Transport for London

Exploring the Road Safety Benefits of Direct vs Indirect Vision in HGV Cabs

Direct Vision vs Indirect Vision: A study exploring the potential improvements to road safety through expanding the HGV cab field of vision

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Executive Summary

The aim of this study is to deliver evidence on the implications of mandating cab design to allow maximum direct vision of vulnerable road users. This evidence is required by the European Commission before they consider future regulatory change relating to the design of HGV cabs.

To provide such evidence, this study explores:

- Reaction times to vulnerable road users appearing directly (through windows) vs. indirectly (through mirrors).
- Driver behaviour in relation to vulnerable road users when driving a traditional cab vs. a low-entry cab.
- The impact of additional cognitive processing on reaction times and driving behaviour.

This study is comprised of three phases, which each phase informing the design of the next:

- Phase 1: Literature Review
- Phase 2: Quantitative surveys of HGV drivers, cyclists and pedestrians
- Phase 3: Laboratory experiment into the benefit of direct eye contact

The laboratory experiments were designed as follows:

Three Control Experiments took place in simulated low-entry cabs. These experiments were designed to test reaction time to stimuli displayed directly (through windows) vs. indirectly (through mirrors) while stationary and navigating:

- Control Experiment 1 – Visual Search While Stationary
- Control Experiment 2 – Visual Search Whilst Navigating
- Control Experiment 3 – Pedestrian Visual Search Whilst Navigating

Two Main Experiments took place, comparing driving performance in traditional cabs (with increased direct vision) vs. low entry cabs (with greater reliance on indirect vision). These experiments simulated a disproportionately high number of close proximity VRU interactions. This was important to allow us to explore how varying cab design would impact driver behaviour in such interactions.

- Main Experiment 1 – VRU Interaction
- Main Experiment 2 – Adding a Distractor Task (adding an additional cognitive task to understand how this impacted reaction times and interactions with VRUs)

These experiments aimed to establish whether there is a safety benefit associated with seeing VRUs directly (through windows), as opposed to indirectly (through mirrors) when driving HGVs.

Glossary of Terms

The following terms and abbreviations are used within this document:

Term	Definition
Blind spot	Areas around an HGV which are neither directly nor indirectly visible by the driver
Cognitive Load	The total amount of mental effort being used in the working memory. How much pressure different tasks are placing on your brain to process?
Direct Vision	Viewing stimuli directly through windows.
Eye Contact	The state in which two people are aware of looking directly into one another's eyes – implies some form of connection.
HGV	Heavy Goods Vehicle
Indirect Vision	Viewing stimuli indirectly through mirrors or cameras1.
Low Entry Cab	Lowered driving position in relation to a traditional cab. Potentially has remodelled pillars and glass near-side door panel.
PACLab	Perception-Action-Cognition Laboratory research group
Salience	The state or condition of being prominent. In this context being clearly visible to a driver.
Traditional Cab	‘Brick shape’ cab, placing drivers 2.5m above the ground on average (Summerskill et al., 2015)
VDU	Visual Display Units
VRU	Vulnerable Road User

1 Introduction

London is growing. Population increases and lifestyle changes bring an ever increasing demand for goods, services, and new developments which are typically satisfied by road borne freight movements. Simultaneously, more people living and working in the city is placing greater pressure on stretched transport networks.

Whilst the popularity of cycling, and physical growth of London are both positive trends, an unfortunate consequence is the need to mitigate the potential risk of collision between goods vehicles and Vulnerable Roads Users (VRUs). In 2013 alone, 5123 VRUs were killed or seriously injured on Europe’s roads in collisions involving HGVs. It is important to monitor both the true risk and the public’s perception of risk. Any belief that VRUs are exposed to greater risk can be a barrier to increases in sustainable travel behaviour.

Studies such as this TfL commissioned research inform the debate to help create a climate where perceived barriers to cycling and walking are removed and subsequently promote urban realm and environmental benefits. Transport for London (TfL) have worked hard to mitigate Work Related Road Risk (WRRR) and have been extremely successful in engaging with stakeholders at all levels across policy maker, developer, vehicle operator and vehicle manufacturing communities. However, with the numbers of serious collisions as high as they are, it is clear that further steps are needed to significantly reduce the frequency and severity of incidents on roads in London and across Europe.

