoscope allowed dichoptic stimulus presentations and permitted control of stimulus accommodation and vergence angle. The amblyoscope was modified so that the front surface of the flash tube of a photographic strobe (WOC-2000 AC Slave Flash Unit; Samigon, Hong Kong) was positioned 5 cm behind the diffuser on each side of the amblyoscope, and incandescent video lights (Vidpro ML-2K; Vidpro International, Dallas, TX) were positioned to the back and slightly to the side of the diffuser (Fig. 1).

During trials when the strobes were being used, 0.2 neutral-density filters were placed between the fusers and the strobes. During other trials, when the strobes were not in use, the neutral-density filters were removed, and light was provided by the video lights. Voltage to each video light was controlled by a direct current power supply (Dual Supplyist Model No. WP 707; Viz, Philadelphia, PA). The stimuli were mounted in the viewing tubes of the amblyoscope. An extra −2.0 D lens was placed in front of the objective lens for each eye to induce 2 D of stimulus accommodation. The reason for this procedure was that this amount of accommodation has been shown to be least affected by ethanol, leading us to think that this would minimize the potential for ethanol-induced blurring from misaccommodation.8

A personal computer was programmed to record subjects' reports of rivalry alternations. During the sessions, all lights were extinguished except some small lamps for the experimenters. When the subject looked
FIGURE 1. Schematic diagram of the amblyoscope, showing the relative positions of photographic strobes, video lights, neutral-density (ND) filters, diffusers, and stimuli (target slides) with respect to the eyes of the subject.

into the amblyoscope, the only visible light visible was that provided by the stimuli.

Stimuli

Two achromatic rivalry targets (Fig. 2A) were mounted on frosted acrylic plastic sheets, 8.26 cm square and 0.64 cm thick. These target slides were back-illuminated by the video lights to provide the "continuous" stimuli. The stimuli were viewed dichoptically, and the borders of circles and diamonds provided fusible contours. The central bars of the two stimuli were oriented orthogonally; each was oriented 45° from the horizontal, and each was 1° long and 0.25° wide. The fixation point in the center of each bar was about 12 minutes of visual angle in diameter.

Luminances (in cd/m²) of the black central bar and its surrounding white field were as follows: left eye, white field = 21.4; left eye, black bar = 9.9; right eye, white field = 14.4; right eye, black bar = 4.0. Although the luminances were different, the apparent brightnesses were approximately the same, according to observations made by the first author at the start of the experiment. The luminances were set to these values because they satisfied two criteria. The first was that our pilot subjects reported moderate alternation rates (approximately 30 to 40 alternations per minute), which meant they were not so slow as to risk floor effects nor so fast that subjects would be unable to keep track of them. Also, the difference in luminance was not particularly noticeable to our subjects and, perhaps more important, resulted in approximately even predominance for four pilot subjects tested. Having set the luminances, they remained unchanged for the duration of the experiment. This was verified by performing luminance measurements on completion of the experiment.

The "afterimage" stimuli (Fig. 2B) were white figures on a dark background, with peripheral squares and a circle to provide fusible contours, and a central bar tilted 45° from the horizontal, 8.0° in length, and 1.0° in width. It was necessary that these central bars be larger than those of the continuously illuminated

FIGURE 2. The stimuli used in the continuous illumination condition (A) and the afterimage condition (B). Dimensions are listed in section entitled Stimuli.
stimuli to prevent the afterimages from fading away during the approximately 40 seconds between initial exposure and completion of the trial. Afterimages were produced by flashing the strobes and back-illuminating the target slides. Exposure duration of the strobes was approximately 1 msec. The combination of strobes and filters was within safe exposure limits.18

Once induced, afterimages were viewed against a flat black wall, at a distance of approximately 1.5 m from the subject’s eyes, with a small gray dot as a fixation target. An intermittent strobe light (cat. no. 42-3009-A; Realistic Xenon Strobe Signal Appliance; Radio Shack, Fort Worth, TX) provided flickering illumination of the wall to prevent the afterimages from fading prematurely. The flicker rate was set at 4 Hz.

**Experimental Design and Procedure**

Each subject experienced three sessions on separate days. The first was a screening and training session. During each of the second and third (i.e., the experimental) sessions, the subject received a placebo (PL session) or ethanol drink (AL session). The order of the PL and AL sessions was counterbalanced across subjects.

