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EFFECTS OF ALCOHOL ON DIVIDED ATTENTION AND ON ACCURACY OF ATTENTIONAL SHIFT

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Effects of alcohol on divided attention and on accuracy of attentional shift. Two experiments are described in which a group of students (39 in experiment 1, 32 in experiment 2) carried out: 1- a dual task, 2- a test of auditory attentional shift, both under two conditions: A- after drinking an alcoholic beverage until reaching a blood-alcohol level of between 0.3 and 0.4 gr/l in experiment 1, and between 0.2 and 0.3 gr/l in experiment 2; B- after drinking a similar beverage with negligible alcohol content. Results showed that these low blood-alcohol levels –below the legal limit for car drivers in Spain– impaired accuracy in attentional shift and affected the capacity for dividing attention. Possible implications for driving behaviour and road safety are discussed.

Se describen dos experimentos, en los cuales un grupo de estudiantes (39 en el experimento 1, 32 en el experimento 2) llevaron a cabo: 1- una tarea dual 2- una prueba de cambio atencional auditivo. En ambos casos, los sujetos pasaron por dos condiciones: A- ingerían una bebida alcohólica hasta alcanzar un nivel de alcohol en sangre entre 0,3 y 0,4 gr/l en el experimento 1 y entre 0,2 y 0,3 gr/l en el experimento 2, y B- ingerían un preparado similar con un contenido en alcohol despreciable. Los resultados muestran que esos bajos niveles de alcohol en sangre, permitidos a los conductores en el estado español, empeoran la precisión del cambio atencional y afectan a la capacidad de dividir la atención. Se discuten las posibles implicaciones para la conducción y la seguridad vial.

The consumption of alcohol is one of the main indirect causes of road accidents. This incontrovertible fact makes the study of the effects of alcohol on driving one of the most important areas within psychological research in this field. It also means that the analysis of the effects of different blood-alcohol levels on the diverse psychological processes and crucial skills necessary for driving has become, over the years, one of the most prolifically studied issues in road safety. Indeed, as early as the 1960s and 70s, rigorous studies were carried out in Spain on the effects of alcohol on driving (Linares Maza, 1971), and even at that time, these pioneering studies strongly recommended the prohibition of alcohol consumption by those in charge of a vehicle.

Nowadays, it is widely known that the effects of alcohol on the central nervous system (CNS) lead, among other things, to: a false state of euphoria, an unfounded sensation of security and confidence, increased reaction time, reduced visual capacity and motor performance, impaired capacities of judgement, reasoning and attention, and a false perception of speed and distance (Spanish General Directorate of Traffic (DGT), 1996). All of the above constitute important causes of road accidents.

Statistics on the relationship between high alcohol intake and serious accidents have become increasingly. In 1984 only 2.1% of accidents in Spain were found to be alcohol-related (Soler and Tortosa, 1987a). However, in recent years there has been a dramatic increase, with the latest figures estimated at approximately 30% (DGT, 1996). It seems that the probality of suffering a traffic accident rises as the bood-alcohol level increases: in arithmetic progression between 0.4 and 0.9 gr/l, but in geometric progression over 1 gr/l (Montoro, Tejero and Esteban, 1995).

These statistical data alone constitute para mount argumentes which justify, in most western countries, the existence of legal blood-alcohol limits, above which driving is forbidden.

In Spain, this limit is has recently been set at 0.5 grams of alcohol per litre of blood for drivers of private vehicles, and at 0.3 gr/l for professional and beginner drivers. In other countries, the legal limit for drivers of private vehicles is even lower –as low as 0.0 gr/l in some cases. This would appear to be more in line with experimental findings related to the influence of alcohol on some of the variables directly affecting driving ability: according to some studies (Moskowitz, 1973; González

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Luque and Álvarez, 1995), these variables are affected at levels of as low as 0.2 gr/l. Other studies have refuted the myth that low doses of ethanol improve the skills necessary for driving (Moskowitz, Burns and Williams, 1985).