One promising avenue of research is vehicle re-design. The majority of HGVs are designed to maximise the load space that can be achieved within the legally permitted maximum dimensions. This means that the ‘brick’ shaped cab is seen widely across the European Union (EU). Optimised for trunk road operations, when employed in congested urban environments where there are greater numbers of VRUs and road users typically share the highway in closer proximity there are potentially negatives to this ‘traditional’ cab shape. These include lack of driver direct vision of VRUs at the front and side of the cab – resulting from drivers sitting high up from the road, and side-doors being opaque, thus resulting in a reliance on mirrors. Research suggests that the current dimensions of cabs contributes to the significant number of serious injuries and fatalities experienced by VRUs (Woolsgrove, 2014).

We have been unable to locate any published empirical research directly addressing the question of HGV design in a dynamic setting and its impact on collision rates. Specifically, we explored potential benefits of seeing vulnerable road users directly (through a window) as opposed to indirectly i.e. through mirrors or camera systems. Given the number of VRUs killed or seriously injured by HGV related collisions, this represents a significant gap in scientific and industry led research.

The aim of this TfL Commissioned Project is to deliver evidence that addresses this research gap and provides clarity around the implications of mandating direct vision. This evidence is required by the European Commission before they consider future regulatory changes to the design of HGV cabs.

The key research questions identified to provide such evidence are noted below (see Appendix 1 for more detail).

Are reaction times, hazard detection, and driving accuracy impacted by:

1. Direct vision
2. Spatial location of visual information
3. Driver height proximity to the road / road users
4. Cognitive load
5. Direct eye-contact
6. Feelings of empathy (through direct eye-contact)

2 Summary of Findings

The laboratory experiment findings are summarised below. For more detail and an interpretation of these findings, please refer to Section 6.3.

A highly salient stimuli (i.e. a blue dot) led to considerably faster reaction times (RTs) than a less salient stimuli (i.e. a grey dot).

Reaction times did not differ significantly when viewing stimuli directly through windows vs. indirectly through mirrors when stationary.

Visual Searches While Stationary

Viewing a pedestrian directly resulted in reaction times that were approximately 0.7 seconds quicker than indirect viewing (resulting in 4.7m extra travel prior to breaking when navigating at a speed of 15mph)

Reaction times to stimuli seen through mirrors were slower when driving as opposed to when stationary.

Reaction times to stimuli seen through windows were faster when driving as opposed to when stationary.

Participants responded more slowly to stimuli appearing in their mirrors, as opposed to those appearing through the windscreen.

Visual Searches Whilst Navigating

VRU Interaction

When navigating in a traditional cab, 27% of drivers tested collided with at least one pedestiran, compared to 3% of those driving a low-entry cab - a 23% difference.

Collisions with VRUs dropped by 40% when seen directly through the windscreen (low entry HGV), compared to when seen indirectly through Class VI mirror (driving a traditional HGV), even when carrying out the distractor task.

This aligns with reaction time results: Participants took double the response time to detect stimuli presented in the Class VI mirror as opposed to stimuli presented on the front windscreen.

Viewing cyclists passing on the inside of the vehicle directly (through the side window in the low entry cab) did not result in fewer collisions than when viewing them indirectly (through mirrors in the traditional cab).

3 Overarching Approach

3.1 Project Team

The team delivering this project was selected so as to combine a range of specialist skills to ensure that the approach adopted produces suitably compelling and comprehensive results. This team comprised of:

- Academics
- Business Psychology Consultants
- Logistics Consultants with operational backgrounds

The collaboration between academia and consultancy facilitates the practical application of rigorous academic research expertise that contribute to real-world impact. Notably, the team includes Dr Richard Wilkie and Dr Callum Mole from the Perception-Action-Cognition (PACLab) research group in the School of Psychology, University of Leeds. Combined they have over 20 years' experience actively researching human perceptual-motor control and have published >30 articles in the top journals in the field.

