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## Subject Area - Sciences

### Alcohol Reaction Time

The experiment tested whether alcohol had any effect on reaction time.

#### Abstract

Objective: The experiment tested whether alcohol had any effect on reaction time.

Method: Subjects were required to identify the threshold at which a flickering light became constant (critical flicker fusion threshold) using a computerised flicker fusion system. Frequency increased at a rate of 4 hertz per second. Critical flicker fusion threshold is a well accepted and documented non-invasive measure of reaction time. Ten female subjects were tested under control conditions and following ingestion of 2 units (80 mg) alcohol. It was hypothesised that alcohol would cause an increase in reaction time, which would translate to a delay in recognising the critical flicker fusion threshold, thus higher frequency results.

Results: Ingestion of 2 units (80mg) of alcohol was associated with an increase in mean critical flicker fusion threshold from 14.6 hertz to 15.4 hertz ( $p < 0.0001$ ). This increase in mean critical flicker fusion threshold translated to an increase in reaction time equivalent to 0.2 seconds.

Conclusion: 2 units of alcohol had the effect of increasing reaction time by an average of 0.2 seconds, which has serious implications for the consumption of alcohol prior to tasks involving complex motor skills such as driving.

#### Introduction

##### Alcohol and its effects

Alcohol is believed to be the oldest drug used by humans, predating even the use of opium by 2000 years to around 8000 BC (Kerr, Hindmarch 1998). Whilst legal age limits exist for the purchase of alcohol in the United Kingdom, it is widely regarded within the Western world as an acceptable drug.

In recent household studies in the UK it was found that 75% of men and 60% of women consumed at least one alcoholic drink per week. In addition, 40% of men and 23% of women were found to have exceeded the national recommendations on alcohol consumption within the previous week (Office for National Statistics 2005). The Institute For Alcohol Studies ranks the United Kingdom as 9th in per capita consumption of pure alcohol within European Nations, with 9.6 litres of pure alcohol being consumed per capita in 2002 (Institute for Alcohol Studies 2005).

Alcohol is known for its psychoactive effects, which include alterations in vision, motor tasks and skills such as car driving and flying. In addition it is repeatedly shown, whether anecdotally or via scientific measurements, that a strong correlation exists between alcohol consumption and violence.

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Alcohol is known to be a contributory factor in road accidents, with 9% of casualties showing evidence of alcohol consumption, this figure rising to 31% when considering pedestrians (The Scottish Office Central Research Unit 1998). Research carried out in the 1980s by the Transport Research Laboratory indicated that alcohol was involved in 35% of fatal road traffic accidents, with the figure falling slightly to 31.5% in a similar study completed in 2000 (Tunbridge, Keigan & James 2001). However neither of these reports explained why the association existed between alcohol and road traffic accidents, whether resulting in death or not.

Of import for this report is the association between alcohol and reaction time. The majority of alcohol consumers can identify a slowing down of their faculties following alcohol consumption, regardless of claims to the contrary. Research has shown that alcohol impairs the ability of individuals to carry out complex motor tasks.

One example involved bus drivers being asked to drive a vehicle through a narrow space, or highlighting the fact that the gap was too narrow if necessary. It was shown that alcohol consumption was correlated with a reduced ability to accurately guide the bus through the gap, coupled with an inability to accurately gauge the width of the gap. Hence bus drivers who had consumed alcohol were more likely to judge a gap as to be wide enough when it was not, than those who had not consumed alcohol and whose spatial awareness remained intact (Rang, Dale & Ritter 1999a).

Recommended stopping distances at 30 miles per hour are 23 metres / 75 feet, of which 9 metres / 30 feet are the 'thinking distance'. This is based on an average reaction time of 0.7 seconds when the car is travelling at 44 feet / second. Therefore if reaction times increase, stopping distances will do so also, with serious implications in an accident.

It has been indicated by some research that low levels of alcohol consumption have very little effect on reaction time if attention could be focussed on a single objective (Jaaskelainen et al. 1996). Where attention needs to be divided between task objectives, even low blood alcohol levels were found to impair performance. This suggests that alcohol is not going to greatly impair reaction time during simple tasks, but complex tasks which require several aspects to the performance would be much more likely to be impaired. This was further supported by the research of Bartholow et al which found that response times per se were relatively unaffected by the presence of alcohol but the ability to respond appropriately to tasks that required complex attention were (Bartholow et al. 2003). Indeed the authors implicate alcohol in impairments of cognitive processing, rather than the motor responses that result from these processes. They cite data from studies that have shown that alcohol acts to reduce the ability to respond to stimuli as well as interpret and process the correct relevance of these stimuli. This inability to respond fully to cues from the environment is described as the attention-allocation model, as the brain is selective in which cues are actually attended to and processing within the brain. Further research has indicated that alcohol can sometimes actually improve the ability of subjects to resist distraction from a task (Erblich, Earleywine 1995) but this is not in keeping with the majority of research.

