Worrying statistics
There are currently 700,000 people with dementia in the UK with a projection of 1.4 million in 30 years time. Two-thirds of people with dementia are women and 64% of people living in care homes have a form of dementia. About 60,000 deaths per year are directly attributable to dementia, whilst delaying the onset of dementia by five years would reduce this rate by 30,000 a year. Two-thirds of people with dementia live in the community, being cared for by family carers, whilst the remainder live in a care home. AD accounts for 50-70% of dementia cases, the prevalence of which is age-related (Figure 1).

Visual variant of Alzheimer’s disease
More than 60% of people with AD have a decline in one or more visual function(s). AD causes vision impairment not by affecting the eye but by deterioration of neurological function within the brain. Patients have difficulty perceiving motion, depth and colour, rather than problems with clarity. However, not everyone with the disease will experience visual and perceptual problems to the same degree. Disturbances of the visual system can pre-date other manifestations of dementia. Unfortunately, because of characteristically vague symptomology and normal “eye sight” examination findings at presentation, the diagnosis may be overlooked. Patients with AD usually seek an ophthalmic consultation because of disturbances of pattern processing and recognition. Typical symptoms experienced include:

- Visual deterioration under stress
- Blurred vision at distance, intermediate (eg, computer screens) and/or near, which is not fully relieved with spectacles
- Problems with judging depth
- Eye strain with no apparent cause
- Slow reading
- Loss of concentration when reading
- “Can’t be bothered” with reading small print
- Driving a car causes strain or tired eyes
- Light sensitivity
- Restricted depth of focus when reading
- Eyes “just don’t seem quite right”
- Balance and/or postural problems
- Clumsiness, falls, walking into objects, and/or knocking over ornaments, etc.

Difficulty with near reading is the most common symptom and may present as skipping of words or lines on a page, ‘dancing print’ (a form of acquired visual dyslexia) and/or blurred vision; this can progress to alexia in advanced disease. Other well-documented difficulties include an inability to recognise faces (prosopagnosia), an inability to pick out individual objects in a group, and/or disorders of visuo-spatial processing. Many of these symptoms can be
explained by defects of visual function that research has found to be causative in AD, as summarised in Tables 1 and 2.11-13

**Motion**

One of the most debilitating effects of AD is a tendency to become lost in familiar surroundings.14 Medical researchers have commonly attributed this loss of orientation to mental confusion.15 However, studies suggest that people with AD become lost, not because they are confused, but because their visual processing associated with akinetopsia (motion blindness) is impaired.16 Research into motion blindness has found that some people with AD are unable to sense movement and instead their view of the world is like a series of still frames instead of the “movie” most of us see. Indeed, people with AD had more than twice as much difficulty interpreting patterns than either healthy young people or healthy elderly people.17 It was theorised that this deficit is a result of damage to the magnocellular pathways of the brain (rather than the parvocellular system) (Figure 2).18 In addition, people with AD may have impaired form identification (parvo-cellular stream)18 and visuo-spatial (location) skills,19 affecting ability to judge depth. This may make shadows on the floor or a dark rug look like holes in the ground, despite a good (high) level of visual acuity (VA).19

Such evidence counters the generally accepted impression that AD is simply a disorder of memory, highlighting the visual problems that can be caused, resulting in a synergistic deficit of memory and vision. Such visual disorientation is often one of the first symptoms that presents in AD, and could be useful in early diagnosis of the disease.20-22

**Contrast and contrast sensitivity**

Contrast sensitivity is the smallest difference in luminance between an object and its background, which can be just detected. Research has shown that the ability to detect contrast is reduced in people with AD (Figure 3),21,24 and this is an important factor that has a significant impact on everyday living. Certainly this is very relevant to the task of reading, since people with AD may not be able to adequately detect text in, for example, phone books, magazines and newspapers. It can even impact the detection of objects in the surrounding environment and have consequences for mobility, thus compounding the deficits of motion discussed in the previous section.