One of the crucial human-factor variables in driving, and that on which blood-alcohol level appears to have the most serious repercussions, is the attentional variable. Numerous works demonstrate that the ingestion of alcohol affects the attentional system (Moskowitz and Sharma, 1974; Moskowitz and Burns, 1990). Many believe that it is precisely this fact that explains why alcohol consumption so greatly increases the probability of serious accidents (Shinar, 1978). However, research into the effects of alcohol on attention is a complicated matter. Evidence indicates that what we call attention is not a unitary construct of a strictly central nature Rosselló, 1999). Thus, attentional ability is not a simple one, and is, in fact, determined by a set of specific and often independent sub-abilities. This reinforces the concept of the attentional system as modular, despite being co-ordinated by a central executive system (Posner and Petersen, 1990). Factorial analysis applied to different attentional factors has indicated the existence of at least three differentiated factors: selectivity, resistance to distraction and the ability to switch from one focus of attention to another (Sack and Rice, 1974). Further evidence is provided by studies of differences between and within individuals (Rosselló and Munar, 1994). These studies show conclusively that, while subjects may perform well in selective attention tasks, they perform poorly in vigilance tasks (or vice-versa), and that even for the same type of task they perform differently depending on the sensory modality. Attention is, then, a mechanism of multiple character, a fact lucidly expressed by the illustrious Mira i López. "There are as many "attentions" as "psychons" in the brain" (Mira i López, 1920).

There would appear to be four relevant attentional skills involved in driving.

1. Vigilance
2. Selection
3. Attentional shift
4. Attentional distribution (divided attention)

Many studies show that there is a decrease in vigilance subsequent to ethanol ingestion (Gereb, 1975; Jacobs, 1976; Leigh, Tang and Campbell, 1977; Gustafson, 1986; Rohrbaugh et al., 1987; Rohrbaugh et al, 1988). Less abundant is research on the effects of alcohol on attentional selectivity (Hamilton and Copeman, 1974; Moskowitz and Sharma, 1974; Jubis, 1986). A great deal of research has been carried out with dual tasks for determining the effects of alcohol on the capacity to divide attention (Moskowitz and Depry, 1968; Brewer and Sandow, 1980; Moskowitz, Burns and Williams, 1985; Patel, 1988; Moskowitz and Burns, 1990; etc). However, as most of these works studied the effects of high or moderate blood-alcohol levels, we decided to undertake, as a first experiment, the study of the effects of low intake levels on the distribution of attentional resources, that is to say, their influence on so-called divided attention.

Furthermore, despite the fact that, as early as 1920, Mira i López spoke of the importance of "attentional mobility" in perceptual ability, and how it was inadvisable to drive when this mobility was slow, the most neglected area of research into the effects of alcohol on the different attentional variables is that of how it affects attentional shift (if indeed it does).

Due precisely to the scarcity of references in this area, it was decided to carry out the second experiment described here. The objective was to examine the accuracy with which subjects carried out an auditory attentional shift task based on the experimental paradigm used by Rhodes (1987).

Finally, the influence of the sex variable was examined, previous studies having indicated that women´s cognitive capacity was affected more than that of males, given similar levels of alcohol ingestion (Niaura et al, 1987).

EXPERIMENT 1

Method

The experimental group was comprised of 39 subjects, 20 females and 19 males, with ages ranging from 18 to 30. They were chosen from first and second year psychology students at our university, with the stipulation that they drank an average of between 6 and 12 units of alcohol per week (one unit of alcohol being equivalent to a glass of wine, a small glass of beer or half a glass of spirits), that they were not receiving medication, that they were not habitual users of psychotropic drugs, and that they did not suffer from any illness which would make alcohol ingestion inadvisable. The selection process was carried out through the use of an *ad hoc* questionnaire.

A repeated-measures, counterbalanced and double blind design was used, with two conditions. In Condition A subjects were administered 500 millilitres of beer with alcohol content (5% a.b.v.) in two stages, until a blood-alcohol level of between 0.3 and 0.4 gr/l (0.15 – 0.2 mgr. per litre of exhaled air) was attained.

The measurement was taken using a Drager 7110 ethylometer. In Condition B, the same amount of beer was administered, but its alcohol content was negligible. Subjects had to perform a dual task consisting of a pencil and paper test based on that of Toulosse-Pièron (T-P) and a simultaneous follow-up task involving the shadowing of a message that they heard through headphones. The experimenter's instructions stressed the importance of carrying out both tasks correctly. Given that the design was a repeated-measures one, and in order to avoid any memory effect, two versions –with similar levels of difficulty– of each task were constructed. Each subject was administered a different version in each condition. Dependent variables were number of errors made and the number of items undetected in our adaptation of the T-P.

