CLINICAL STUDY

The effect of pupil dilation with tropicamide on vision and driving simulator performance

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Abstract

Purpose **To assess the effect of pupil dilation on vision and driving ability.**

Methods **A series of tests on various parameters of visual function and driving simulator performance were performed on 12 healthy drivers, before and after pupil dilation using guttae tropicamide 1%. A driving simulator (Transport Research Laboratory) was used to measure reaction time (RT), speed maintenance and steering accuracy. Tests of basic visual function included high- and low-contrast visual acuity (HCVA and LCVA), Pelli–Robson contrast threshold (CT) and Goldmann perimetry (FIELDS). Useful Field of View (UFOV – a test of visual attention) was also undertaken. The mean differences in the pre- and post-dilatation measurements were tested for statistical significance at the 95% level using one-tail paired *t*-tests.**

Results **Pupillary dilation resulted in a statistically significant deterioration in CT and HCVA only. Five of 12 drivers also exhibited deterioration in LCVA, CT and RT. Little evidence emerged for deterioration in FIELDS and UFOV. Also, 7 of 12 drivers appeared to adjust their driving behaviour by reducing their speed on the driving simulator, leading to improved steering accuracy.**

Conclusions **Pupillary dilation may lead to a decrease in vision and daylight driving performance in young people. A larger study, including a broader spectrum of subjects, is warranted before guidelines can be recommended.**

Key words Driving, Pupillary dilation, Visual function

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In today's society driving is an important aspect of many peoples lives. It has become an essential part of daily routine, for both business and leisure. With 35 million Driving Licence holders in the UK alone (unpublished figures from the Driver and Vehicle Licensing Agency, May 1992), the impact of any condition that influences the ability to drive is widely felt. Many researchers believe that the majority of the sensory input to the brain required for driving comes from vision.[1] Although a large number of medical conditions are clearly not compatible with safe driving, the concept of visual fitness to drive is complex and has long been debated. The difficulty in reaching a consensus is partly reflected in the wide range of standards required by different countries.[2] Current Driving and Vehicle Licensing Agency (DVLA) regulations in the UK require that a person must be able to read, in good daylight, a registration mark (number plate) fixed to a motor vehicle containing figures 79.4 mm high at a distance of 20.5 m. In addition, a person must have a field of vision of at least 120° on the horizontal and 20° above and below the vertical meridian.[3] Although these requirements at first glance appear straightforward there are situations where visual performance is affected but still remains within these limits. It is then unclear whether driving is legal or not.

An example of this is the loss of accommodation and depth of focus induced by pharmacological dilation of the pupils. There are many clinical situations where pupillary dilation is frequently performed, as it facilitates meticulous fundal examination and assessment of the peripheral retina. For example, to prevent blindness in diabetics early detection and treatment of retinopathy is vital, not least as diabetic retinopathy is the commonest cause of blind registration amongst people of working age in the UK.[4] Pupillary dilation is frequently utilised by hospital practitioners, primary care physicians and optometrists to facilitate diabetic screening. It has also been estimated that one-tenth of clinically important fundal lesions lie outside the view of the direct ophthalmoscope used through an undilated pupil.[5]

Drops to dilate the pupil not only produce a large unreactive pupil, with consequent increased optical aberrations and glare, they also induce an element of cycloplegia.[6,7] Many patients wish to drive following their eye examination; hence there is frequently concern amongst practitioners about what advice to give to these patients, and there are no official guidelines. This often results in patients being advised not to drive; if the patient is unable to avoid driving they may be asked to return for a further examination. This is time-consuming, wasteful of resources and may lead to a delay in the diagnosis and treatment of potentially blinding pathology. Alternatively, the patient may be examined without pupil dilation; this may increase the risk of failing to detect sight-threatening ocular disease.

Previous studies have found a significant decrease in high-contrast visual acuity, in some to below that legally required for driving, in a small number of subjects after dilation.[6–8] It has also been shown that post-dilation compensatory measures such as miotics and sunglasses are not necessarily helpful.[8] It is important to establish whether pupil dilation influences other tests of visual function and also driving performance so that appropriate guidelines may be instituted.

