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Attention tasks as skills performance measures of drug effects

H. MOSKOWITZ
Department of Psychology, University of California, Los Angeles, California 90024, USA

1 Both empirical epidemiological data on the causes of traffic accidents and conceptual models of skilled human performance stress the central role of perception and cognition. This paper examines the effects of drugs on two major components of cognitive perceptual performance, namely, concentrated attention or vigilance and divided attention.

2 It is demonstrated that these two types of attention tasks are differentially affected by various drugs, so that sometimes one and sometimes another of these tasks is impaired. Various experimental paradigms to investigate these two attention functions are presented.

3 It is demonstrated that attention tasks are frequently highly sensitive to drug effects, suggesting the importance of examining these functions when investigating the effects of drugs on skills performance.

Keywords attention tasks performance drug effects

There are many reasons to assert that evaluating drug effects on skills performance requires tests of perception and cognition. The theoretical approaches offered by investigators such as Broadbent (1971), Fitts & Posner (1967), and Welford (1968), place perceptual-cognitive functions at the core of the models used for analysis of man–machine interactions.

Empirical reasons for examining the effects of psychotropic drugs on perception and cognition are found in the evidence from multidisciplinary accident investigation teams that the majority of driver-related errors leading to accidents fall into the category of information failures (Clayton, 1972; Joscelyn & Treat, 1976; Perchonok, 1977). Moreover, perceptual, especially attention errors, are the most frequently cited errors leading to driving accidents in the one drug, ethanol, about which we have somewhat adequate epidemiological data.

This presentation will discuss concentrated-attention or vigilance tasks and divided-attention tasks, important components of the perceptual cognitive demands of complex skills situations. Clearly, there are other aspects of skills performance which these tasks do not measure, such as judgement and decision-making. These cognitive areas are less well represented by reliable experimental measures. In contrast, there exists an extensive literature of vigilance tasks and division of attention tasks studies in both applied settings and as models of information processing tasks.

A concentrated-attention task, or vigilance task, is one in which the rate of information processing requirement is low. Typically, it contains a signal detection task which is examined over an extended duration of at least 45 min to 1 h. Decrements in performance frequently appear after 10 to 15 min, independent of any additional treatments. The reasons for the decrement in performance on long duration, low information processing demand tasks has been a matter of debate for some 30 years, without final resolution. Nevertheless, they appear to be good laboratory models of situations which require tedious, repetitious tasks involving the need for alertness, as is required in industrial work, flying or driving.

A divided-attention task requires simultaneous performance of two or more subtasks, and I suggest a necessary concomitant would be that sufficient information processing demand is required so that either one or both of the subtasks are performed at a lower performance level than would be the case if performed alone.

It appears that divided-attention tasks measure situations where the capacity of the human organism to absorb and respond to all relevant information is in an overload situation. It should be stressed that it is not merely the information overload requirement that is important. There are often situations where information from a single source is too great to be processed completely. Rather, the divided-attention task is a model of situations where attention has to be time-shared sequentially between two or more information sources. There appears no way *a priori* to determine whether the combinations of any two tasks will require time-sharing. There is currently considerable research examining what situations can be processed in parallel versus situations which require time-sharing. Thus, the creation of a divided-attention task requires empirical examination to ensure that it exhibits the subtask interactions as evidence of serial processing.

This paper will summarize several studies which have examined the effects of drugs on divided-attention tasks and on vigilance and concentrated-attention tasks. The initial studies were based on the observation that epidemiological reports indicated increased accident probabilities at low blood ethanol concentrations (BACs) and that these accidents were associated primarily with perceptual failure. Yet, examination of simple sensory functions, such as visual acuity, glare recovery, peripheral vision, showed resistance to ethanol impairment, except at high concentrations.

The following studies examined the possibility that the behavioural site of ethanol-induced performance failures was likely to be associated with central information processing functions rather than with sensory transducer functions. The studies began with measures of concentrated and divided-attention and vigilance. Later studies, not discussed here, utilized measures of information processing rates, decision theory, signal detection theory, information theory, eye movements, spectral analysis of tracking and others, all of which have roles in a well-balanced program of analysis of behavioural drug impairment.

Figure 1 illustrates a study by Moskowitz & Sharma (1974) with subjects under ethanol treatments. Subjects faced a 204-degree visual arc with a fixation light at the centre and peripheral lamps at 6-degree intervals from 12 to 102 degrees on both sides. The study employed three central light conditions: (1) the fixation light was unblinking, (2) the fixation light blinked at 0.4 and (3) at 0.8 blinks/s. The experiment proceeded by a series of 20 s trials. The subjects performed two simultaneous tasks. The first task was to fixate on the central light and, if it was blinking, to report the blink total at the end of each 20 s trial. Simultaneously, the second task required subjects to report if a light