Results

For the purpose of obtaining the results, a 2x2 ANOVA was applied, based on the factors sex and condition, for each of the dependent variables. Considering condition with respect to number of errors in the T-P test, it can be stated that subjects make fewer mistakes with a blood-alcohol level of 0 gr/l than with a level of between 0.3 and 0.4 (p = 0.001) (see Figure 1).

Regarding the factors sex and condition with respect to number of errors in the T-P test, it is clear that females make more mistakes when their blood-alcohol level is between 0.3 and 0.4 gr/l (p=0.036). However, with a blood-alcohol level of 0 no significant inter-sex differences are found.

On analysing the number of undetected T-P test items, it seems that subjects with a blood-alcohol level of between 0.3 and 0.4 detect fewer target stimuli than sober subjects (p= 0.002) (see Figure 2). In this case, no significant differences according to sex are found.

EXPERIMENT 2

Method

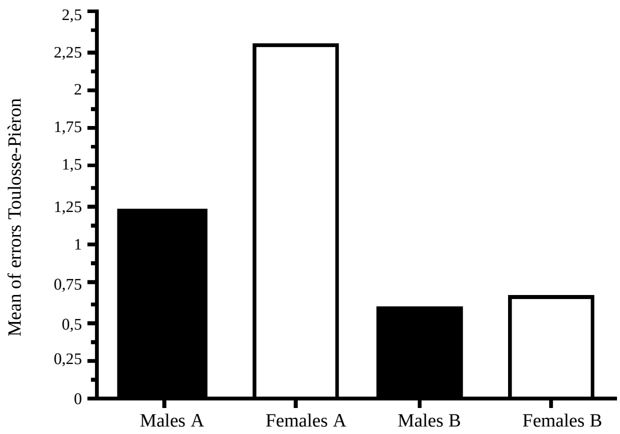
32 subjects were selected, 16 male and 16 female, with ages ranging from 19 to 30. Selection criteria were similar to those for Experiment 1, but in addition, subjects underwent a hearing test in order to discard those with auditory deficiencies. A repeated-measures, counterbalanced and double blind design was applied.

The auditory attentional shift task was carried out using six loudspeakers, the positioning of which can be seen in Figure 3. These speakers emitted a broad band sound (1500-7000 Hz) at 45 db. for 150 msec. The subject's eyes were covered using blindfold goggles. In order to measure vocal reaction time, a microphone connected to a computer was attached to each subject. When the subject indicated the loudspeaker from which s/he believed the sound had come, the vocal reaction time (in msec) and the response given were registered automatically. The experiment was carried out in a soundproofed room with absorption panels to minimise reverberation.

As in Experiment 1, there were two conditions : A (alcoholic drink) and B (non-alcoholic drink). The drink was divided into two doses. In Condition A, the subject's blood-alcohol level was between 0.2 and 0.3 gr/l (0.1 and 0.15 mgr/l of exhaled air). In Condition B, the level was 0 gr/l The subject was given explicit instructions to keep his/her attention focused on the last loudspeaker activated since there was a 40% probability of the same speaker sounding again in the next trial. The

Figure 1

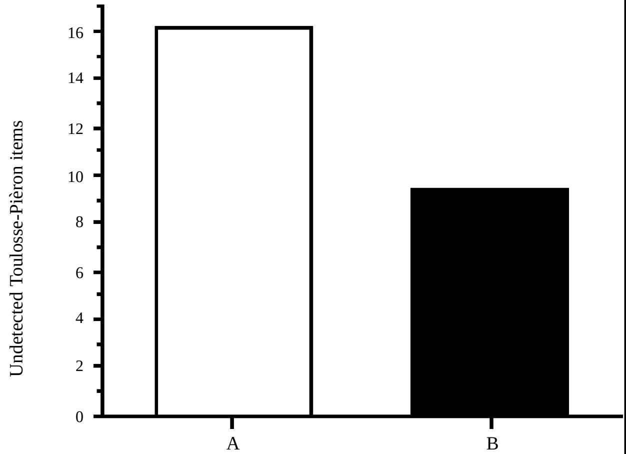
Mean of errors made in the Toulosse-Pièron test by sex and condition



A: blood-alcohol level 0.3-0.4 gr/l B: blood-alcohol level 0.0 g/lt.

Figure 2

Mean of undetected items in the Toulosse-Pièron test by condition



blood-alcohol level 0.3-0.4 gr/l blood-alcohol level 0.0 g/lt.