The study presented here was designed to investigate this matter by examining the influence of pupil dilation with tropicamide, a widely used topical antimuscarinic preparation, on various parameters of visual function and driving simulator performance.

Materials and methods

Subjects

Twelve healthy volunteers took part in the study: 8 women and 4 men. Their ages ranged from 19 to 37 years (mean 26.4, SD ± 5.2). None of the subjects had a history or signs of ocular disease. Distance spectacles were worn by 7 subjects, with the mean spherical equivalents ranging from −3.00 to +2.00 dioptres, and cylindrical errors ranging from 0.25 to 1.25 dioptres. These spectacles were worn during testing.

Data on tests of visual function and driving simulator performance were collected over three non-consecutive days.

Tests of visual function

A number of tests of visual function were carried out on day 1, first without and then with pupil dilation. All tests were carried out, where applicable, in lighting conditions according to manufacturers' specifications.

Contrast threshold (CT) was measured using a Pelli–Robson chart[9] at a working distance of 1 m and adopting 'by-the-letter' scoring.[10] Bailey–Lovie charts[11] were used to measure the logarithm of the minimum angle of resolution (LogMAR) at a working distance of 3 m. The 'by-the-letter' scoring method[12,13] was adopted to determine both high-contrast (HCVA) and low-contrast visual acuity (LCVA). For ease of interpretation, LogMAR scores were converted to the Snellen fractions, where the denominator was determined by multiplying the antilog of the LogMAR score by 6. (For example, a LogMAR score of 0.3 is equivalent to a Snellen denominator of 12 so that the Snellen fraction becomes 6/12).

The sensory visual field was measured using a Goldmann perimeter with the III4e target as specified in the definition of the minimum field of safe vision for driving.[3] This yielded an efficiency score (FIELDS) ranging from 0 to 100%, based on a comparison with the field expected in normals.

Visual attention was measured using the Useful Field of View (UFOV) analyser, performance on which has previously been found to correlate with crash involvement.[14] The UFOV is described in detail elsewhere.[14] In brief, it measures the spatial area over which subjects can be alerted to peripheral events. Three tasks were carried out during this test. The first task assessed processing speed and involved identification of a central target. The second task assessed divided attention and involved carrying out the first task in addition to location of a peripheral target. The third task assessed selective attention and involved carrying out the first and second tasks in the presence of peripheral distracting targets (or clutter). An overall measure of performance on these tasks was provided and took the form of a percentage reduction of the UFOV, the maximum diameter of which was 70°. Again, for ease of interpretation, this percentage was converted to indicate the angular extent of the UFOV. For example, a 5% reduction of the UFOV would shrink the field from 70° to 66.5°.

Guttae tropicamide 1% was used to achieve bilateral pupil dilation with no light reaction. The above measurements were then repeated, and completed within 60 min (it is known that the mydriatic effects of single instillations of tropicamide 0.5% are sustainable over a period of at least 90 min[15]). Total subject participation time, before and after dilation, did not exceed 2 h.

Driving simulator tests

On days 2 and 3, trials were carried out on the driving simulator at the Transport Research Laboratory. Subjects carried out two driving simulator trials, one with pupil dilation with guttae tropicamide 1% and one with saline instilled as a placebo. In order to remove learning effects, half the subjects had tropicamide instilled on day 2, the other half on day 3. It was intended that neither the subject nor the person administering the drops should be aware of which type of drop had been given, in order to achieve double-masking; in practice, however, the effects of pupil dilation were obvious to both parties.

