ORIgINAL ARTICLE

Reaction time as a measure of enhanced blue-light mediated cognitive function following cataract surgery

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ABSTRACT

Background/aims Since 2002 the discovery of a novel population of intrinsically photosensitive retinal ganglion cells, expressing the photopigment melanopsin, has attracted broad interest in human blue-light mediated non-visual effects including circadian regulation and cognitive function. Ageing is associated with insomnia and cognitive decline. It has been postulated that reduced blue-light transmission through the formation of cataract impairs melanopsin dependant non-visual brain responses mediated by intrinsically photosensitive retinal ganglion cells. We aimed to establish if any objective improvement in cognition could be demonstrated using a reaction time task (RTT) following cataract surgery and intraocular lens implantation.

Methods Following strict inclusion and exclusion criteria, 15 patients (age range 59–87, mean 75.4 years) with bilateral cataract performed the RTT before and after surgery on one eye. The mean and the SD of two modalities of reaction time, namely complex reaction time and simple reaction time, were measured and analysed.

Results Responses became both quicker and more consistent following surgery, with statistically significant improvements in the complex reaction time (p=0.016) and the complex reaction time SD (p=0.055), which were not due to a learning effect or improved vision.

Conclusion The results suggest that improved blue-light transmission following cataract surgery has a beneficial effect on cognitive function. We advocate the RTT as an objective platform for exploring these benefits in large sample randomised controlled trials.

INTRODUCTION

Ageing is associated with insomnia, depression and cognitive decline. It has been postulated that reduced blue-light transmission through senile miosis and formation of cataract impairs non-visual brain responses mediated by intrinsically photosensitive retinal ganglion cells.1 2

Melanopsin-expressing intrinsically photosensitive retinal ganglion cells transmit irradiance signals to multiple subcortical structures via the retinohypothalamic tract, including direct projections to:

- The suprachiasmatic nuclei, site of the master body-clock oscillator
- The ventrolateral preoptic nucleus, involved in alertness and sleep regulation
- The intergeniculate leaflet, implicated in circadian photoentrainment
- The olivary pretectal nucleus, involved in pupillary constriction.

Additionally, indirect connections link the suprachiasmatic nuclei to arousal centres in the forebrain and brainstem.3

Blue light has been shown to be most effective in enhancing both self-reported performance, well-being and sleep quality,4 5 measured wavelength dependant reaction times,6 cognitive performance7 and brain responses.8 Current research is examining the potential benefits of environmental blue-light enrichment in the institutionalised elderly.1 2

With ageing, the chronologically oldest lens fibrils cause the lens nucleus to take on a yellowish appearance, which may or may not have a measurable effect on vision. This results in an alteration in the quantity and quality of light reaching the retina, particularly in the short wavelength range. It has recently been shown that the transmission of light at the peak melanopsin sensitivity of 480 nm is reduced by 72% in the 80-year-old crystalline lens as compared with a 10-year-old child’s lens.8

Removal of a yellow opaque crystalline lens and replacement with a clear intraocular lens (IOL) as a means of increasing blue-light transmission thus has potential benefits to non-visual melanopsin-dependant brain responses, the human circadian rhythm and its downstream physiological effects.9 10

Previous studies11 12 have shown subjective improvements in sleep quality following cataract surgery. We aimed to establish if any objective improvement in cognition could be demonstrated using a reaction time task (RTT) following cataract surgery and IOL implantation. Reaction time forms the basis of mental chronometry and is the elapsed time between a sensory stimulus and a physical response. It is considered to be a measure of cognitive processing speed and has been shown to be correlated to general fluid intelligence.13 Reaction times are widely used as a valuable predictor in the fields of cognitive psychophysiology and cognitive neuroscience.

METHOD

Participants

This study adhered to the precepts of the Declaration of Helsinki and ethics approval was obtained through the College of Medicine at the University of Edinburgh. This non-invasive questionnaire and task-based study was conducted on participants who had routinely been referred for consideration of cataract surgery.

Fifteen patients with bilateral cataract undergoing routine first-eye cataract surgery at the...
Princess Alexandra Eye Pavilion in Edinburgh (latitude 55°55’N) were recruited between March and May 2010.

All potential participants were subjected to a detailed slit-lamp ophthalmic examination, general medical screening, a validated sleep questionnaire and the RTT pre-operatively. Reaction times were measured both pre- and post-operatively using a validated purpose built portable device of a type first used in the United Kingdom Health and Lifestyle Survey. Two modalities of reaction time were measured with the standardised reaction time device, simple reaction time (sRT) and complex reaction time (cRT). The mean of each along with the SD were recorded. Patients listed for surgery had their cataracts removed by phacoemulsification and received an ultraviolet-blocking IOL (AMO AR40 Sensar; Abbott Medical Optics, Santa Ana, California, USA) as per standard Princess Alexandra Eye Pavilion protocol. The RTT was then repeated post-operatively (mean 12 days; range 5–18 days).

Inclusion criteria
Patients were included in the study if:
1. They had a Snellen visual acuity of 6/12 or worse in both eyes.
2. They had cataracts present in both eyes.
3. They were listed for surgery.

Exclusion criteria
Patients were excluded from the study if:
1. They were unable to comply with the study due to severe cognitive impairment such as dementia or Alzheimer’s disease.
2. They had sleep disturbances such as sleep apnoea and restless leg syndrome.
3. They had co-existing ocular morbidity such as age-related macular degeneration, diabetic retinopathy, glaucoma and retinal damage.
4. They had received previous cataract surgery.
5. They could not read the display on the RTT machine.
6. They had communication difficulties or declined participation.