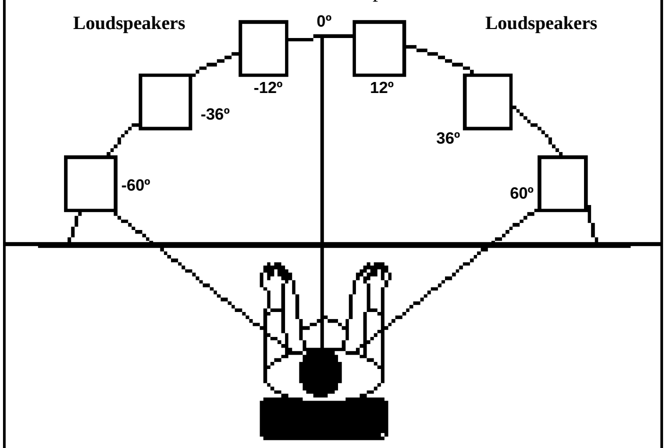
subject's head was to be kept still and rested on a special cushion, and he/she was instructed not to make irrelevant vocalisations (such as "hmm..."), which would cause the timing device to stop automatically. Two 20-trial training blocks were administered, in the first of which the subject was given feedback. Before each new trial the instructions about concentrating on the last loudspeaker activated were reinforced by the words, "pay attention to X" (X being the number of the last loudspeaker to have sounded). In the second training block no feedback was given. The experimental blocks, which followed immediately, consisted of 50 trials per block, and feedback was not given. The dependent variable was number of errors in identifying the loudspeakers from which each sound came.

Results

Firstly, an ANOVA (I) was applied to the percentage of errors, with the variables block, counterbalance, sex and condition. Both the factor sex (p = 0.029) and the factor condition (p = 0.011) presented significant effects on number of errors, but their interaction did not. Both in this analysis and in the subsequent ones, and on the basis of previous research on auditory attentional shift (Rhodes, 1987), trials with a reaction time of less than 300 msec or more than 3 sec were discarded. In this way, the number of trials valid for the analysis was not the same for all subjects, and therefore the number of errors in terms of absolute values has been converted into percentages.

Subsequent to this, the distance factor of the attentional shift (0º, 24º, 48º, 72º, 96º, 120º) was introduced. To do so, only trials preceded by correct responses were used, as this was obviously the only way of verifying the starting point of the focus of attention.

Figure 3
Distribution of loudspeakers used for the auditory attentional shift experiment



In this case, according to the ANOVA (II) carried out, condition (p = 0.031) and distance (p (0.01) had significant effects on number of errors, but not sex (p = 0.164).

In any case, since the distance factor and the distance-condition interaction violated the assumption of sphericity, we turned to non-parametric analysis, which confirmed the significant effect of the distance variable. With regard to the distance-condition interaction, and applying the Wilcoxon test, significant differences were found between distances of 48º (z = -2.42, p = 0.016) and 72º (z = -2.19, p = 0.029), and differences close to significance at 98º (z = -1.68, p = 0.09). These results are shown in Figure 4.

The interaction of distance and sex was also significant (p = 0.05), although the significant differences between sexes are found for the greater distances (72º, 96º, 120º) rather than the lesser ones (0º, 24º, 48º). This result can be seen in Figure 5.

Finally, it is worth pointing out that, in both the first ANOVA and the second one (in which trials not preceded by correct responses were discarded), females made more mistakes in both conditions, though the difference

Figure 4
Mean of percentage of errors by condition (A: blood-alcohol level 0.3-0.4 gr/l and B: blood-alcohol level 0.0 gr/l) and angular distance between sound sources

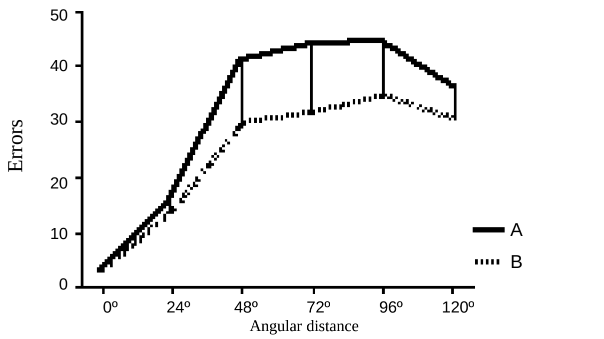
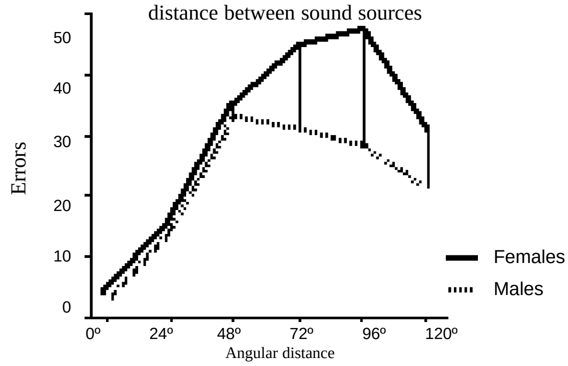