Contrast sensitivity, especially at low frequencies (mediated by the magnocellular visual pathway), has been shown to be deficient in patients with AD, as measured using both the Nicolet Vision Tester and the Vistech contrast sensitivity wall chart.21,24 This reduced contrast sensitivity can develop in as little as six months of the onset of the disease. Increasing stimulus contrast may therefore be an effective means of enhancing cognitive performance in AD.25

**Visual attention and visual short-term memory**

Visual short-term memory (VSTM) is an important visual process for most daily tasks in which visual information (eg, an object or location of an object) must be maintained across a substantial delay. Eye movements produce such substantial delays, which causes a suppression of input to visual areas. Because VSTM has a limited storage capacity, attentional processes must regulate the information that enters the visual memory. This transfer of perceptual information into a VSTM appears to be a slow, effortless process.
suggesting a role for focal attention. Once items are consolidated into VSTM, they themselves become objects of attention. Attention not only influences entry of items into VSTM but also selects items for storage demonstrating the multiple effects of attention. VSTM has been shown to be impaired in patients with AD,\textsuperscript{30} with consequential impairment of attention.

### Colour vision

Colour perception naturally diminishes with age, for example due to changes in the pigmentation of the ocular media (eg. “yellowing” of the crystalline lens). However, for people with AD, there seems to be even greater deficits in the ability to see colours, particularly in the shorter wavelength, blue-end of the spectrum.\textsuperscript{27} Though a study by Pache found that when using the Ishihara test, patients with AD were more likely to make errors on plates 5, 9 and 10-15,\textsuperscript{28} the Ishihara colour vision test is unsuitable for assessment of tritan problems and therefore the City University Test or Farnsworth D15 test ought to be used instead. Indeed, colour vision testing is important, but rarely carried out routinely on elderly patients, because attempts to improve colour contrast can help individuals with AD to improve both short-term memory and spatial awareness, allowing them to find their way around easier;\textsuperscript{29} the colour red should be used to make items stand out.\textsuperscript{30}

### Visual field assessment

Visual fields, though sometimes difficult to assess in patients with AD, are usually full in the early stages of the disease. As the disease progresses, there can be measurable visual field loss reliably detected by automated perimetry; most notably this is readily detected by Frequency Doubling Technology (FDT) (eg. Zeiss FDT field screener).\textsuperscript{21} Histopathological studies have shown that patients with AD exhibit significant selective loss of neural elements within the visual cortex, particularly affecting the magnocellular pathway, which could account for this visual field loss.\textsuperscript{11} It certainly appears that FDT visual fields screeners are more sensitive to this type of defect over standard threshold fields tests (see article 1 in this series, OT, January 14, 2011),\textsuperscript{33} although threshold field tests are more appropriate for monitoring progression of a combination of diseases such as co-existing glaucoma.

### Glaucoma

When patients with AD also have glaucoma, the course of vision loss related to glaucoma is much more rapid and aggressive than in those patients who have glaucoma but not AD. Originally it was thought that glaucoma affects visual function at the initial site of neural activity, the retinal ganglion cells, and ultimately destroys their afferent axons at the nerve fibre layer in the retina.\textsuperscript{34} However, it has been suggested that the first sign of injury to the neurological system in glaucoma actually occurs within the brain, with neural damage being similar to that found in Parkinson’s disease (PD) and AD.\textsuperscript{35} AD impacts cells that may be considered terminal or intermediary in the visual pathway in the brain, with loss of nerve fibre connections and atrophy, thus reducing neural input. Pathological evidence of neural degeneration has been correlated with clinical, optic nerve head, visual field, and neuro-radiology findings.

### Alzheimer's disease and driving

A study by Frittelli\textsuperscript{36} found simple visual reaction times were significantly longer in patients with AD compared to a group with mild cognitive impairment and healthy controls. The study also revealed that measures of driving competence were borderline significantly poorer, when assessed by simulation; this included

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**Table 2**

Summary of visual pathology associated with Alzheimer's disease.\textsuperscript{12,13}