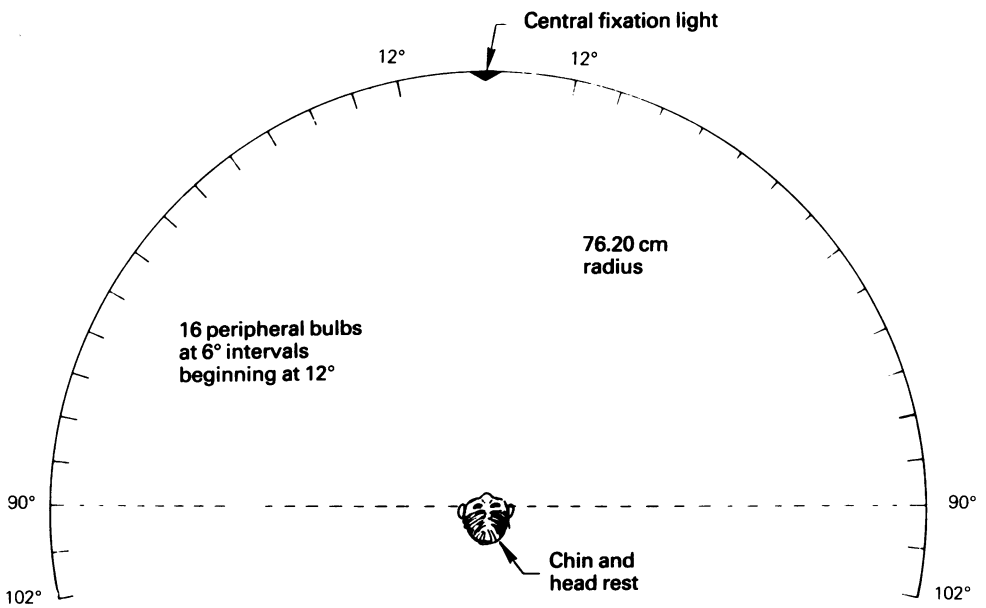

Figure 1 The design of the study by Moskowitz & Sharma (1974).

appeared during the trial at some point on the periphery. If a lamp was lit, it was on for 1 s. There were three levels of ethanol treatments administered at weekly intervals, resulting in roughly 0.045% and 0.09% BACs. In the first of the three conditions, when the central light is unblinking, the task is considered a concentrated-attention task emphasizing the detection of the peripheral light appearance. However, if it is necessary to count the blinking lights as in conditions 2 and 3 while attending to the peripheral vision signal detection task, then the task is considered a divided-attention task.

Figure 2 indicates that ethanol has no effect on peripheral signal detection when the central fixation light does not blink and there is no requirement for central vision information processing. Incidentally, this result is consistent with several major ophthalmological studies of peripheral vision which failed to find ethanol impairment. However, when the subject was required to process information from the blinking light in central vision, signal detection of the peripheral light decreased sharply. The impairment induced by any given ethanol dose is greater as the demand on central visual information processing increases. Furthermore, there was a concomitant increase under ethanol of errors in counting the blinking central light.

This study correlates with the statements of many drivers involved in ethanol-related accidents that they failed to see vehicles or pedestrians or traffic signals. These claims appeared improbable on the basis of earlier studies which failed to show deficits of either central visual acuity or peripheral vision under ethanol. It is clear that the deficit is upon perceptual performance only under the requirement of division of attention, which is so integral a requirement of many driving, flying and industrial performance situations (Billings *et al.*, 1972).

This experiment required somewhat longer than 1 h to run. It conforms with the typical duration of a vigilance task. In this case the vigilance aspects or concentrated-attention aspects failed to demonstrate any decremental effect of ethanol treatment. To verify this result, an additional experiment was performed utilizing a modification of the Mackworth clock task. In this modification, a series of lamps placed in a 12″ diameter circle are lit in succession, so the light appears to be jumping around the circle. At infrequent intervals, roughly every 1.5 min, the light skips a lamp position. The subject's task is to report whenever a signal occurs, that is, whenever a lamp is skipped.

Figure 3 represents the result of a 60 min

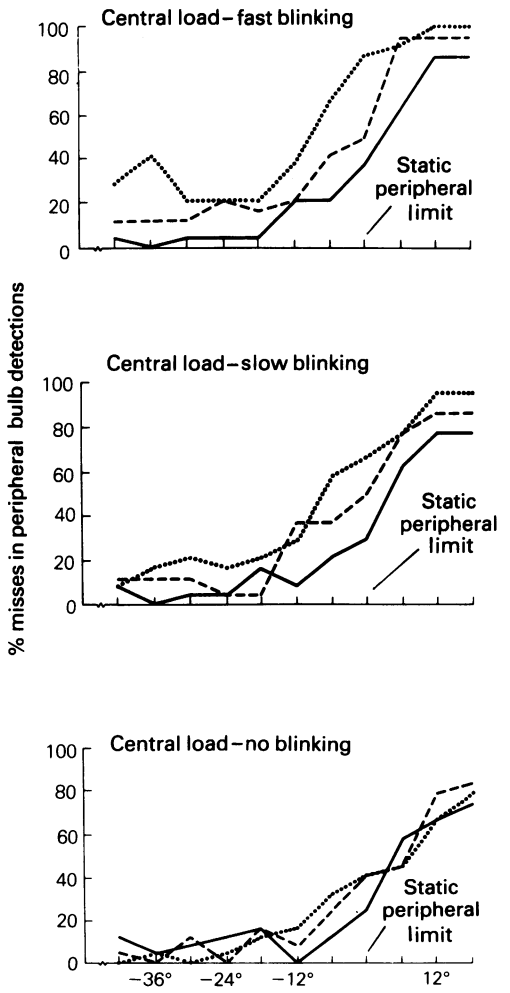

Figure 2 The effect of placebo (—) and ethanol (--- 0.414 g, ...0.828g/kg body weight) on peripheral signal detection.

