Q&A: Driver's vision, and what influences it

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The question

How is the vision of a driver impacted by emotion, age, speed, time of day, and distance? This Q&A explores how these factors can impact a driver's vision, and consequently their safety, on the road.

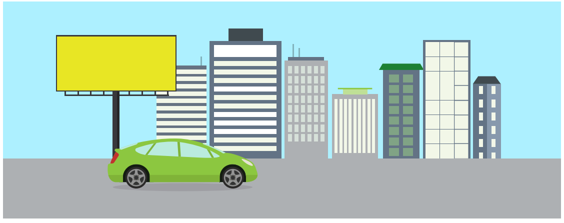
Why it matters

The quality of your vision influences your ability to recognise and respond to hazards on the road, and understanding how vision is linked to road safety reduces risk for drivers as well as vulnerable and other road users. Drivers have a legal and moral responsibility to have a minimum level of vision, and employers should consider vision as part of fitness for duty checks for their drivers.

4 key things to know

If you can't read a normal car licence plate from about 20m away, your vision probably doesn't meet the minimum condition to hold a licence.

A driver's age and emotional state, the time of day, speed and following distance all change how well you 'see' on the road.



To reduce risk on the road, scan your surroundings, slow down, avoid emotional stimuli, increase following distance, and don't drive if emotional.

Viewing objects or other road users via 'indirect' vision adds 0.7 seconds to reaction time; double if the road user is a pedestrian.

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Scope of the problem

Driving, particularly in the work setting, is potentially one of the most dangerous activities a person can do in the course of their day. It is also an activity that relies on vision, and drivers scanning the road ahead, to drive safely. There are many ways vision can be impacted while driving: the driver's emotional state and age, for example, can have a significant impact on their visual ability and, therefore, their ability to drive safely. And research shows a variety of visual abilities are connected to safer driving, including visual acuity, visual field, contrast sensitivity, and visual processing speed (Owsley & McGwin Jr, 2010; West et al., 2003).

Reflecting the importance of vision in road safety, Australia has a legal minimum level of eyesight drivers must meet if they are to hold an unconditional licence. This minimum 'uncorrected visual acuity level' is 6/12, which means that drivers can discern details at 6 metres that someone with normal eyesight would be able to discern at 12 metres. Generally speaking, drivers should be able to read a normal car licence plate from about 20 metres away.

This Q&A explores how an individual's visual ability can be reduced or impaired through several factors, such as a driver's emotional state and age, time of day, and the speed of the vehicle and its following distance.

The issue explained

4 factors that influence visual ability

Visual acuity

The most common method of measuring visual ability and the basis of minimum visual ability to hold a licence in Australia. It includes the ability to resolve details in vision or the clarity with which they see. In other words, a driver's ability to read signs and avoid hazards.

Visual field

How large an area an individual can see when they are focused on a single and central point. A small visual field makes drivers more likely to be involved in road incidents. However, drivers with visual field degradation may develop other ways to compensate.

Contrast sensitivity

An individual's ability to recognise the differences between shades and patterns (Katz & Bothwell, 2017). Poor sensitivity is associated with an increased risk of being involved in a road incident. Contrast sensitivity is particularly important for night driving, as limitations in this area affect a driver's ability to recognise road signs, obstacles, and pedestrians more than visual acuity.

Visual processing speed

How quickly an individual can process information and respond. Not surprisingly, drivers with slower visual processing speed are also more likely to be involved in a road incident. As the visual environment constantly changes during driving, higher visual processing speeds means drivers are more capable of recognising and responding to unexpected additions to their visual environment.

Source: Owsley & McGwin Jr, 2010

Emotion

Emotion can influence driver behaviour as well as impact vision. Research has shown an individual's emotional state can have a significant impact on their behaviour and attention, which has a direct impact on driving performance. Angry drivers, for example, have been shown to increase speed and leave a shorter braking distance to the vehicle ahead (Chan & Singhal, 2013; Steinhauser et al., 2018; Tamir & Bigman, 2018). However, emotions and emotional stimuli can also impact driving ability by affecting a driver's vision, for example, viewing emotionally stimulating content on a billboard.

Experiencing emotions

Emotions affect the length of eye fixations, which is the attention captured by an object in the visual environment. Lengthy eye fixations often result in a reduced likelihood of recognising hazards in a constantly changing environment.

One study investigating how mood impacted length of eye fixations and response times found people who were sad had the longest eye fixations and response time. A happy or neutral mood had no effect on fixation length and, therefore, on driving in this manner (Zimasa, Jamson, & Henson, 2017).