3.2 Project Phases

This project entailed three key phases which, combined:

- Improve our understanding of visual processing of information in a driving context
- Establish the extent to which increased direct vision could reduce driver reaction times
- Establish the extent to which driving performance in direct/indirect vision situations is impacted by cognitive load

These phases are outlined below and each influenced the design and delivery of the subsequent stages.

1. Literature Review

A literature review was vital to understand the existing research that had previously been conducted in-line with the key research questions for our project.

It was important that the design of our study was:

i. Informed by existing academic research;

ii. Filling a gap in existing research.

2. Survey

Based on the findings from the literature review, we conducted surveys with:

i. HGV drivers

ii. Pedestrians

iii. Cyclists

This was important to understand driver and VRU attitudes, opinions and experience of the benefits of increased direct vision upon road safety.

3. **Laboratory Experiments**

A series of laboratory experiments were informed based on the literature review and survey findings. The aims and methodology for these experiments were informed by past research approaches, identified gaps in the current literature and our analysis of survey responses.

4 Literature Review

4.1 Literature Review Methodology

Search Strategy

Our search strategy was based on the key research questions for the project (see Appendix 1).

Based on these questions we identified key-words to automate our literature scanning activities and ensure our search strategy captured all relevant and meaningful evidence.

We established major and minor search terms for each research question (see example in Table 1).

Table 1 Search terms utilised to explore Research Question 1.

Research Question	Major Terms	Minor Search Term
Does direct vision improve: (i) reaction times (ii) hazard detection, iii) driving accuracy	'Direct Vision'	'Driving'
	'Indirect Vision'	'Response'
	'Mirror Use'	'Accurate Response'
	'Windows'	'Reaction'
		'Fast'
		'Accurate'
		'Accuracy'
		'Hazard'
		'Hazard detection'
		'Detection'
		'Errors'

These search terms were applied to three academic and scientific databases:

- EBSCO
- Web of Science
- Dialog

Table 2 demonstrates the number of 'hits' generated for example search terms entered into each of the databases. This provides an insight into the quantity of existing literature in each areas explored by this study.

The variation between searches was drastic with the most hits received for a search (3,020 x hits) equating to more than a thousand times the lowest number of hits received (3 x hits). This variation helped identify the areas where our research can most usefully address gaps in the existing body of knowledge.

Our review showed that hits generated are not always relevant, e.g. 'Mirror use AND driving' generated articles with no relevance to the current research, including:

- 'Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements?'

- 'Alzheimer's disease and driving: prediction and assessment of driving performance'
- 'The neural origins and implications of imitation, mirror neurons and tool use'

Table 2. An example of the number of 'hits' generated by example search terms.

Research Question	Search Term	EBSCO	Web of science	Dialog
Does direct vision improve: (i) reaction times (ii) hazard detection, iii) driving accuracy?	Direct vision AND driving	0	1	1
	Direct vision AND hazard detect*	0	0	0
	Indirect vision AND driving	4	1	12
	Mirror use AND driving	0	12	2
Does spatial location of visual information impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?	Spatial location AND hazard detect*	0	0	0
	Spatial location AND driving	0	2	0
Does driver height proximity to the road / road users impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?	Driver eye height AND hazard detect*	0	0	0
	Eye height AND driving	1	0	1
Does visual cognitive overload impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?	Cognitive load AND driving	15	14	29
Does direct eye-contact impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?	Eye-contact AND driving	0	0	0
Does direct eye-contact create feelings of empathy?	Eye-contact AND empathy AND driving	0	0	0

Note. Using an asterisk following 'detect' allowed the search engine to identify literature including the word 'detect', 'detection', 'detected'.

A detailed summary of the literature reviewed follows in the subsequent section of this report.