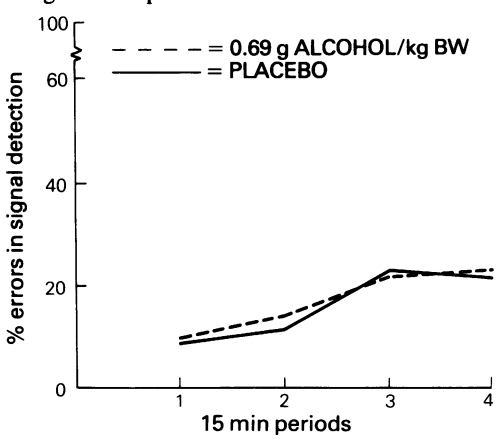

Figure 3 The effect of placebo (—) and ethanol (0.69 g/kg body weight, ---) on % errors in signal detection.

duration experiment with subjects tested at weekly intervals after ethanol treatments producing 0 and 0.075% BAC. In agreement with the preceding experiment, ethanol failed to produce impairment, although the task itself exhibited the typical decremental effects of time on task.

Clearly, the divided-attention task is sensitive to the presence of ethanol. Its sensitivity is such that, in additional studies, impairment has been demonstrated in both auditory and visual divided-attention tasks at BACs below 0.02%

What is involved in the task is not influenced by the sensory modality. Similar results have been obtained using auditory-auditory visual-visual combinations tasks. The specific tasks are not of importance except insofar as they make the requisite demands on the organism for information processing in a time-sharing situaion. To determine whether or not this task correlates with other tasks is to ask to what degree that task contains similar behavioural demands.

In an example with relevance to the driving task, Moskowitz & Burns (1981) examined the effects of ethanol on performance in a driving simulator where the response variables were 26 measures of car control. Ethanol at 0.10% BAC failed to produce a significant decrement on these measures. The same experiment was replicated with the concomitant necessity to perform a visual subsidiary task, the intermittent presentation of four signal lights requiring differential responses. On replicating the experiment under these conditions, not only was there an impairment in the signal recognition task, but more than half the car control variables, including tracking, were significantly impaired.

Similar results have been found in a study by Huntley (1973) working with automobiles in closed-course situations. Thus, the correlation of this task with other measures is a function of the degree to which both are samples of the same behaviours, e.g., requiring time-sharing. There are other laboratory tasks sensitive to the presence of ethanol, for example, ethanol gaze nystagmus. Ethanol gaze nystagmus is increasingly being used by officers in the United States as a roadside behavioural test of the presence of ethanol impairment. As a measure of ethanol impairment it is sensitive but unrelated to the task requirements of skills performance. The advantage of examining divided-attention tasks is that one is studying a variable of importance in driving and other skills performance.

On the other hand, there are situations in driving and other man-machine situations which are characterized by low demand for information processing. These situations also require examination under drugs. The following is an example of a drug which impaired vigilance behaviour but not divided-attention behaviour. The measures described above were utilized to study smoked marihuana treatments of 0, 50, 100 and 200 μg tetrahydrocannabinol per kg bodyweight (Moskowitz *et al.*, 1972).

Figure 4 presents the results. It is clear that marihuana produced considerable impairment of signal detection in peripheral vision. Note that, unlike ethanol, this impairment occurred under both concentrated and divided-attention. Statistical analysis indicated that the greater impairment under divided-attention conditions was not an interaction with the marihuana treatment but simply the linear additions of the marihuana effect on peripheral vision signal detection, with the increasing impairment induced by the requirement of division of attention by itself. Marihuana also impaired the counting of the central light blinks, again with only an additive effect from the different information processing requirement levels.

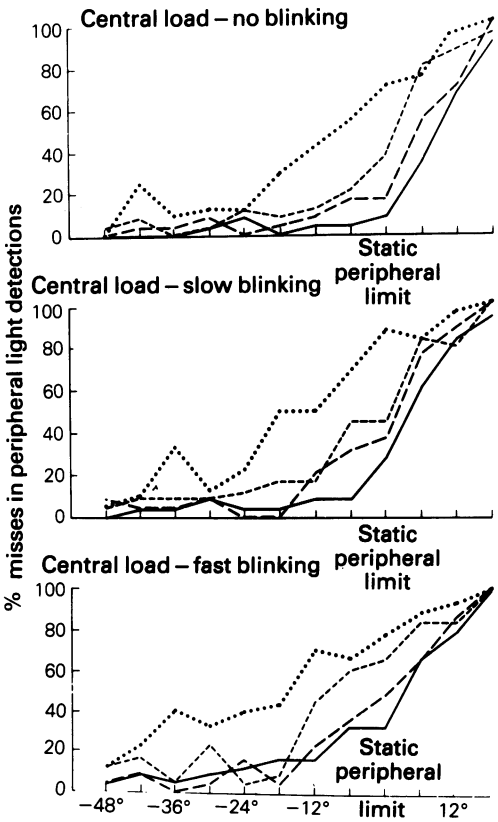

Figure 4 The effect of placebo (—) and tetrahydrocannabinol (--- 50 μg, --- 100 μg and .... 200 μg/kg body weight) on peripheral signal detection.