This result can be explained because sadness creates a psychological condition where the individual experiences "tunnel vision" and, to avoid the source of the sadness, does not explore the environment (Carver, 2003). The increased fixation time caused by sadness is likely to result in less visual scanning of the environment and may result in increased likelihood of a road crash as a sad driver is less likely to see potential obstacles (Zimasa et al., 2017).

Engaging in an emotional conversation can also be detrimental to an individual's driving ability. In a simulated driving study, drivers with a phobia of spiders and drivers without the phobia maintained a conversation about spiders. Phobic drivers displayed greatly reduced visual scanning, which resulted in tunnel vision and could lead to a higher rate of crashes (Briggs, Hole, & Land, 2011).

Emotional stimuli

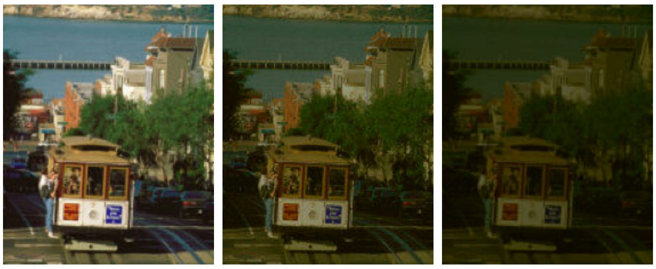
Emotional stimuli are more likely to grab and hold people's attention, diverting attention away from road related activities. This impacts where a driver is looking and, in turn, their driving ability (Chan & Singhal, 2013).

Roadside billboards, for example, often contain emotional content to motivate consumer behaviour. Research in a simulated environment examining the effect of emotionally stimulating billboards on driving behaviour showed higher recall of emotional words. This is explained as drivers taking their eyes off the road for longer to process the emotional content of the words, to the detriment of other driving related processing (Chan & Singhal, 2013). This was also associated with an increase in the average speed of the vehicle while passing the billboard and immediately after, which has the potential to impact driver safety.

Age

Drivers aged over 75 represent a large proportion of the population involved in road crashes. In fact, per capita, only the high-risk and over-represented 15-24 year old age group have a higher crash rate. As individuals age, their vision declines gradually (Desapriya et al., 2014), which broadly correlates with a reduction in an individual's ability to drive safely.

Changes in transmission of light through optic media



Age 20 **Age 60** **Age 75**

Source: http://jimbogar.com/wp/2016/08/

Decline of visual ability with age

The ability to recognise and respond to obstacles is an important component of driving and relies on the driver's visual ability. A study, which employed a simulated environment, examined how older and younger drivers manoeuvred around obstacles. It found older drivers cut corners more tightly, leaving less space between the vehicle and the obstacle, compared to younger drivers. This was explained as older drivers having less visual capacity, which impacted spatial visualisation and their ability to recognise how much buffer space they had between their vehicle and obstacles. This cutting of corners may result in a higher likelihood of being involved in a road crash. In a low light environment, however, older drivers allowed a greater distance between the vehicle and obstacles (Hine, Wallis, Conlon, & Wood, 2012). Potential explanations for this may be that older drivers are more experienced and cautious when driving at night or, due to poor vision, leave more buffer space than is necessary.

Some of the visual impairments that become more common with age, such as cataracts and blurriness, contribute to older drivers' poorer driving performance. These impairments were simulated by a study that compared young drivers and older drivers as they drove around a closed-circuit road. The results found that, despite being exposed to the same visual impairments, older drivers experienced a greater impact on their ability to drive safely. The negative impact included a reduced ability to cope with distractions and read road signs, and older drivers took longer to complete the course (J. Wood, Chaparro, & Hickson, 2009). This indicates factors other than just visual impairments may be contributing to older drivers' poorer driving performance, such as younger drivers having greater attentional capacity and ability to adapt to sudden (simulated) visual impairment.

Age and behaviour change

Age-related behaviour that impacts vision is also of interest. For instance, older drivers have fewer head movements, which can lessen their field of view (J. M. Wood, 2002) and reduce drivers' ability to be aware of and react to potential obstacles moving into their path from the side of the road.

Research has also shown individuals restrict their own driving to minimise risk when they begin to experience reductions in visual ability due to age. Older drivers recognise the potential risks associated with their decreased visual ability and subsequently self-regulate their driving by limiting driving or avoiding driving at night (West et al., 2003). Interestingly, some older drivers do self-regulate their driving for reasons other than a decline in visual ability. However, these people also experience poor depth perception compared to those that do not self-regulate, so their self-regulation may unconsciously be related to a decline in visual ability.