During driving simulator trials subjects were seated in a car body shell. This was mounted onto hydraulic rams to simulate some of the movement experienced in real braking, acceleration and cornering. The gearbox was automatic. A motorway scene, which included textured road surfaces, bridges, roadside scenery and other road users, was presented. Scenery was displayed on four large video projection screens, providing a 210° forward field and a 60° rear field of view, the latter being visible in the rear-view and both wing mirrors. The forward-facing projection screen was positioned 3 m in front of

Table 1. *Means and standard deviations of readings taken with and without pupil dilation*

Test	Mean ± standard deviation		Incidence of reduced test performance	Range of differences
	Undilated	Dilated		
CT*	1.98 ± 0.12	1.86 ± 0.09	8 of 12 subjects	+0.05 to −0.3
HCVA*	6/7.0 ± 1.1	6/7.6 ± 1.4	8 of 12 subjects	+1.2 to −2.0
LCVA	6/10.5 ± 2.0	6/11.0 ± 1.9	5 of 12 subjects	+5.2 to −4.4
UFOV	67.5 ± 3.2°	68.4 ± 9.2°	1 of 12 subjects	+5.2 to −3.5
RT	1.13 ± 0.23 s	1.26 ± 0.23 s	7 of 12 subjects	+0.33 to −0.62 s
SPEED	33 ± 4 mph	31 ± 4 mph	8 of 12 subjects	+3 to −9 mph
WOBBLE	14.0 ± 3.7	12.9 ± 3.44	7 of 12 subjects	+5.5 to −1.2

CT, contrast threshold; HCVA, high contrast visual acuity; LCVA, low contrast visual acuity; UFOV, useful field of view; RT, reaction time.
*Statistically significant differences at the 95% level.

the driver. Vehicle movements, motorway scenery and driver responses were all monitored by the simulator computer.

On both testing days, each driver had a 15 min familiarisation run prior to carrying out the main trial. The main trial lasted 30 min. The first part involved driving on a stretch of motorway; drivers were asked to travel at their usual motorway speeds and to overtake when necessary. The simulator controlled pulling-out events in which one of the cars being overtaken would suddenly pull into the lane in which the subect was driving. The subject's reaction time to a pulling-out event (RT) was automatically recorded. The second part involved negotiating right and left curves with changing radii whilst attempting to maintain a speed of 30 mph (48 km/h). During this time, the subject's speed was recorded (SPEED) along with the standard deviation of the steering control input, a measure of the subject's steering accuracy (WOBBLE).

Analysis of the results of all eight tests involved determining whether data were normally distributed prior to carrying out one-tailed paired *t*-tests on the differences in test results bought about by pupil dilation. The distribution of the pooled results of each test was taken to be approximately normal if the quotient of the median divided by the mean fell between 0.9 and 1.1 in addition to the mean being at least 3 times larger than the standard deviation.[16] The effects of pupil dilation were tested for statistical significance at the 95% level.

Results

All tests, apart from FIELDS which showed no variation, yielded normally distributed data according to the criteria described above. Table 1 shows means and standard deviations of readings taken with and without pupil dilation. Statistically significant differences, tested at the 95% level, are denoted with an asterisk. FIELDS results are not shown in the table, given their lack of variation with dilation.

CT deteriorated most with pupil dilation, and with significance (d.f. = 11; $t = 3.276$, $p = 0.0037$); this difference amounted to just over 2 misread letters. HCVA also deteriorated significantly (d.f. = 11; $t = 1.965$; $p = 0.0376$); this amounted to 1.5 letters.

The changes in the remaining tests did not reach statistical significance. LCVA deteriorated on average by just over 1 letter. UFOV improved slightly. Longer reaction times (RT) to pulling-out events were found. Undilated subjects tended to drive faster (SPEED) than the specified 30 mph; with pupils dilated, typical driving speeds fell closer to the specified value. Steering accuracy (WOBBLE) reduced (i.e. improved) slightly. Table 1, however, also shows the incidence of reduced test performance. It can thus be seen that pupil dilation reduced test performance in more than half the drivers for all tests except LCVA and UFOV.

Furthermore, Table 1 shows the range of differences in test results that occurred with pupil dilation. While some individuals either improved or exhibited no difference in test performance, others exhibited relatively high levels of deterioration. A reduction of up to 0.3 log units (i.e. 6 letters, a whole line) in CT was found using the Pelli–Robson chart. In another individual, the denominator of the Snellen fraction dropped by 2.0 units (i.e. 6 letters, more than 1 line) on the high contrast Bailey–Lovie chart. Using the low-contrast Bailey–Lovie chart, yet another individual showed a reduction of 4.4 units (i.e. 10 letters, 2 lines). RT increased by 0.62 s in one driver. All four of the above results were found in different individuals.

