Br. J. clin. Pharmac. (1984), 69S–72S

Visual motor co-ordination and dynamic visual acuity

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1 Data on the effect of an antihistamine (triprolidine 10 mg) on visuo-motor co-ordination and dynamic visual acuity were used to establish interactions between these skills. Analysis of covariance and principal component analysis were used.
2 The analyses suggested two main effects—an effect on the activity of the neuro-muscular system and one which impaired ability to anticipate target movement.
3 Detection of impaired performance by any task may have wider implications to the effectiveness of the individual than that obviously suggested by the skill itself.

Keywords visual motor co-ordination dynamic visual acuity triprolidine antihistamine

Introduction

Driving a vehicle, like flying an aircraft, requires many skills. The ability to maintain position, speed and attitude while travelling at speed demands a high degree of visual motor coordination, and visual information from the outside world is combined with signals from vestibular organs and processed selectively to provide an output instruction to the neuro-muscular control system.

Visual, vestibular and motor functions can be combined to form a model of human operator performance (McRuer & Krendel, 1974), and while it is, at least, possible to evaluate the effects of drugs on skilled tasks by using complex modelling techniques, a more practical approach may be to identify key elements in the task and investigate each separately. Two such elements are visuo-motor co-ordination and dynamic visual acuity, and we have studied the effect of various psychotropic drugs on these skills (Borland & Nicholson, 1974, 1975; Clarke & Nicholson, 1978; Nicholson, 1979a, b). In this paper we deal with the interaction of visuo-motor co-ordination and visual dynamic acuity using data obtained from studies with an antihistamine which has obvious effects on performance (Nicholson & Stone, 1983, 1984).

Methods

Visuo-motor co-ordination (VMC)

There are two basic forms of VMC tasks—compensatory and pursuit. In the former the display presents a stimulus which shows only the difference between the forcing function and the system output, while in a pursuit tracking task there is a visual presentation of both the forcing function and the system output. Both cases require the operator to maintain a minimum error score, but in a pursuit task the operator can use an element of anticipation based on his knowledge of the parameters of the forcing function.

The equipment is a micro-processor based pursuit tracking test, in which the mean amplitude is automatically adjusted to match the subject's skill. The target circle (1.5 cm diameter) is driven in x and y planes across the face of a cathode ray oscilloscope providing a distortion free central display area (25 by 25 cm). The subject, who is seated, views the screen at a distance of about 40 cm and maintains a marker dot within the moving circle by manipulating a free-moving two axis joystick. Success is rewarded by a gradual increase in the mean amplitude of the target move-

ments, and failure is penalised by a rapid reduction of movement. Each test run lasts 600 s, and the last 500 s is scored.

There are two fundamental, but conflicting, criteria that must be met in the design of a pursuit tracking task. Firstly, the overall difficulty of the task should remain sensibly constant from run-to-run, while the actual sequence of movements must change so to prevent subjects remembering some or all of the task. This can be achieved by:

1. digitally low-pass filtering a random sequence to produce a task having the required amplitude and frequency characteristics, but only lasting about one eighth of the required total time
2. selecting within the main sequence two overlapping subsequences (x and y) of different length. They are chosen so that if the end of each is looped back to its beginning no discontinuity of movement will be detected
3. choosing a random starting point within x and y for each trial
4. playing out x in the forward direction and y in the reverse direction and looping back at the appropriate points to produce a continuous task of the desired length.

The micro-processor updates circles and dot positions 40 times per second and computes a radial error signal (re) which is compared with the circle radius (rs). An instantaneous error score E computed.

$$E = 0.025.K.(re - rs)^2 \text{ for } re < rs$$
$$E = -K.(re - rs)^2 \quad \text{for } re > rs$$

and is integrated over the whole run to provide a task multiplier value M

$$M = \int_{t=0\,s}^{=600\,s} E.dt \quad \text{(the M value is limited such that } 10.0 > M > 0.0)$$

The x and y movements of the target circle are scaled by this continually updated value, and the task difficulty is adjusted automatically to the subject's ability. An overall score for a run is computed from

$$\text{Score} = 2 \times \int_{t=100\,s}^{t=600\,s} M.dt$$

Movements of the hand controller are limited to ± 20 degrees in each axis and the output signals are passed through second order low-pass filters with a cut-off frequency of $5/\pi$ Hz. This frequency is well below the neuromuscular response limit of between 5 and 10 Hz, and introduces a time delay of about 0.1 s.

At the maximum task difficult (M = 10) the theoretical maximum velocity of the target across the screen face in any one axis is 28 cm/s, and this corresponds to a visual angular velocity of about 40 d/s: the maximum rms velocity of 19.8 cm/s corresponding to a visual velocity of 28.2 d/s. This level of task performance is never reached, and the average score attained by trained subjects is 6. To maintain this average level of performance the subject must ensure that the total lag time in the system does not exceed 70 ms. However, since the neuromuscular system introduces time delays of about 0.2 s and the inbuilt delay in the control circuitry provides a further 0.1 s of delay, the average subject must have the ability to provide about 0.23 s of task prediction.

Dynamic visual acuity (DVA)

Dynamic visual acuity is not a fundamental visual attribute, but is dependent on the dynamic performance of the oculo-motor control system: position or velocity errors which increase with target velocity are characterised by a decrease in visual acuity. Dynamic visual acuity is measured using Landolt ring targets with critical detail ranging from 1–10 min of arc projected on to a curved screen by a rotating mirror galvanometer placed at its centre of curvature. The screen has a radius of curvature of 1.5 m, and it subtends an angle of ±30° in the horizontal and ±10° in the vertical planes to the subject's eye. The screen is painted matt white and is illuminated (luminance: 6.4 cd/m^2) by a single lamp placed on the centre line of its cylinder of arc.