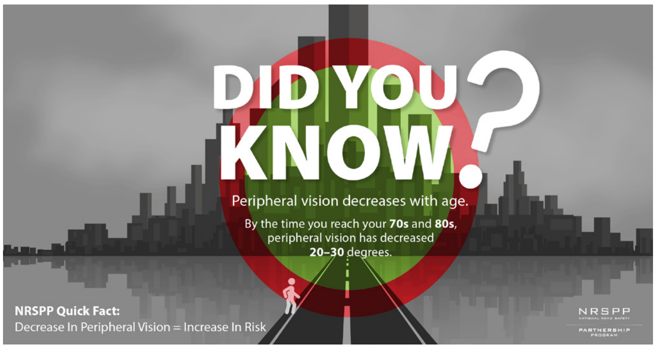
It is important to note that some research has found no difference between rates of accidents in older drivers compared to younger drivers (Hakamies-Blomqvist, Raitanen, and O'Neill, 2002). When controlling for the reduced kilometres travelled by drivers over 65 years old, and their tendency to drive shorter distances in predominately built-up areas, accident rates in this age group are on parallel with younger drivers.

Speed

The speed a vehicle is travelling influences the vision and visual scanning of its driver. Almost one in three road crashes in Australia are attributed to vehicles speeding, with increases in speed making it more likely a vehicle will be involved in a road crash.

One way speed can impact drivers' visual scanning is reducing their ability to recognise stimuli in their periphery at higher speeds. A study examining the field of view of drivers in a simulated environment exposed drivers to two conditions: 90kmh and 130kmh (Rogé et al., 2004). This study demonstrated that as speed increases, the useful visual field decreases. At higher speeds, drivers were less likely to detect lights on vehicles, such as indicators, in their periphery. When vehicles were travelling at a slower speed, the effect was reversed, as they were less likely to recognise lights in the centre of their visual field, which is directly in front of the vehicle.

This demonstrates that at higher speeds, stimuli on the periphery, which could include other vehicles, are less likely to be recognised. Thus, these objects have the potential to become a hazard that is recognised later than they otherwise would be if the driver was travelling at a slower speed. This is particularly pertinent to vehicles travelling alongside one another on a highway at high speeds.



Another visual behaviour relevant to driving is visual fixations. This is where the driver's eyes fixate on a single object or location. Fixations can vary in length and frequency. More fixations in a specific area when driving indicates that the area is relevant and important to the driver. Longer fixations reflect greater mental workload in interpreting information from that area, and potentially reflect difficulty in extracting information from an area. A study testing a small number of drivers on a real road found that the number of eye fixations decreased as speed increased. They also found that eye fixation length decreased as speed increased (Qin, Dong, Xu, Zhang, & Leon, 2018). The decrease in both fixation frequency and length indicates that at higher speeds a driver's cognitive engagement with specific areas may be reduced. It may also be explained as objects will be moving passed the driver at a faster rate when they are travelling faster, so the driver has less ability to fixate on those objects.

Time of day

Road crashes are more frequent at night, and those road crashes that do occur at night or during dusk, are more likely to result in fatalities than crashes during the day.

There are several reasons why time of day impacts driver safety; drivers' reduced visual ability is one. This is demonstrated by significant reductions in road crashes, injuries, and fatalities when overhead public lighting is present (Elvik, 1995). Interestingly, some research suggests that when driving along a road at night with street lights, drivers increase their speed and decrease attention compared to when driving along a road with no lights (Easa, Reed, & Russo, 2010).

Driver reaction times are significantly longer in low luminescence environments: night time, dusk, and dawn. This is because visual processing, such as detailed vision and colour and motion perception, are greatly diminished, and can be completely negated, under low light conditions. As a result, drivers have greater difficulty at night recognising contrast differences between low contrast targets (small differences between brighter and darker objects) and the speed of other objects, like vehicles approaching intersections. This means drivers take more time to respond to things in the environment, which leads to longer braking distances. This demonstrates how night time and the subsequent lowered visual ability can impact driver safety and, in part, explains the increased incidence of road crashes.