This study indicates the advantage of having both concentrated and divided-attention conditions within the same experiment since otherwise an impairment of the divided-attention situation might be ascribed to the requirement for time-sharing, which is not the case as can be seen in the concentrated condition situation.

That the behavioural site of impairment of marihuana is different from ethanol is further substantiated by the results of a study with a clock vigilance task under marihuana treatments (Sharma & Moskowitz, 1973). The significant and prolonged drug dose related impairment of vigilance performance exhibited in Figure 5 contrasts to the lack of ethanol impairment on the same task (Figure 3). There is epidemiological evidence that marihuana use produces increased probability of driving accidents. Anecdotal evidence suggests that many of these are due to perceptual failure but, clearly, our results suggest that it is not the quantity or character of the information being processed which is the site of the impairment.

A further corroborating study which indicates that the necessity for testing different functions is an experiment performed by Moskowitz *et al.* (1976) which recorded eye movements in a driving simulator while under the influence of either ethanol or marihuana. Ethanol produced a large increase in the duration of visual fixation, a 27% increase at 0.075 % BAC. Typically, such increases in fixation duration are associated with increased difficulty in processing information such as reading a technical text. Finding that ethanol increases fixation duration agrees with the suggestion that under ethanol a problem for divided-attention tasks is an effect on information processing rate. On the other hand, marihuana had no effect on fixation duration.

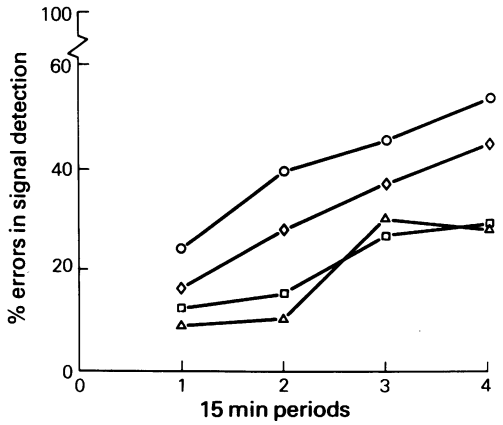

Figure 5 The effect of placebo (△) and tetrahydrocannabinol (□ 50 μg, ◇ 100 μg and ○ 200 μg/kg body weight) on % errors in signal detection.

While the opportunities to use the vigilance tasks have been somewhat limited, I can report on the use of the divided-attention task to examine a variety of drugs other than those mentioned above. These drugs have been examined both by themselves and in interaction with ethanol. Drugs which have been examined include diazepam, secobarbitone, chlordiazepoxide, methaqualone, diphenhydramine, flurazepam, buspirone, caffeine, trazodone and amitriptyline. In these studies a revised form of divided-attention task was utilized, replacing the central blinking light task with a tracking task and replacing the peripheral lamp detection task with a peripheral vision search-and-recognition task for digits. This revised form of divided-attention apparatus was tested utilizing both ethanol and marihuana treatments, and produced the same results as the earlier form of the task. The change was designed to make the task more representative of the specific subtasks of driving and thus to permit examination, if desired, of tracking or visual search by itself. With the exception of trazodone and buspirone, significant impairment was demonstrated by all other drugs on the new form of the divided-attention task. Variation in magnitude of impairment and duration of impairment was found as a function of both drug and dose level differences. One study examined drugs over a 24 h period, testing periodically to determine behavioural impairment as a function of time and blood plasma levels.

Figures 6, 7, 8 and 9 are from an unpublished study examining the effects of flurazepam on a divided-attention task. There were four dose levels of 0, 0.22, 0.44 and 0.73 mg/kg bodyweight, or roughly, 0, 15, 30 and 55 mg. All four figures illustrate long duration impairment beyond 12 h for a single dose treatment.