<table>
<thead>
<tr>
<th>Structure</th>
<th>Affects of AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye</td>
<td></td>
</tr>
<tr>
<td>Lens</td>
<td>β-amyloid is present in lens fibres</td>
</tr>
<tr>
<td>Aqueous Humour</td>
<td>β-amyloid is present</td>
</tr>
<tr>
<td>Optic Nerve</td>
<td>Nerve degeneration</td>
</tr>
<tr>
<td>Retina</td>
<td>Ganglion cell loss</td>
</tr>
<tr>
<td></td>
<td>β-amyloid deposition</td>
</tr>
<tr>
<td></td>
<td>Reduction in thickness of RNFL</td>
</tr>
<tr>
<td>Sub-cortical Visual Centres</td>
<td></td>
</tr>
<tr>
<td>Lateral Geniculate Nucleus (LGN)</td>
<td>β-amyloid plaques</td>
</tr>
<tr>
<td>Pulvinar</td>
<td>β-amyloid plaques</td>
</tr>
<tr>
<td>Superior Colliculus</td>
<td>β-amyloid plaques &amp; Neurofibrillary Tangles (NFT)</td>
</tr>
</tbody>
</table>

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**Figure 3**

The effect of reduced contrast for a person with Alzheimer’s disease.
the length of journey time, the number of infractions (omission of stop at pedestrian crossings and speed limit violations), the number of stops at traffic lights, the mean time to collision, and the number of off-road events. This study reflects the importance of visual deficits in AD and the potential impact this can have on driving performance. Indeed, once a licence holder has been diagnosed with a notifiable medical condition (eg, PD, AD, and glaucoma) they should notify the DVLA.37

Alzheimer’s disease and falls
Due to changes in the brain that are caused by AD, it has been reported that the risk of falling is significantly increased.24 Slower reaction times and difficulty recognising changes in the height or depth of a step can, for example, lead to tripping and falling; such changes are likely to be compounded by the types of visual deficit described previously in this article. Changes in balance and co-ordination, combined with poor memory, can make it difficult for a person with AD to both get from one place to another and avoid hazardous objects at the same time.20

Melatonin and Alzheimer’s disease
With ageing there is a decline in both serotonin transporters39 and serotonin receptors40 in the brain. Serotonin is the precursor for melatonin, which, as described in article 2 (see OT, January 28, 2011) is a hormone produced by the pineal gland at night and influences circadian and seasonal rhythms, most notably the sleep-wake cycle and seasonal reproduction. Melatonin production reduces as we age (Figure 4) and elderly people with AD have half the blood levels of melatonin as normal people of the same age; this is particularly relevant because melatonin is important for inhibiting the aggregation of β-amyloid protein into β-sheets;41 the β-amyloid protein, which is the most commonly implicated marker of AD, is most neurotoxic and most resistant to proteolytic degradation when it aggregates into beta-sheets, thus affecting normal brain function. Melatonin also reduces the hyperphosphorylation of tau protein, which leads to the neurofibrillary tangles of AD (Table 2).42

Stimulation of melatonin production may be a feasible “treatment” for AD. It has been reported that sleep patterns improved and mood problems reduced in a group of patients that were given extra melatonin and extra light.43,44 Increasing light alone (ie, no extra melatonin) was enough to reduce cognitive deterioration by as much as 5%, whilst depressive symptoms fell by 19%.45 This finding compares well with treatments such as Aricept, which are designed to slow the progression of AD.46

Eye health complications
The RNIB and Thomas Pocklington Trust47 have recently expressed extreme concern that patients with dementia are failing to have regular eye exams, with the consequent increased risk of sight loss from typical age-related sight problems such as cataract, glaucoma and age-related macular degeneration. Assessment and treatment of these problems can improve quality of life by affecting balance posture, walking ability, as well as the visual aspects of motion awareness, contrast, improved VA, and colour vision, allowing an improved ability to read and watch TV etc. and more importantly extending quality of life.

Summary
AD does not lead to refractive visual problems alone, but can have a major effect on the visual processing systems which impact on quality of life. Given the diagnostic limitations of standard examination techniques, attention has focused on ‘higher visual function’, with a battery of tests required to identify, diagnose and manage patients with AD sooner. The role of the optometrist in meeting this challenge will be discussed in the next article of this series.

About the author
Geoff Shayer qualified as an optometrist from City University in 1973. He is in private practice in Dorset. His special interests involve developing and utilising new assessment and therapy techniques for conditions that are affected by dysfunction or damage to the neural pathways, such as Streff syndrome, strabismus, mild traumatic brain injury, stroke, Alzheimer’s and Parkinson’s diseases.

Further reading

References
See http://www.optometry.co.uk clinical/index. Click on the article title and then download “references”