Figure 5
Means of percentage of errors by sex and angular distance between sound sources



is only significant in the first analysis. regarding the increase in errors by condition, it is greater in females than in males, though the difference is not significant in either of the two ANOVAs carried out.

Discussion

With regard to the dual tasks, which involve divided attention, subjects make more mistakes and detect fewer target stimuli with blood-alcohol levels of between 0.3 and 0.4 gr/l than with levels of 0 gr/l. In auditory attentional shift tasks, subjects make more errors at blood-alcohol levels of between 0.2 and 0.3 gr/l than at levels of 0 gr/l. In this second type of task, the distance variable (size of the angle of displacement of attentional focus) has a significant effect on number of errors. The general tendency observed is that the greater the angular distance, the greater the number of errors. This tendency is interrupted when the angular distance exceeds 90º.

In the dual tasks, females commit more errors when their blood-alcohol level is between 0.3 and 0.4 gr/l. In contrast, there are no significant differences between sexes at blood-alcohol levels of 0 gr/l. In auditory attentional shift tasks, significant differences between sexes are found at angular distances of 72º, 96º and 120º, both in Condition A (blood alcohol-level of between 0.3 and 0.4 gr/l) and condition B (0 gr/l).

In considering these results it should be borne in mind, as mentioned in some published works (Buela Casal, 1992), that performance is a function not only of the blood-alcohol level of each individual, but also of the individual's tolerance to alcohol. In the case described here, given the characteristics of the sample selected, we can speak of a moderate degree of tolerance, higher than that of abstemious subjects, but lower than that of heavier drinkers (more than 12 units per week). There is also evidence that performance in certain tasks (dual tasks in the case of our study) may vary according to certain inter-individual variables (the sex variable in our study), given similar blood alcohol levels. Taken together, these two circumstances represent a strong argument for not limiting alcohol controls on drivers to the mere measurement of the level of alcohol in the blood (or exhaled air), and considering also the option of systematic behavioural tests sensitive to cognitive-behavioural deficiencies produced by alcohol consumption. The fact that it seems reasonable to assume that some intra-individual variables act in the same way simply reinforces the previous argument.

In the domain of Psychology of Driving, emphasis has traditionally been placed on the importance of attentional variables (Coren, Porac and Ward, 1984; Soler and Tortosa, 1987b). However, this emphasis has concerned the selective property of attention in relation to incoming information. In our view, attentional control is not simply a question of the selection of incoming information: it also affects processing itself –processes of anticipation, foresight and decision– as well as action or execution (Rosselló, 1997, 1999). Driving is a complex behavior, in which attention plays a fundamental controlling and supervising role. The attentional system performs a key function not only in the driver's perceptual exploration, but also in guiding search and information-processing strategies; it also has an important part to play in controlling the different actions involved, especially those which have not become automatic through practice.

Given that attention controls these three fundamental aspects of driving, any attentional deficit will have repercussions on those three levels –it will affect perception, the processing of perceived information and the driver's actions. It seems that deficits in the first two aspects may be more relevant as causes of accidents (Soler and Tortosa, 1987c). Given that the execution of driving actions is largely automatic –and therefore uninfluenced by attentional control–, deficits at this level would not be potentially so dangerous.

If it could be shown that deficits in the attentional variables studied produced by the considered alcohol levels had repercussions on driving ability, it would be necessary to carry out further research. If this research were to produce results of a similar nature, we would be forced to question the legally-permitted blood-alcohol limits of private vehicle drivers in Spain, and to consider bringing them into line with those of other countries (Hungary: 0.0 gr/l; Sweden: 0.2 gr/l; New South Wales, Australia: 0.2).

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