Figure 6 presents the response time measure for detecting the appropriate digits in the search-and-recognition visual search task. Figure 7 presents the combined errors of either entirely missing the signal, making an incorrect response, or a false alarm. Figure 8 presents the tracking task error level. Finally, Figure 9 is a measure of combined impairment on both the visual search and tracking time. The response time scores and the tracking error are converted into standard scores and added together for each subject under each treatment to produce a single score indicative of performance on the divided-attention task as a whole. Quite often this measure is more sensitive than either of the two subtasks by themselves. Subjects may decide, as we have frequently found under stress, to concentrate on one task and ignore the second task. This results in all the errors

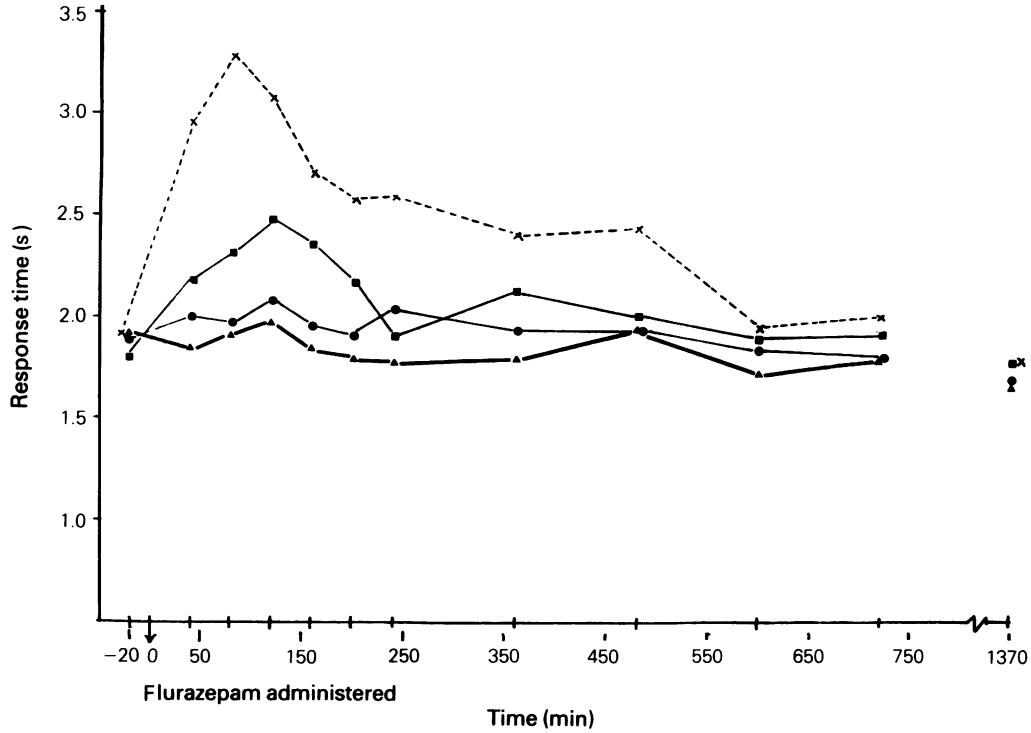

Figure 6 Mean response times for signal recognition during the divided attention task after placebo (▲) or flurazepam (● 0.22 mg, ■ 0.44 mg and × 0.73 mg/kg body weight).

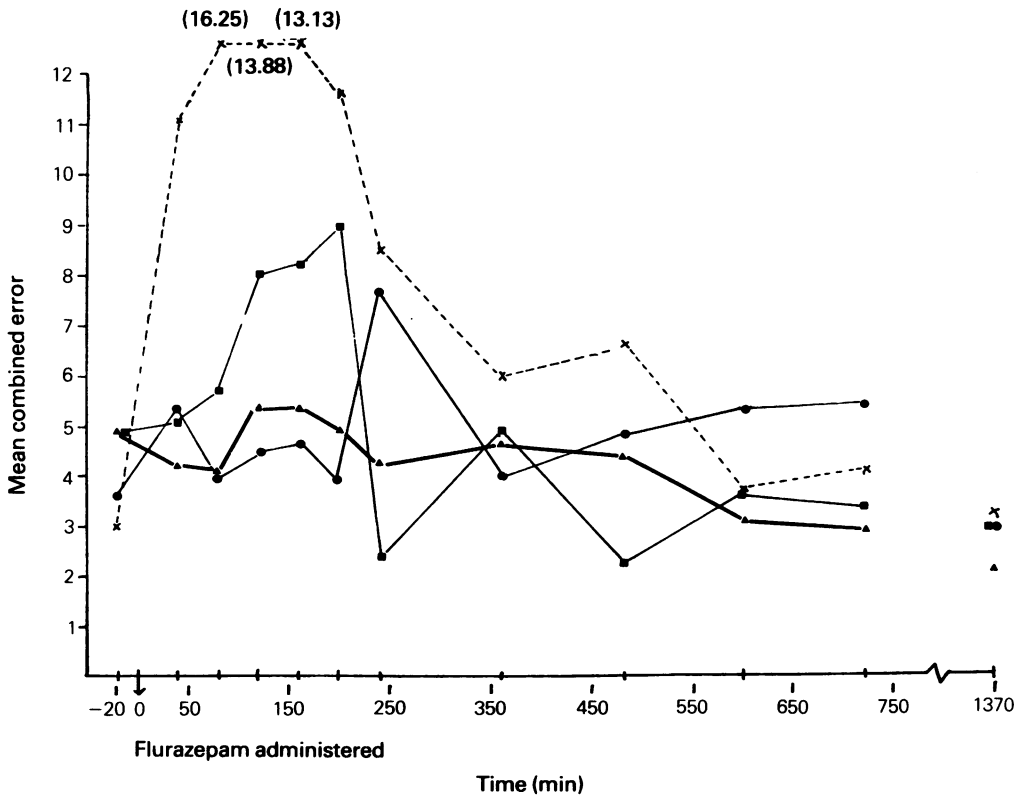

Figure 7 Mean number of combined errors of incorrect responses, false alarms and misses during the divided attention task after placebo (▲) or flurazepam (● 0.22 mg, ■ 0.44 mg and × 0.73 mg/kg body weight)