Given the existing data this experiment was designed to assess the ability of female subjects to respond to a change in a single form of stimulus. There was no distraction, nor a divided attention focus required, in an effort to ensure that the effects of alcohol on reaction time, if any, were more obvious.

#### Flicker fusion threshold

The human eye is capable of distinguishing between intermittent stimuli such as flickering light, up to a threshold, which

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is usually around 16 Hertz. The frequency at which the human eye is no longer able to distinguish individual stimuli is defined as the critical flicker fusion threshold. It is at this frequency that the individual stimuli have fused to form a single continuous stimulus. The flicker fusion threshold will vary between individuals depending on their eyesight, hence the use of a number of study participants. It will also vary between an individual's readings depending on their reaction time at each stage – ie the time at which they actually consciously register that the hitherto flickering stimulus has now become constant and are able to respond to this knowledge.

The purpose of this experiment was to use the measurement of critical flicker fusion threshold as a correlate to reaction time.

For this experiment the experimental hypothesis was that alcohol acts to increase the reaction time of female subjects.

The null hypothesis was that alcohol has no effect on the reaction time of female subjects.

Thus it would be expected that an individual with a slower reaction time would give results indicating a higher critical flicker fusion threshold, measured in hertz.

In other words it would be expected that the frequency at which subjects indicated that the flickering light (for full details of methodology please see below) had fused into a single light would be higher under alcohol conditions than control. This would not be due to an enhanced ability to differentiate between flickering and constant light, rather a delay in the ability for this change to register and be processed by the brain, and the subject to press the button.

#### Method

Ten female subjects aged from 18-35 years, with a body mass index of 19-28 were selected as part of an open experiment into the effect of alcohol on reaction time. All subjects were informed of the purpose of the experiment prior to taking part and were required to complete medical questionnaires to exclude medication that might affect the results of the experiment. Known negative effects of alcohol consumption were also excluded and subjects all had a history of regular alcohol consumption of at least 2 units, once per week.

Subjects were required to refrain from eating or drinking for the 2 hours prior to each test, which took place on consecutive days, with the control (no alcohol) test taking place prior to the alcohol test. The 2 hour nil by mouth regulation was put in place in an effort to standardise the absorption of the alcohol by reducing stomach contents to a more uniform amount, thus providing a similar surface area available for alcohol absorption in each study participant.

On arriving at the test room subjects were required to complete a health and safety questionnaire and were again reminded of the aims and purposes of the experiment. Subjects were free to leave at any time, and signed consent forms to allow their results to be used.

Following the initial briefing subjects were given a training briefing on the specialised equipment and allowed to take a small number of practise tests to familiarise themselves with the equipment requirements. Following this training period a five-minute break was allowed.

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For the test itself each subject was required to drink 250ml of pure orange juice, with a five-minute timespan being allowed for the drink to be consumed. Forty minutes after the drink had been consumed subjects critical flicker fusion threshold was tested using the Model 12021 Flicker Fusion System (Lafayette Instruments).

This time scale was used as the 2 units of alcohol would have reached a peak blood alcohol concentration of approximately 80 mg/100 ml 45 minutes following ingestion (Wilson, Benjamin & Sreenivasan 2003). Assuming absorption and metabolism at the accepted 4 mmol/l per hour (Rang, Dale & Ritter 1999b), the alcohol would be expected to have been removed completely from the body within 6 hours (Wilson, Benjamin & Sreenivasan 2003).

Subjects were requested to look in to the binocular eye piece at two white simultaneous lights. The use of a separate light for each eye was used to prevent differences in eye focussing from causing conflicting critical flicker fusion thresholds.

The initial flash frequency of 4 hertz was set to ascending at a rate of 4 hertz / second. The subject was provided with a push button connected to a 1 metre cable and was required to push the button when the flickering ceased and the lights became fused to a single light emission. The point at which the button was pressed was taken as the critical flicker fusion threshold.

Each subject was required to undertake ten reaction time recordings.

The experimental procedures on day 2 were identical to day 1, except that 2 units of alcohol (vodka), approximately 80mg of pure alcohol, had been added to the 250ml of pure orange juice that the subjects were required to drink. A further ten reaction time recordings were made using the flicker fusion system.