The screening and training session had two principle functions: an initial screening and training on the rivalry tracking task. During screening, we determined the candidate’s age, tested his vision, and determined if he met weight criteria. Candidates who met all criteria proceeded to train on the rivalry tracking task. For training, the subject was instructed to maintain fixation on the point at the intersection of the two central bars. He was to signal that a bar was dominant (seen as occluding the other bar) by pressing the corresponding keyboard button and to release the button (and push the alternate bar’s button) when the bar was seen to be occluded by the other bar. He was told that if he saw both bars complete or connected through the middle (as a solid X), he was to press both buttons simultaneously. The subject then practiced tracking the course of rivalry of the continuous stimuli using the forefingers of each hand to track rivalry alternations with two buttons on the computer keyboard. The subject was shown the afterimages, the exposure procedure was described, and the subject was given a few trials to get used to tracking rivalry alternations with the afterimages. Each subject practiced tracking rivalry with both types of stimuli until the standard deviation of his mean baseline alternation rate over ten 30-second training trials was ±10% of the absolute value of the mean alternation rate for that baseline. When the training was completed, each subject was instructed not to eat or drink anything for 3 hours, nor to drink ethanol or take any medications for 24 hours before either experimental session. Each was told not to use any caffeine or tobacco the day of the session and to get a “normal” amount of sleep before each session.

Each subject took part in two experimental sessions, each session corresponding to one of the two dosage conditions, the PL condition and the AL condition. The order of the two conditions was counterbalanced across subjects, with five receiving the PL condition on the first day.

Each experimental session began at midday. The subject was seated at the amblyoscope; chair height, chin height, the vergence angle, and interpupillary distance of the amblyoscope were adjusted. Then the subject was given a series of 30-second practice trials using the continuous stimuli. He continued practicing until his trial-to-trial alternation rate stabilized.

The rest of the experimental session consisted of multiple trial sets, each trial set containing 14 trials: seven each of continuous stimuli (CONT trials) and afterimages (AFT trials), in alternating order. Between trial sets there were 38-minute rest periods; 90 minutes elapsed between the beginning trials of consecutive trial sets. The first trial set consisted of 14 predose baseline trials, and the other trial sets consisted of 14 postdose trials each.

Before the first baseline trial, the subject’s breath was sampled with the intoximeter to confirm that he had no ethanol in his blood. The subject then completed 14 trials as described above. CONT trials were conducted in the following manner: When the subject was in position, the experimenter gave a ready signal and turned on the video lights that illuminated the continuous stimuli. The subject began tracking rivalry dominance alternations as soon as he was ready, typically within 5 seconds. The computer delayed recording the subject’s keypresses for a random interval of 1 to 5 seconds after the subject’s first keypress, and then began recording the exact durations of the keypresses. Thirty seconds after it began recording, the computer signaled the end of the trial and simultaneously stopped recording keypresses. There was then an intertrial rest period of 3 minutes, 25 seconds. In total, 4 minutes elapsed between the start of successive trials.

For AFT trials, the subject fixated the apparent intersection of the two bars, which was dimly illuminated by the full-charge indicator light-emitting diodes on the strobe units. When the subject indicated he was ready, the experimenter fired the strobes. The subject then turned his head to his right and looked at the fixation spot on the wall. This spot and the surrounding area were illuminated by the strobe light. He began tracking rivalry alternations as soon as he felt ready, typically within 10 seconds of initial exposure. The computer controlled the course of the trial as it did for the continuous trials.

After the baseline trials were completed, the sub-
ject was given 95% ethanol (1.4 ml/kg) mixed with 7 ml/kg diluent (sugar-free, fruit flavored), and some plain white bread (0.9 g/kg) in the manner described by Miller and colleagues.\textsuperscript{9-11} The subject then did the postdose trial sets. Immediately after each postdose trial, the subject provided a breath sample to the In- toximeter. No subject was informed of his actual BAC at any point during the session.

The subject continued in this manner until 7 hours elapsed (PL session) or until his BAC fell below 0.02% (AL session). Beginning at least 60 minutes after the drink was consumed, the subject was fed more bread during each rest period (0.9 g/kg of body weight) to prevent him from becoming uncomfortably hungry. He was allowed free access to water throughout all sessions. When each session was terminated, the subject was driven home by the experimenter. No subject reported experiencing any nausea or other serious discomfort during any of the sessions.