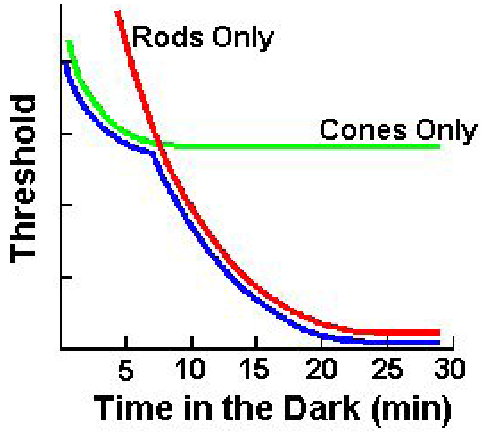
As individuals age, their ability to see in low light (not necessarily completely dark) conditions decreases substantially, and their glare sensitivity increases dramatically. These gradually developing visual limitations around night vision occur independently to any ocular disease in older drivers (Gruber, Mosimann, Müri, & Nef, 2013).

Drivers under night conditions also experience an increase in the duration of their visual fixations. This indicates that they need more time to cognitively process the stimuli (Konstantopoulos, Chapman, & Crundall, 2010).

Drivers also demonstrate less fixations overall when in low light conditions, indicating that less information from their visual field is being attended to and processed. Both these changes in fixation behaviours potentially contribute to the high rate of road crashes that occur at night.

How our vision adapts to the dark is also relevant to road safety. Rods and cones are two different receptor cells in the eyes. Cones are used for colour precise vision, and rods are more sensitive to light that allows vision at night. The sensitivity cones decreases substantially (functionally disallowing precise colour vision) in low light conditions. Rods take a longer time to adapt to the dark but their lower absolute sensitivity threshold allows them to be useful in lower light environments.

As the figure below shows, it can take some time for an individual's vision to completely adapt to dark conditions. As a result, it may be beneficial for night drivers to allow their rods time to adapt before beginning to drive.



Source: http://www.visualexpert.com/Resources/nightvision.html

Direct vision

Vision of the obstacles and other road users that surround a driver is heavily influenced by an individual's ability to see out of their vehicle. Vehicle obstructions can impede direct vision and mirrors can expand indirect vision. Various forms of blind spot mirrors are common and mandatory on larger trucks, to eliminate blind spots around the vehicle. This includes side- and forward-facing mirrors. Research has shown that, on average, there is a 0.7 second increase in reaction time when responding to obstacles, objects or other road users when viewing them via indirect rather than direct vision. This increase in reaction time when viewing obstacles through indirect vision puts at risk the safety of vulnerable road users (pedestrians, motorcyclists and cyclists). In fact, when it comes to viewing pedestrians through indirect vision, reaction time doubles (see table below).

Decreased accurate recognition with indirect vision (mirrors) is partly due to how the orientation and distortion of mirrors make them less intuitive to interpret (Cook et al., 2011; Summerskill & Marshall, 2015).

Because of this distortion, misaligned mirrors can cause serious problems as the percentage of correct recognition of objects in mirrors decreases when those objects are near the edge of the mirror. This is referring to the wide angle mirrors used to address blind spots on trucks (Cook et al., 2011).

Research also indicates that expanding the direct vision of heavy vehicle drivers, by removing blind spots and adding glass panels to the front and side of the cab, improves the driver's ability to see vulnerable road users close to the vehicle.

Speed travelled	25kmh	30kmh	40kmh	50kmh	60kmh	80kmh	100kmh
Extra distance travelled with a 0.7 second average increase in reaction time due to indirect vision	4.86m	5.8m	7.77m	9.72m	11.66m	15.55m	19.44m
Approximate braking distance at indicated speed	4m	5m	9m	15m	21m	38m	59m
Total stopping distance	**8.86m**	**10.80m**	**16.77m**	**24.72m**	**32.66m**	**53.55m**	**78.44m**

Source: http://content.tfl.gov.uk/road-safety-benefits-of-direct-vs-indirect-vision-in-hgv-cabs-technical.pdf
Note: Exact data on reaction time for different types of obstacles was not available

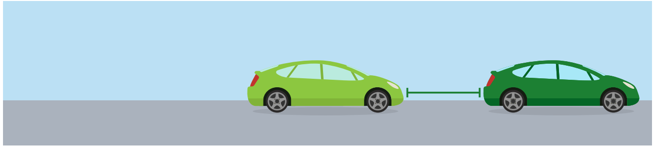
Distance to other vehicles

Appropriate following distance is an important feature of safe driving, with 28% of rear end collisions caused by vehicles following too closely (Michael, Leeming, & Dwyer, 2000). So it is important drivers are able to effectively judge the distance between themselves and other vehicles, and choose to follow at a safe distance. Drivers who have been involved in rear end collision crashes are more likely to engage in 'tailgating' (leaving a short following distance) (Evans & Wasielewski, 1982).