## Results

Each subject was able to provide 10 reaction time recordings, which ranged from a minimum of 11.5 Hertz (subject 9, recording 6, no alcohol) to a maximum of 19.4 Hertz (subject 3, recording 8, with alcohol).

The mean for the control / no alcohol test was  $14.6 + 3.6$  Hertz. The mean for the alcohol test was  $15.4 + 4.0$  Hertz.

Tables 1 and 2 below show the individual reaction times of each subject participant on the two tests.

Table 1. Reaction times of 5 female subjects with and without alcohol, as measured by critical flicker fusion threshold

It can be seen by a comparison of the mean and median averages for each subject that there are small differences between these two figures in the majority of instances, but these do not exceed 0.4 hertz, or less than 3% variance.

Overall the average response time of subjects without alcohol was 14.6 hertz, compared to 15.4 hertz with alcohol. The standard deviation was 1.4 and 1.6 respectively, indicating that the level of variation around the mean was also relatively low. In other words, the mean average did genuinely represent the results that were obtained, and there were few results that were substantially different from this mean.

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A direct graphical comparison of the means for each subject is shown in figure 1. The standard error bars have been set to show the standard error of the mean.

Figure 1. Mean reaction times for identification of critical flicker fusion threshold for control and alcohol tests.

Figure 1. Mean reaction times for identification of critical flicker fusion threshold for control and alcohol tests

To further investigate the actual relevance of the results they were analysed using statistical tests. Whilst it can be seen from tables 1 and 2 and figure 1 that the results do differ, this could be due to chance alone, as opposed to the presence of alcohol being responsible for the differences. The identification of a difference in results, which appears to be significant but is actually due to chance alone, is known as a Type I statistical error.

Therefore a statistical test was carried out, which indicated the probability that the differences in the results, specifically the means, occurred due to chance alone.

As the results were from the same individuals with the only thing changing being the amount of alcohol consumed – eg nothing or 2 units, then it was assumed that there was a single variable changing, that of the presence of alcohol. All other variables were assumed to be constant. As the same number of reaction times were obtained under identical conditions, the results from test day 1 and test day 2 could be paired. It was assumed that the subjects would respond in a pattern of normal or Gaussian distribution, hence the use of the t-test. Therefore a paired t-test, with a two tailed P value, was used, utilising the online software available from GraphPad software (GraphPad Software 2005).

The difference between the mean of the control group without alcohol (14.6 hertz) and alcohol group (15.4 hertz) was found to give a probability (p) value of 0.0133, which is statistically significant, according to commonly accepted criteria. The probability that the differences in the results arose due to chance alone was less than 2 chances in 100.

Therefore it could be concluded that alcohol did cause a significant increase in reaction time.

As well as the test on the overall results, a similar test was performed on the raw data, eg each individual reaction time from each of the individual subjects. The means for control / alcohol were the same, when rounded to 1 significant figure, but the p value came out at 0.0001, which is considered to be extremely statistically significant.

It was found that 6 of the 10 subjects showed a statistically significant increase in reaction time following alcohol consumption, with p values ranging from 0.042 to 0.0003. Furthermore 5 of the subjects showed an increased reaction time with a p value of 0.01 or lower, deemed very or extremely statistically significant by scientific standards. Indeed if the t-test calculation was performed on only those individuals' results a mean of 14.6 and 15.9 for control / alcohol respectively was obtained. This gave an overall p value of 0.0001, which is considered extremely statistically significant.

## Discussion

This experiment did support the hypothesis that alcohol increased reaction time in female subjects, as defined by flicker fusion threshold. Alcohol increased the flicker fusion threshold by 0.8 hertz. As the ascending rate of the flicker had been set at 4 hertz per second it can be concluded that alcohol increased reaction time by an average of 0.2 seconds. Two

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subjects had average differences of 0.4 seconds.

In terms of car stopping distances this would result in an increase in reaction time of 29%, and an increased distance before braking of 9 feet.

The difference in the statistical significance of the results obtained from the original raw data as opposed to the means of these data is interesting. It could indicate that the use of means from each subject is not as accurate a measure of the reaction time of the individuals. However, and more likely, the use of a greater number of data sets on which to perform the statistical tests enables the statistical significance to become more pronounced. It is always easier to be more certain of observed results if they have been obtained from a larger number of experiments. Thus when sample size = 10 chance can underlay observed variation in more cases than when sample size = 100.

The results obtained in this experiment are contrary to those found by Liguori and Robinson who found that alcohol had no effect on reported critical flicker fusion threshold (Liguori, Robinson 2001). Likewise Ridout et al suggest that impaired / altered CNS function, as would be expected through alcohol consumption should reduce the critical flicker fusion threshold (Ridout et al. 2003), not increase it, as this experiment showed. However the results support those found by eg Azcona et al which showed that alcohol did increase critical flicker fusion threshold (Azcona et al. 1995).