RESULTS

Basic Blood Alcohol Concentration

All BAC readings during the PL condition equaled zero, as expected. For the AL condition, the mean peak BAC for the nine subjects was 0.104\% (SD, 0.01; range, 0.09\% to 0.12\%). The mean time at which peak BAC was first observed was 58.78 minutes (SD, 29.02; range, 30 to 128 minutes) from the moment the subject began consumption. Subject’s self-reports suggested that the effectiveness of the placebo varied considerably, with some subjects reporting significant feelings of intoxication during the PL session, and others reporting little or no feelings of intoxication.

Alternation Rate

Alternation rate was obtained for each trial by dividing the total number of keypresses during the trial by 0.5 (the duration of the trial in minutes). A $2 \times 2 \times 4$ analysis of variance (all repeated measures) was then performed on the resultant alternation rates. The independent variables in this analysis were stimulus type (CONT versus AFT), dosage condition (PL versus AL), and four levels of blood-alcohol range (BAR1, BAR2, BAR3, and BAR4).

To derive the four BARs, each subject’s alternation rate data were divided into four categories based on his AL condition BAC values. For a given subject, the BAR1 value was the mean alternation rate obtained during those trials when his BAC was 0.02\% through 0.04\%. BAR2 was the mean of all values for that measure when his BAC was 0.05\% through 0.06\%. BAR3 was the mean of all values for that measure when his BAC was 0.07\% through 0.08\%. BAR4 was the mean of all values for that measure obtained when his BAC $\geq 0.09\%$. Alternation rates were unavailable when BAC was $<0.02\%$ because subjects’ BACs were typically above this value by the time alternation rates were first measured after drink consumption, and the AL session was terminated when a subject’s descending BAC reached this value. The reason for choosing unequal intervals for BARs is as follows: We needed more than 10 trials for each cell for each subject, and using BARs with a range of 0.02\% was the minimum range that allowed this for all subjects. The actual range of BAR4 was 0.09\% to 0.10\% (mean peak BAC), which makes the range of BAR4 effectively equal to BAR2 and BAR3. BAR1 had a range of 0.03\% because we did not want to disregard trials $< 0.03\%$. Finally, BACs were available only to the nearest hundredth of a percent because the intoximeter measures BAC with that amount of precision.

For the PL condition, the four BARs represented trials with times of occurrence corresponding to those trials in the AL condition. For example, if postdose trials 1 to 10 defined BAR4 for the AL condition for a particular subject, then postdose trials 1 to 10 defined BAR4 for the PL condition for that subject. Those trials in the AL condition for which there were no equivalent-time trials in the PL condition were not included in the analysis.

The analysis of variance showed a significant main effect due to BAR ($F[3,24] = 7.30, P = 0.001$) and a significant BAR $\times$ alcohol condition interaction ($F[3,24] = 4.49, P = 0.012$). None of the other main effects or interactions were statistically significant. There was no main effect of stimulus type ($F[1,8] = 0.17, MSe = 117.43$).

The BAR $\times$ alcohol condition interaction is illustrated in Figure 3. A significant main effects analysis (collapsing across stimulus type) revealed the effect
of BAR to be significant for the AL condition \( (F[3,24] = 7.73, P = 0.001) \), but not for the PL condition. Newman–Kuels analyses comparing the PL and AL condition at each level of BAR showed significant differences at BAR3 and BAR4 (both at \( P < 0.01 \)), but not at BAR1 or BAR2. Newman–Kuels comparisons of all pairs of BAR levels for the AL condition showed BAR1 to be significantly different from BAR3 and BAR4 \( (P < 0.01) \). The rest of these comparisons were not significant.

**Simultaneous Dominance Phase Duration**

To determine if the likelihood of apparent fusion increased with BAC, an analysis of simultaneous dominance phase duration data was performed. This measure was derived for each trial by first determining the total dominance duration for each eye (the total amount of time that eye’s view was signaled as dominant during that trial). Then, for each trial, the total dominance durations for both eyes were summed, and 30 seconds were subtracted from the total (any sum of the total dominance durations greater than 30 seconds could only result from the simultaneous dominance phase durations for that trial).