Ability to judge the distance to other objects is based on binocular and monocular depth cues. Binocular depth cues come from the fact humans have two eyes to scan the visual environment. With two eyes that are in different positions, each receives slightly different images of the world. When interpreted together, these two images help us construct a three-dimensional world, which allows us to judge depth and how far objects are from us. This form of depth perception becomes less effective in the 20-40 metre range (Palmisano, Gillam, Govan, Allison, & Harris, 2010). Monocular depth cues only require one eye and can be used at longer distance. This includes cues such as relative size, blur, definition and textures, and motion of objects. Drivers are often observing and reacting to objects at a distance where only monocular depth cues are available (Racette & Casson, 2005).

A driver's following distance can moderate the amount of visual attention they allocate towards vehicles in front of them. When there is a shorter distance between two vehicles, the driver of the following vehicle devotes more attentional resources to the vehicle they are behind.

Research has demonstrated that when there is a shorter following distance, the following driver has a faster reaction time when the lead vehicle begins to decelerate (Lamble, Laakso, & Summala, 1999). When the distance between the two vehicles is greater, it takes longer for the driver to react. This shows the driver places greater visual attention on vehicles that are closer. It is important to note greater attention does not indicate an overall better reaction time; following closely still increases the risk of that driver being involved in a road crash.



The shorter the following distance, the more 'visual attention' the driver devotes to the vehicle in front of them.

Visibility also plays a part in following distance and driver safety. When drivers are travelling in foggy conditions, their behaviour changes: the speed at which they travel decreases and their eye movements increase. Increased eye movements indicate an increased cognitive tax on the individual to recognise and interpret all the information presented to them. As a result, drivers find it more difficult to judge the speed of vehicles in front of them. Research demonstrates that, as a result, drivers are less likely to decelerate and stop on time when vehicles in front of them slow down in limited visibility environments (Deng, Wu, Cao, & Lyu, 2018).

Australians and eyesight

- 76% consider vision their most important sense
- 59% worry about the quality of their eyesight
- 71% of males and 63% of females had their eyes tested by an optometrist after failing a driving test
- 19% of 35-54 year olds find it difficult to read road signs during the day, more than older drivers
- 22% squint while driving at night, 15% squint while driving during the day

Source: The 2020 Vision Index, Optometry Australia

Strategies for safer driving

With many factors related to visual ability and scanning behaviour impacting driver safety, there are several strategies drivers can employ to improve their safety.

Direct attention away from emotional stimuli

Avoid paying attention to emotional stimuli when in control of a motor vehicle. The type of stimuli that can be avoided may include emotional billboards or certain topics on the radio. As well as attempting to avoid viewing or being exposed to these stimuli, this could include not ruminating on them after exposure to ensure attentional resources are not being consumed by the emotional stimuli and subsequent emotional response.

Visual scanning increases hazard recognition

Constant visual scanning of the environment provides drivers with a better chance of recognising hazards in a constantly changing environment.

Don't drive if you're emotional

Lengthy eye fixations or visual tunnelling can also be dangerous and can be caused by several factors. Drivers experiencing specific emotional states, such as sadness, tend to engage in this behaviour more. If drivers are experiencing such emotions strongly, they should temporarily avoid driving.

Slow down and notice what's around you

Vehicle speed can influence visual scanning. While travelling at higher speeds, it is important drivers take note of other vehicles travelling alongside their vehicle in their periphery. This reduces the tendency for tunnelling of vision and failure to recognise stimuli in the periphery while travelling at higher speeds.

Increase following distance

Increase your following distance, particularly while travelling in low luminescence environments. This is not only at night, but also dusk and dawn. This increased distance allows for an increase in response times when viewing objects in low light. This is due to the reduced contrast sensitivity that occurs at night, which makes it more difficult to recognise the speed of other vehicles. This also lends itself to a recommendation to place more attention towards other vehicles and their speeds while travelling at night.

Several resources produced by the National Road Safety Partnership Program can help drivers combat some of these risks outlined above, including quick fact sheets on emotional drivers, road rage, and speed.

Increasing knowledge and awareness of safe driving, and incorporating those behaviours in your daily driving practises, will increase safety and avoid unnecessarily increasing risk on the roads. Drivers should have their eyes tested regularly, particularly if they're noticing a decline in vision, and employers could consider vision as part of fitness for duty checks.

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