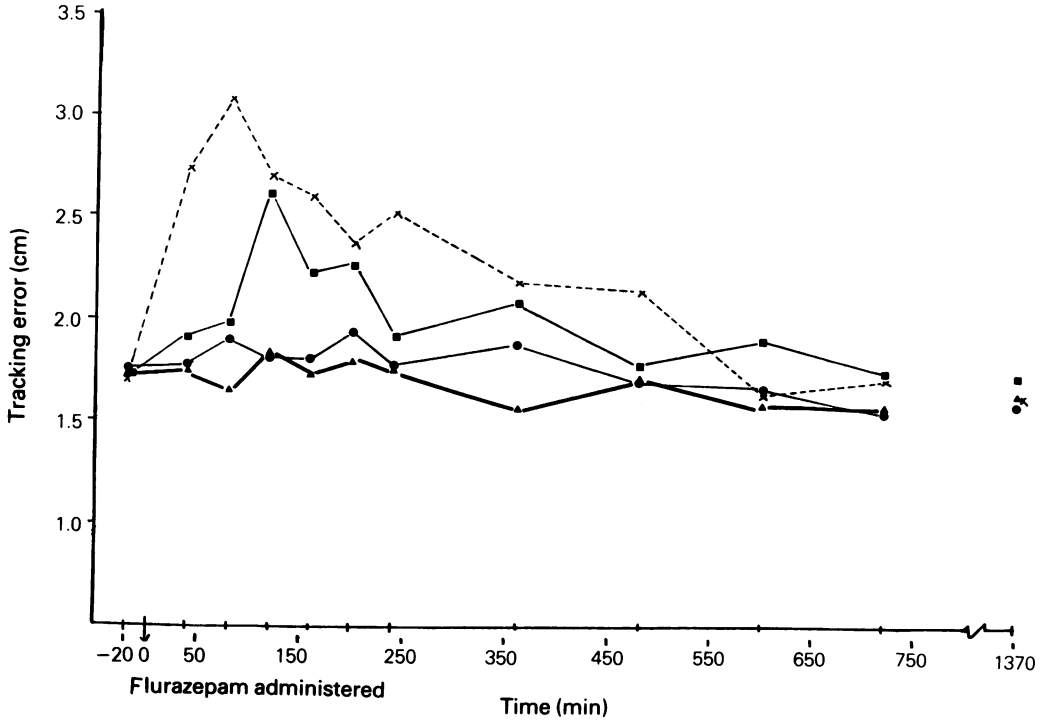

Figure 8 Mean tracking error during the divided attention task after placebo (▲) or flurazepam (● 0.22 mg, ■ 0.44 mg and × 0.73 mg/kg body weight).