Discussion

Although HCVA was significantly reduced by pupillary dilation, this reduction was small, amounting to less than 2 letters, so that the equivalent Snellen fraction with dilation amounted to 6/7.6. This represents a higher level of vision than the British number plate standard, which has been found to be equivalent to a Snellen acuity of 6/9–2.[17] Nevertheless, one individual showed a decrease of more than 1 line on the high-contrast chart and previous studies have demonstrated a fall in HCVA, sometimes to a level below that legally required for driving, in a small proportion of subjects.[6–8]

CT was also significantly reduced. This test, and also by the same argument LCVA, is probably of more relevance to driving than HCVA, considering most objects on the road are of low contrast. Indeed, CT has previously been found to correlate with crash frequency.[14] Nevertheless, the mean change in CT amounted to fewer than 3 letters on the Pelli–Robson chart (although one individual showed a deterioration of 1 line), and could be argued to be of little importance, although there was one subject in whom LCVA reduced by 2 lines. Other studies have also found that dilation has no significant effect on contrast sensitivity.[8,18] It might be contended that CT exhibited a more significant effect than LCVA and HCVA due to the testing distance of 1 m, compared with 3 m for the other tests, making CT more prone to the cycloplegic effect of tropicamide. Gilmartin *et al.*[15] reported that young people retain 2–4 dioptres of accommodation after dilation with 0.5% tropicamide, and the difference in testing distance is therefore unlikely to have been of importance. LCVA was not significantly changed in this study.

UFOV was also not significantly affected. As stated above, this test has previously been found to correlate with crash involvement to a higher degree than visual acuity and peripheral vision.[14] This is presumably because it is a superior measure of higher-order perceptual function. Peripheral visual field defects have also been found to correlate with crash frequency.[14,19] There was no reduction in the Goldmann field in our study.

It was interesting that no parameters of driving simulator performance showed statistically significant change. Some changes did approach significance and also there were again alterations in some individuals' performance which could arguably have an appreciable impact on driving. For example, the increase in reaction time in one individual of 0.62 s would, at 30 mph, amount to over 8 m extra stopping distance (i.e. a 35% increase on the Department of Transport's quoted 23 m stopping distance at 30 mph[20]).

With regard to the relatively large changes in some individuals' performances, detailed examination of the data collected from each subject showed that worst test performances did not occur in the same individuals, indicating that no group of individuals was particularly susceptible to the effects of dilation.

Our study did not take into account the influence of glare, sources of which, such as bright sunlight and car headlamps, are frequently encountered while driving. Previous studies have shown that glare reduces visual acuity in the presence of pupillary dilation.[8,21] In this study measurements of LCVA with dilated pupils showed little difference to measurements made with undilated pupils, although there were no subjects with ocular pathology such as lens opacity, which is known to increase susceptibility to glare.[22]

As previously stated, the intended masking was not achieved. A slight, statistically insignificant, reduction in speed after dilation was found and may have been because drivers became aware of subtle visual deterioration and slowed down; the reduction in speed could in turn explain the slight improvement observed in steering accuracy (WOBBLE). Nevertheless, we do not believe that the objectively measured reaction time, and also the tests of visual function, would have been influenced to any degree by subjects' awareness of dilation or the lack of it.

Pupillary dilation forms an integral part of many ocular examinations, and our results, like those of previous authors,[23] suggest that deterioration of vision and driving ability does not necessarily occur with its use in young healthy adults with corrected low refractive errors driving a car in the daylight hours immediately following fundoscopy. Nevertheless, some individuals exhibited reductions in visual parameters which could have an important impact on driving ability and these results must therefore be interpreted with caution. We recommend that a larger study be carried out, investigating a greater number of drivers over a wider range of ages, with and without a variety of ocular pathology, before firm guidelines are recommended to practitioners.

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