It should be noted that simultaneous dominance phase duration could exceed zero on any trial for two reasons, only one of which represented simultaneous dominance of the bars. The other reason was a response bias: subjects often signaled the onset of a dominance phase for one eye slightly before releasing the other eye’s button. This resulted in a non-zero baseline for this measure in all conditions. The important question, however, is whether simultaneous dominance phase duration increased with BAC. This question was addressed with a 2 X 4 (alcohol dosage condition \( \times \) BAR) repeated measures analysis of variance, collapsing across stimulus type, with simultaneous dominance phase duration as the dependent variable. This analysis revealed no significant main effect of dosage condition or BAR, nor was there a significant interaction. We should note that if an increase in periods of phenomenal fusion were accompanied by increased phases of simultaneous suppression (neither button pressed), any increase in phenomenal fusion would be masked. Post hoc analyses of our data reveal that this was not the case.

**DISCUSSION**

We confirmed Bárány and Hallden’s4 principal finding. It is clear that alternation rates decreased with increasing BAC. This relation was observed for rivalrous afterimages as well as for stimuli that were continuously illuminated. Furthermore, the lack of an interaction between the type of stimulus and alcohol condition supports the conclusion that this effect occurred without oculomotor mediation—that is, the effect of ethanol on rivalry alternations was caused by changes at or beyond the level of the retina, and ethanol-induced changes in oculomotor mechanisms played no role in the effect we found.

There was, however, almost no support for Bárány and Hallden’s4 claim that ethanol intoxication can lead to phenomenal fusion. The failure of the current experiment to provide evidence for phenomenal fusion. The failure of the current experiment to provide evidence for phenomenal fusion does not mean, of course, that it could not occur at higher BACs. If our finding that rate of rivalry alternations decreases with increasing BAC is pursued to its logical extreme, one would expect that at some BAC higher than those tested in the current experiment, the rate would reach zero. However, it is unclear on a priori grounds whether an alternation rate of zero would coincide with phenomenal fusion or stable dominance of one eye’s view. Thus, it is possible that Bárány and Hallden’s4 observations of such fusion were for subjects with high BACs, but we cannot be certain because Bárány and Hallden did not report BAC values for their subjects.

Any attempt to delineate the exact mechanism by which ethanol affects alternation rate is speculative at this point. One possibility, however, may be that this reduced rate is an outcome of ethanol-induced reduction in contrast sensitivity. Simultaneous binocular reductions in stimulus contrast yields decreased alternation rates.5 It also has been demonstrated that low-contrast stimuli increase the potential for phenomenal fusion or at the very least extend the period over which nonfusible stimuli must be viewed before they begin to engage in rivalry alternations.19 That study also reported that near-threshold sinusoidal gratings presented orthogonally, one to each eye, can even result in the perception of “dichoptic plaids.” These plaids presumably result from some form of binocular combination of the images from both eyes—a form of phenomenal fusion. Further, several investigators have reported that contrast sensitivity is significantly reduced in observers who have consumed ethanol.9,19–25 Thus, one possible explanation for our results is that ethanol reduced our subject’s contrast sensitivity, producing the functional equivalent of reduced contrast in the stimuli, a sufficient condition for reducing alternation rates. Were this functional reduction of contrast severe enough, it might have led to phenomenal fusion, in keeping with the effect reported by Liu et al.19

A recent account of binocular rivalry has distinguished explicitly between rivalry alternations and rivalry suppression.5 Although his model is meant to be purely descriptive, Fox5 strongly suggests that rivalry inhibition and rivalry alternations are controlled by separate mechanisms. Under Fox’s conception, reduced alternation rates can be attributed to some
change in the interplay between excitatory signals in the monocular inputs from each eye and inhibition of those channels sent from an inhibitory suppression mechanism. This leaves two possible accounts for the reduced alternation rates we found. The first is the account we suggest, that ethanol-induced decreases in contrast sensitivity reduces excitatory signals in each monocular input by approximately the same amount. The second possibility is that alcohol reduces the strength of the inhibition from the inhibitory mechanisms. If this were true, we would expect to find small but reliable decreases in threshold elevation during suppression phases under alcohol. Unfortunately, we cannot know this because test probes were not presented to our subjects.

Key Words
afterimages, binocular rivalry, ethanol, stimulus strength, suppression

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References