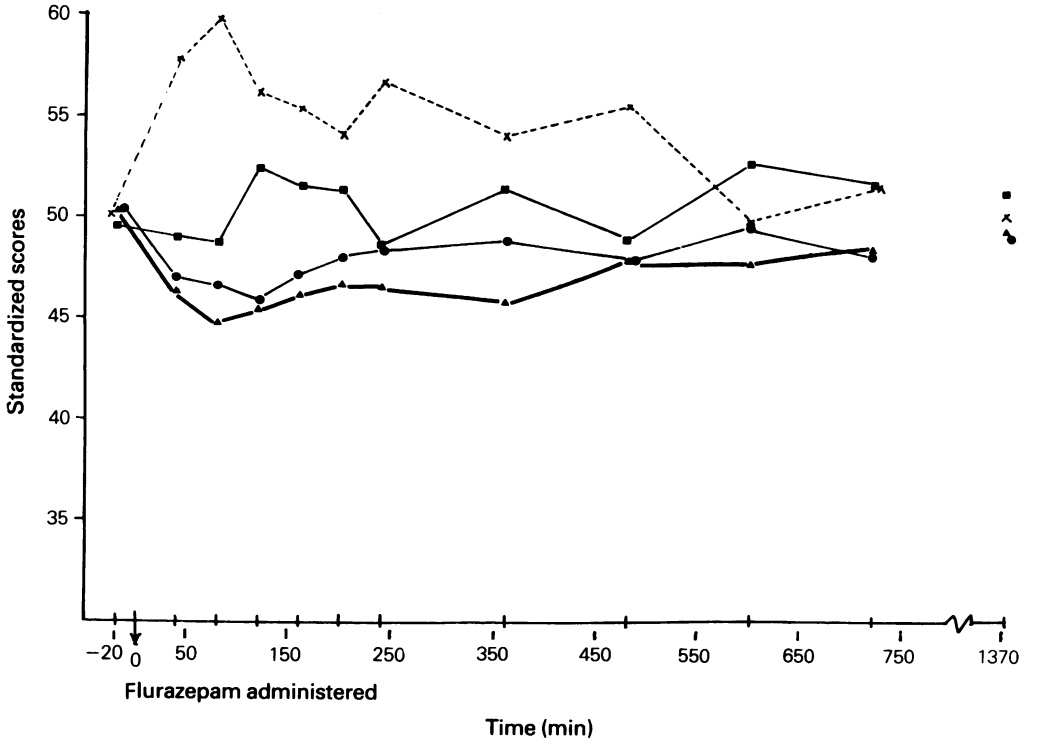

Figure 9 Mean standardized scores for response times in signal detection and tracking during the divided attention task after placebo (▲) or flurazepam (● 0.22 mg, ■ 0.44 mg and × 0.73 mg/kg body weight).

being taken on one task and little error on the other task.

In essence, they convert the divided-attention task into a concentrated-attention task, with the penalty of very poor scores on the other task. However, since different subjects may decide which task to throw away, this increases the variability on the performance measures on each of the subtasks and makes statistical analysis less sensitive. Combining the standardized scores for the two tasks together produces a less variable and frequently more sensitive measure of impairment.

The next set of figures is from studies involving the combination of a drug and ethanol. Figure 10 presents the results of the divided-attention task under the combination of diphenhydramine and ethanol (Burns & Moskowitz, 1980), Figure 11 on diazepam and ethanol (Moskowitz & Burns, 1977). They illustrate the ability of the task to discriminate the impairments produced by each of the treatments alone and in combination. Figures 12 and 13 are from a study on the combination of caffeine and ethanol and illustrate caffeine modulation of ethanol impairment (Moskowitz & Burns, 1981).

Regretfully, there are far fewer studies of vigilance behaviour under drugs, so that we are less capable of determining its sensitivity. However, if it is agreed that vigilance behaviour is an important component of driving and other similar situations, the fact that its sensitivity has been established for at least one drug, marihuana, suggests the value of examining it. What is necessary is to determine whether the variety of vigilance tasks that have been used produce the same results with respect to any drug, since it is not obvious that the vigilance tasks are all testing the same behavioural variable.

A broader battery of these tasks would also assist in developing a behavioural taxonomy into which psychotropic drugs can be placed. Given the current intensive investigations into the neuropharmacology of drugs, it would be helpful to relate whatever the pharmacological results uncovered to behaviour. This requires a better specification of the behavioural differences which characterize the drugs. For such a venture, more than tests of concentrated-attention, vigilance and divided-attention are necessary.

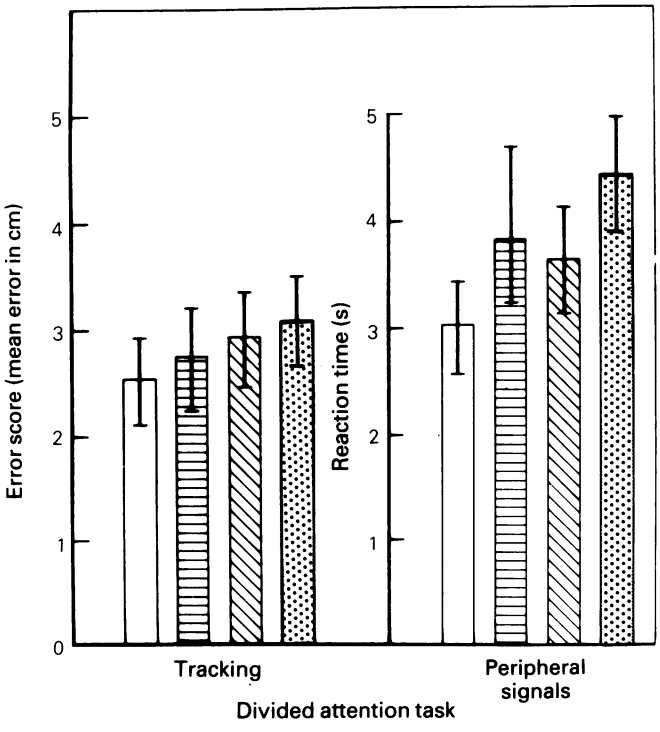

Figure 10 The effect (mean ± s.d.) of placebo (□), diphenhydramine (0.74 mg/kg body weight, ▤), ethanol (0.58 mg/kg body weight, ▧) and ethanol and diphenhydramine in combination (▦) on the divided attention task.