The targets (luminance: 150 cd/m^2) are brighter than the screen (negative contrast 96%), and the gap in each ring is orientated to an oblique meridian. The image sweep is limited to the central 30° of the screen by shutters external to the subject's field of view, and the images sweep from right to left at a constant velocity of 43 or 68°/s. The order of the presentations and speed of each sweep are controlled by a fixed balanced random table of numbers programmed into the trials generator. An experimental run consists of eight trials of 10 target sizes at each of the angular velocities (160 in all), and each run starts at a random point within the table.

Five minutes are allowed to adapt to the lighting intensities of the room. The targets are viewed monocularly with the right eye, and the left eye is covered. The position of the head is held steady using a chin-rest and browmount, and the subject is provided with fixation lights on the right hand side of the screen. A buzzer warns of each presentation. The subject has to

indicate within 1 s after completion of the target sweep the position of the gap in the ring by pressing one of four buttons arranged to correspond with the oblique meridians. They are instructed to respond only if certain of the orientation. Subjects are trained on the task until they reach steady day-to-day performance, though there may be additional learning when the subjects are tested several times within a few hours.

The threshold of detection for each target velocity and for each subject is determined by fitting the cumulative integral of the normal distribution to the frequencies of correct responses at the different target sizes. These frequencies are assumed to be samples from binomial distributions with means $f(x_i)$, and are given weights proportional to

$$[f[x_1); 1 - f(x_1))]^{-½}$$

Fitting is performed by a non-linear least squares program with weights recalculated at each iteration. The percentage correct of the total number of presentations at each angular velocity were also calculated for each subject.

Results

In two recent studies VMC and DVA were among the tests used to investigate the possible central effect of H_1- and H_2-histamine receptor antagonists, and in each study the H_1-receptor antagonist, triprolidine (10 mg), was used as an active control. In the first study (Nicholson & Stone, 1983) triprolidine impaired VMC from 1.5 to 5.5 and DVA around 0.5 h, and in the second study (Nicholson & Stone, 1984) it impaired performance on VMC from 0.5 to 5.5 h and on DVA from 0.5 to 3.5 h. To establish any interactions between VMC and DVA these results were subjected to an analysis of covariance. There was no evidence of any residual correlation between VMC and DVA when the triprolidine data were excluded. The principal component analyses of the difference between triprolidine and controls are given in Tables 1 and 2.

Discussion

The analysis showed a remarkable degree of agreement between the two studies in the estimation of the component values. The first component had dose and time effects. It accounted for most of the variance and applied a similar weighting and contrast to the three variables. The second component revealed opposite contrast of DVA and VMA, and this was without a dose effect in the first study due to a large difference between the values obtained with the two placebos. The third component was small, and was made up entirely from the DVA data. It showed a time effect in both studies with performance improving at the higher speed of target movement throughout the day.

The analysis indicates an interaction between VMC and DVA, and suggests that there are two separate effects. The dominant effect seen with both DVA and VMA may be due to the common element between the two tasks of the activity of the neuro-muscular system—even though it is peripheral in one case and ocular in the other. The second component relates to VMC only; and so may reflect an impaired ability to anticipate target movement, while improvements in detection with time at the

Table 2 Analysis of variance

	Study 1 *Component*			*Study 2* *Component*		
	1	*2*	*3*	*1*	*2*	*3*
Dose (D)	*	NS	NS	*	*	NS
Time (T)	*	NS	**	**	NS	*
D × T	NS	NS	NS	NS	NS	NS

Table 1 Principal component analysis for DVA and VMC. (A positive component indicates a decrease in performance)

	Study 1 *Component*			*Study 2* *Component*		
	1	*2*	*3*	*1*	*2*	*3*
DVA—Low speed	0.62	−0.31	0.72	0.60	−0.42	0.68
—High speed	0.61	−0.38	−0.64	0.61	−0.32	−0.73
VMC	0.49	0.87	−0.05	0.52	0.85	−0.06
% Variance	76	20	4	74	18	8

higher speed of target movement in DVA may be due either to learning or to some circadian influence related to the usual improvement of performance during the day.

The effect of psychotropic drugs on oculomotor function has also been studied by Bittencourt *et al.* (1981, 1983). Benzodiazepines reduce the peak velocity of saccadic eye movement, and decrease smooth pursuit tracking ability during sinusoidal ocular tracking. However, sinusoidal pursuit tracking may also involve an element of prediction, as it is possible to continue to 'track' quite successfully for several seconds with eyes closed. It is therefore possible that some of these effects may also be due to difficulty in anticipating target position. Indeed, impaired anticipation of events has been identified as an important aspect of the effects of benzodiazepines on driving ability (de Gier *et al.*, 1981).

These results suggest that though drug studies using a complex task such as visuomotor co-ordination may be very sensitive and provide useful and relative information on the persistence of the drug effect, the interpretation of the impairment as that of the obvious skill implied by the task may not be entirely correct. In this context the antihistamine, triprolidine, not only impairs neuro-muscular mechanisms, but also impairs the ability to anticipate a response. The finding of an impairment with any task raises the question of modulation of the activity of the central and/or peripheral nervous system beyond that obviously suggested by the skill of the task itself, and in general terms this may imply that the detection of impaired performance with any task—no matter how mundane—may have wider implications to the effectiveness of the individual than generally appreciated.

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