Following conflicting reports about the validity of using critical flicker fusion threshold as a measure of the effect of alcohol on reaction time the Health and Safety Laboratory undertook research to assess whether there was in fact a correlation between the two measures. The results, published in 2003, found little difference in critical flicker fusion threshold obtained following alcohol ingestion, when compared to those completed prior to ingestion, and following complete alcohol metabolism. In addition critical flicker fusion thresholds were several times higher than in the present experiment, averaging 43 Hertz (Wilson, Benjamin & Sreenivasan 2003). The authors did note, however, that there was a reduction in critical flicker fusion threshold 1 hour after alcohol ingestion, ie the same time at which the present experiment was undertaken. They also noted that study participants found it difficult to actually concentrate on the apparatus as the alcohol induced drowsiness and a reduced ability to focus eyes. This was not a concern in the present experiment, which only measured critical flicker fusion threshold at the predicted maximal blood alcohol concentration, which was much less than in Wilson et al's study. However it would have been interesting to see whether critical flicker fusion threshold changed with time.

Whilst on face value, and following statistical analysis, the results appear to provide strong support for the hypothesis that alcohol increase reaction time, there were a number of sources of error that may have influenced the results. These are discussed below.

### Expectancy

Expectancy is a recognised psychopharmacological term that refers to the developed association between two events that follow each other. The repeated pairing of the two events cause the two to become so associated with each other that the second event is actually physiologically expected when the first occurs (Fillmore, Vogel-Sprott 1994). For instance, if an individual regularly experiences a particular psychomotor effect upon consuming alcohol then this effect is predisposed on future consumption of alcohol. In terms of alcohol consumption this could involve a habitual drinker expecting a

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specific physiological response, such as mood changes or motor disturbances.

It has been shown that if participants are told that alcohol might have a specific effect upon their performance then they are likely to compensate for this, such that the warned of effect will be almost reversed. In one study participants were told that alcohol would slow their reaction time and actually compensated to give faster reaction times under alcohol conditions (Fillmore, Blackburn 2002).

As each subject involved within the present experiment was a habitual alcohol consumer she might have demonstrated expectancy with regard to reactions upon consuming the vodka on day 2 of the test. It has been shown that heavy social drinkers are less likely to experience motor impairments as a result of alcohol consumption than those who consume more moderate amounts. As no differentiation was made between any of the subjects on the actual amount of alcohol they habitually consumed, it was possible that some individuals consumed considerably more alcohol, thus had a different expectancy in terms of psychomotor response, than did other subject participants.

The experiment was conducted on an open basis – ie the subjects involved were fully aware of when they were consuming alcohol. It is perfectly feasible that subjects were able to subconsciously alter their reaction time to account for the fact that they knew that they had consumed alcohol. All subjects chosen were regular drinkers of at least 2 units per week so would be assumed to have reasonable knowledge of the effect that alcohol had upon their faculties.

It would have been interesting to run the experiment using a blind methodology so that participants were not aware of whether they had consumed alcohol or not on the test day. In this case expectancy would have been reduced.

The effect of practice on critical flicker fusion threshold results

Parkin et al showed that critical flicker fusion threshold did not alter upon practice, with the exception of a small but replicated reduction in threshold within the first hour of testing. Those authors recommended an hours practice prior to actual testing on each occasion (Parkin, Kerr & Hindmarch 1997). This was not done in the present experiment. However it would be unlikely that the lack of practice would have had a substantial effect upon critical flicker fusion threshold. The original finding showed only a small reduction in reaction time, and to have increased the testing time within the current study by an hour would have more than doubled the testing time which was considered unnecessary.

Factors affecting the absorption rate of the alcohol.

In this experiment the independent variable was the amount of alcohol consumed by the subject. This was controlled, in that 250ml of orange juice with / out 2 units of alcohol were administered by the experimental administrator. Therefore the amount of alcohol, and other liquid, was controlled during the time in which the subjects were present in the test room.

Study participants were requested not to consume anything for 2 hours prior to the experiment on each of the test days. This was taken on trust and not discretely checked so the results assume that this was in fact the case.