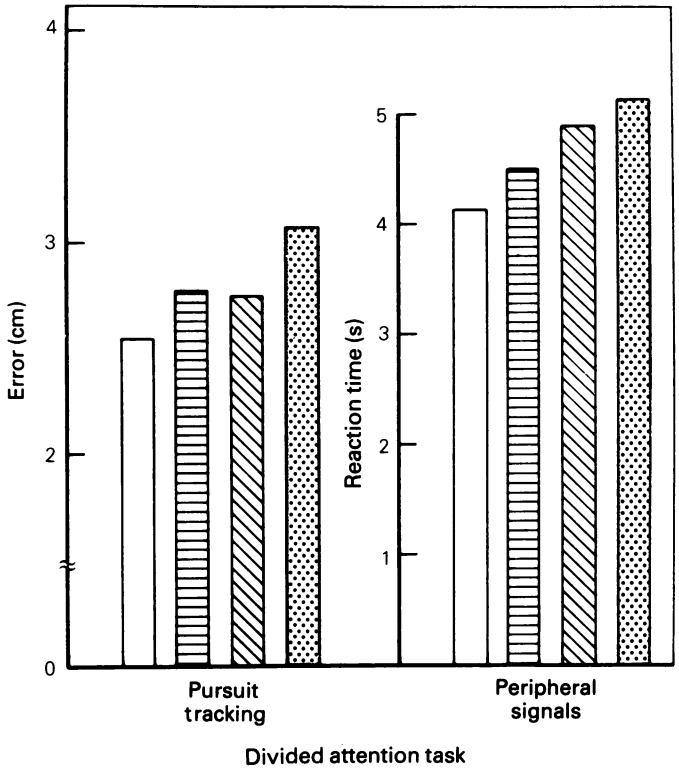

Figure 11 The effect of placebo (□), diazepam (0.073 mg/kg body weight, ▤), ethanol (0.58 mg/kg body weight, ▧) and ethanol and diazepam in combination (▦) on the divided attention task.

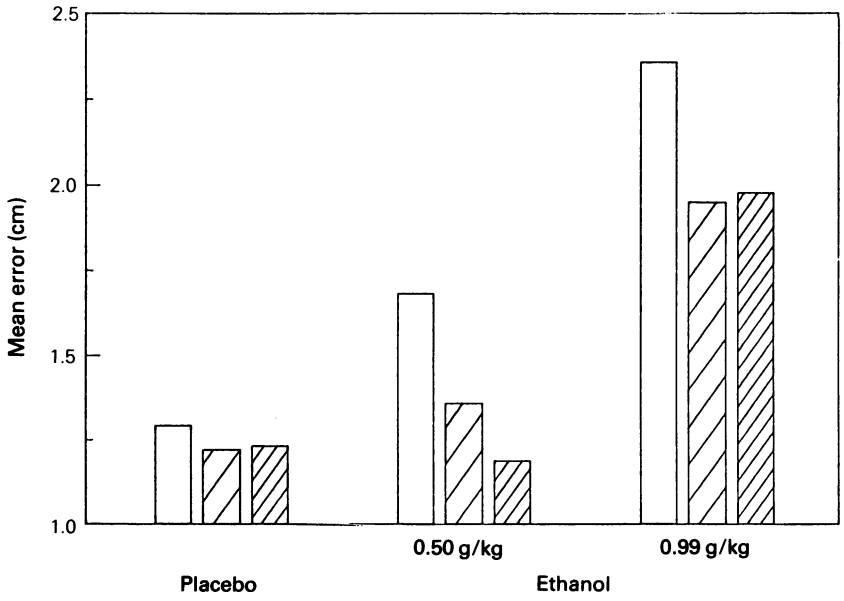

Figure 12 The effect of placebo (□) and caffene (▨ 2.93 mg and ▨ 5.87 mg/kg body weight) alone and in combination with ethanol on the divided attention task (compensatory tracking).

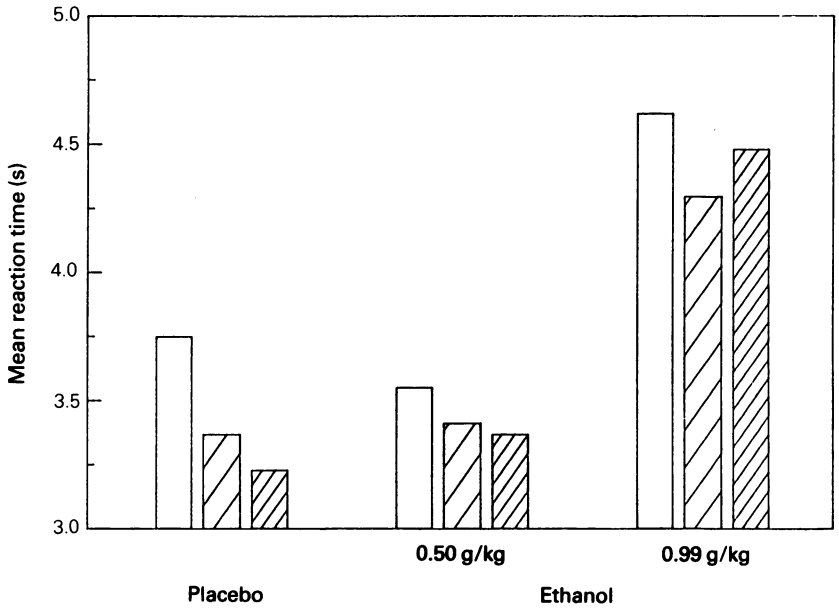

Figure 13 The effect of placebo (□) and caffeine (▨ 2.93 mg and ▨ 5.87 mg/kg body weight) alone and in combination with ethanol on the divided attention task (visual search).

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