Reaction time task
The device has a liquid crystal display below which are five keys labelled 0, 1, 2, 3 and 4. The participant undergoes two tasks, an sRT task (sRTT) and a cRT task (cRTT). In the sRTT, the patient rests their index finger on the 0 key and is asked to press it as quickly as possible when the number 0 appears in the display. (The test display size is equivalent to the N48 measure of near visual acuity.) Eight practice trials are followed by 20 test trials. This is followed by the cRTT in which the participant rests their index and middle fingers of each hand on the keys labelled 1–4 and asked to press each one as quickly as possible when the corresponding number appears in the display. Again there are eight practice trials followed on this occasion by 40 test trials in which the numbers appear in random order. In both the sRTT and cRTT, the numbers appear at random intervals of between 1 and 3 s. The device records the mean reaction time and SD for both complete tests.

Statistical analysis
All analysis was carried out using SPSS software, V.17.0. Because of the small sample size and non-normal nature of the data, a non-parametric analysis was carried out.

RESULTS
Due to the stringent inclusion and exclusion criteria, only 15 patients were recruited to the study. The main reasons for which patients were excluded were having had surgery before or having cataract in one eye only. The age range of the participants was 59–87, mean 75.4 years. In keeping with the hypothesis that cognitive function would improve after surgery, a one-tailed test (ie, p<0.01) was appropriate for significance.

A descriptive summary of the sRT and cRT results before and after surgery is given in figures 1 and 2.

A comparison before and after surgery of the mean reaction times from the 20 trials for each individual using the Wilcoxon signed rank test is shown in table 1. Simple mean reaction times were faster after surgery but did not reach significance (z=−1.1, p=0.28). However, cRT were significantly faster (z=−2.41, p=0.016) after surgery. It was also expected that the intra-subject variation in any 20 test trials would reduce after surgery, indicating better repeatability. Results in table 1 show a similar direction for simple and complex tests but again with variation significantly reduced in cRT after surgery (z=−1.92, p=0.055).

A series of non-parametric tests (Spearman ρ correlations and Mann Whitney U) were carried out to explore relationships...
between reaction time measures and visual acuity, age and gender.

Using the Spearman correlation test we found that visual acuity (better eye, worse eye, difference between eyes) was not related to any of the reaction time measures either before or after surgery. Hence reaction time differences are not due to differences in visual acuity. On age and gender the results were inconclusive. For example, gender had a marginal effect on the SD of cRT, with women having greater variation across the 20 trials (p=0.03 for before and p=0.09 for after surgery). In addition, age appeared to have a marginal significant effect (p=0.047) on sRT at the pre- but not the post-surgery testing, a difference embedded in the change data in figure 3. However, a larger sample size is needed to justify such subdivisions.

DISCUSSION
The improvements in cRT and SD (variability) following cataract surgery in this study group become important when we consider previous work examining the relationship between ageing, cognitive function and reaction times. Cognitive ageing is linked to reaction time variability, and reaction time mean and variability are correlated. Der and Deary’s analysis of 7150 participants in the Health and Lifestyle Survey showed a linear relationship between ageing and the slowing and increased variability of cRT. These reflect the age-related declines in higher cognitive function relating to slower processing speed. In addition, cRT are more closely correlated with intelligence than sRT.\textsuperscript{15} Vandewalle \textit{et al}\textsuperscript{3} demonstrated near-instantaneous cognitive responses to monochromatic light, which correlates well with the measured improvements in our subjects after a relatively short post-operative interval, particularly as the repeat RTT was performed well before best corrected acuity was achieved.

Asplund \textit{et al}\textsuperscript{11,12} found that the beneficial effect of cataract surgery on sleep patterns increased as time elapsed in the post-operative period, with significant improvements in the period between 1 and 9 months post-operatively. They also found further benefits after second-eye surgery. It is tempting to speculate that cognitive benefits might also increase with the passage of time and following removal of a second cataract, however this needs to be explored in larger longitudinal studies.

This study is limited by the relatively small sample group. The advantages are the relatively low cost and portability of the RTT and the ease of administration of the test. The RTT is ideally suited to longitudinal studies such as this in that there is no demand on working memory, and it can therefore be used for repeated task administrations in order to determine intra-individual change.\textsuperscript{16} The fact that there is no learning effect across repeated tests is borne out in this study by the lack of improvement in sRT as opposed to the significant improvements in cRT, which as discussed above, is more closely linked with cognition.

CONCLUSION
The inference that blue-light exposure is associated with improved cognitive performance carries over to the ageing population who may experience non-visual benefits from cataract surgery. Given the limited scope of intervention for cognitive decline, the role of cataract removal and IOL insertion achieves a wider significance. We advocate the RTT as an objective platform for exploring these benefits in large sample randomised controlled trials.

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Competing interests None.

Ethics approval This study was approved by University of Edinburgh Medical School.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

| Table 1 | Significant improvements in cRT mean (p=0.016) and cRT variability (SD) (p=0.055) were found following cataract surgery |
|-----------------|-------------------------------------------------|-----------------|----------|
| Simple reaction time | Complex reaction time |          |          |
| sRT            | sRT SD            | cRT          | cRT SD          |
| Z value        | 1.1                | 2.41         | 1.92            |
| p Value        | 0.280              | 0.016        | 0.055          |

Changes in sRT mean (p=0.280) and SD (p=0.495) were non-significant.

cRT, complex reaction time; sRT, simple reaction time.
Clinical science


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