Likewise it was not possible to control ingestion outside of the testing hours. Whilst subjects were not specifically requested to abstain from alcohol in the time period before the test this perhaps could have been done. It is possible

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that subjects consumed alcohol more than 2 hours before the test and this had yet to be cleared by the liver, meaning that it was still able to have an effect upon the reaction time. Indeed this effect could have resulted on either test day. Without specifically requesting a full food and drink chart to be completed for the 24 hours prior to each of the tests, or even preclude food and drink for a much longer time period prior to the experiment, it is not really possible to completely discount blood alcohol other than that administered within the test parameters. In Wilson et al's research study participants were requested to refrain from alcohol for 72 hours prior to testing. This ensured that all alcohol had been metabolised and any effects observed could be concluded to be due to the administered alcohol (Wilson, Benjamin & Sreenivasan 2003).

Alcohol (ethanol) is a highly lipid-soluble, uncharged molecule, which is rapidly absorbed across mucous membranes. The removal of ethanol from blood plasma follows a so-called saturation kinetics course, whereby removal from the plasma remains essentially constant at 4mmol/l per hour (Rang, Dale & Ritter 1999b), regardless of plasma concentration, see figure 2. This means that there could be expected to be alcohol remaining in the circulation if the subject had ingested alcohol prior to the specified 2 hours preceding the experiment.

Figure 2. Saturating kinetics of alcohol elimination in man (adapted from Rang, Dale & Ritter 1999b)

In addition to pre-existing alcohol the contents of the stomach can also affect absorption (Tagawa et al. 2000). As the ethanol is removed from the plasma at a relatively constant rate, the rate at which it enters the plasma will affect the resultant blood ethanol concentration. Ingesting alcohol on an empty stomach means that the ethanol is absorbed more rapidly, thus the hepatic metabolism is saturated rapidly, so more ethanol remains in the plasma. Conversely ingesting alcohol on a full stomach, or with a meal, means that the ethanol is absorbed more slowly, thus the hepatic metabolism is more able to keep up with the removal of the ethanol, via first-pass metabolism, with the result that less ethanol remains in the plasma.

Therefore the quantity of food and drink consumed within the time preceding the test period could also have affected the absorption of alcohol. Stomach contents do not completely clear within 2 hours, so if one subject participant had consumed a heavy meal immediately prior to this time then a large quantity of food would be expected to be present in the stomach, thus reducing absorption. Likewise another subject may have completely abstained from food or drink for a much greater period than 2 hours, resulting in an almost empty stomach, which would greatly increase the absorption rate of the alcohol.

It would have been useful to calculate the blood alcohol concentration of each study participant in order to ascertain whether results differed due to this factor. This would have been calculated using the following equation where:

Ca = blood ethanol concentration (mg/L)

Vl = volume of alcohol consumed (ml)

D = degree of alcohol content (%)

Vdl = volume of distribution – 0.55 for females

Bw = body weight (Kg) (Wilson, Benjamin & Sreenivasan 2003):

Ca =

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(Vl x D x 0.8)

(Vdl x Bw x 100)

The research by Tagawa et al showed that reaction time was affected to differing extents depending upon blood alcohol concentrations, with an overall positive correlation between increasing blood alcohol concentration and increasing reaction time (Tagawa et al. 2000). However this particular study did not utilise critical flicker fusion threshold as a measure of reaction time so a precise comparison to the present experiment is not possible.

However, whilst a note was made of study participants body mass index, their weights were not recorded. Indeed the body mass index values varied quite substantially, from underweight (19) through healthy (20-25) to overweight (26-28). However the relevance of this to the experimental data cannot be ascertained without a much fuller knowledge of dietary and alcohol consumption habits.

### Conclusion

The data from this experiment do support the hypothesis that alcohol has an effect of increasing reaction time, as measured by critical flicker fusion threshold. Results on overall data obtained showed high statistical significance ( $p < 0.0001$ ).

The UK legal limit for alcohol levels is 80 mg/100ml (Rang, Dale & Ritter 1999a) and blood alcohol concentrations of this amount are obtained within 1 hour of ingestion of 2 units of alcohol (Wilson, Benjamin & Sreenivasan 2003). Therefore it can be concluded that the consumption of 2 units of alcohol would be likely to impair reaction time to a significant extent for at least 2 hours following consumption. The results from this experiment strongly support the UK drink driving limits.

However in order to be more certain of the results it would be advantageous to repeat the experiment, taking into account some of the factors mentioned above to discount other variables from affecting results. In particular the following could be ensured:

The study should take place under blind conditions – eg whilst study participants are aware of the fact that they will be consuming alcohol, they would not be aware of which test day this would take place.

Further data should be obtained from each study participant, including weight, more detailed prior alcohol consumption history and pattern of intake.

Study participants should refrain from ingesting alcohol both 72 hours prior to the study, and between the study days.

Study participants should have a similar amount of food at the same time prior to the test being carried out.

In this way the study conclusions could be more accurate.

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