4.2 Literature Review Key Findings

The scientific research explored in this literature review is summarised below:

- Fact: HGV drivers heavily rely on mirrors to overcome the restricted direct visual field of the cab.
- Findings: Previous reports and academic investigation suggest a number of risks

Mirrors can distort reflected objects

Reflected objects tend to be overlooked in comparison to direct objects

Recognition rates are compromised towards mirror edges

Mirrors may be set up incorrectly, impairing areas covered

View can be influenced by elements such as rain and dirt

to relying on mirrors for safe driving, including:

- Fact: Visual Display Units (VDUs) are being introduced, aiming to extend HGV drivers visual field and aid their decision making.
- Findings: Research suggests a number of risks related to glancing at VDUs when

Increased periods of off-road glances

Drivers take longer to acquire critical information when returning their gaze to the road

Image resolution sensitive to environmental conditions

Limited resolution and colour range, minimal time-delay.

driving, including:

- Findings: Existing academic research suggests that indirect vision through the use of mirrors, and VDUs increases cognitive load, through:
- Findings: Evidence shows that processing indirect visual information can result in

Reduced hazard detection

Abrupt steering wheel movements

Impaired lane-keeping

Requiring off-road glances

Processing additional visual information

Processing the spatial location of the visual information received impaired driver performance:

- Fact: VDUs require drivers to interpret where a vulnerable road user appearing on a screen is in location to their vehicle, and manoeuvre appropriately based on this irritation.
- Findings: Though research is lacking into the impact of spatial location of visual information on driver decision making, existing findings in other contexts suggests that:

Thorough (re)training is required to familiarise drivers with using devices presenting visual information from a different location

Drivers may differ in their adaptation to using such display units

Processing such information requires further cognitive processing than direct visual information, which may impair decision making speeds

- Fact: Traditional HGV cabs place drivers 2.5m above the ground on average (Summerskill et al., 2015).
- Findings: Past research suggests that lower driver eye-height, in low entry cabs:

Increases perception of VRUs in close proximity to the vehicle

Provides drivers with a larger field of view - increasing hazard detection

4.3 Literature Review Detailed Findings

Our literature review instructed the final design of laboratory experiments and also contain findings that may justify further research. Points of interest were noted but not pursued as part of this research. Yet these could, if investigated further, provide data and understanding to support the development of an optimum future HGV design.

4.3.1 Direct and Indirect Vision

Direct and Indirect Vision Defined

Drivers look to a number of locations around the cab to maintain awareness of their surroundings and gain sufficient visual information to safely carry out driving manoeuvers. In the case of HGVs specifically, drivers have a limited direct visual field due to the design and location of the cab in which the driver sits in relation to the road and the rest of the vehicle. This in turn can keep VRUs out of the driver’s direct visual field (Cook, Summerskill, Marhall, Richardson, Lawton, et al., 2011).

Windscreens and mirrors do not provide a complete view of the entire area surrounding the vehicle, creating blind spots, particularly in the case of HGVs (Cook et al., 2011). When considering such fields of view, academic literature differentiates between direct and indirect vision as:

Direct Vision

Analysis of HGV driver behaviour has revealed numerous points of driver error, the majority of which are associated with visual awareness (i.e. cyclists are difficult to identify, and even if a driver registers certain visual indicators, they may not recognise these as being a cyclist) (Delmonte, Manning, Helman, Basacik, Scoons et al., 2012). Based upon these findings, a logical assumption is that a larger visual field – provided either directly through windows, or indirectly through the addition of mirrors and VDUs, will provide more opportunity for drivers to detect, recognise and manoeuvre safely around VRUs. The longer an object is in a driver's visual field the better chance they have of accurately processing the visual information.

However, evidence discussed in the next section suggests that reliance on indirect vision presents risks such as the presence of blind spots, and the increased visual and cognitive load of processing this information.

Indirect Vision through Mirrors

Although mirrors are necessary driving aids that undoubtedly increase a driver's visual field, there are a number of safety issues regarding their use and effectiveness:

- UK research has found that the line of vision capturing cyclists to the left and front of the HGV (when turning left) can be poor even when mirrors reaching the legal standard are used (Delmonte et al., 2012).
- Research shows that correct detection of an object (car, cyclist, child pedestrian or bin bag) and recognition rates are compromised towards mirror edges (Cook et al., 2011).
    - However - 90% of objects were recognised in this experiment, demonstrating that a full view of a mirror is useful in providing indirect vision of the prescribed areas (Note. This study included Class IV, V and VI mirrors).
- Mirrors may be set up incorrectly and as a result reduce the potential area of coverage, which may mask VRUs from the drivers' field of view (Cook et al., 2011). This highlights the importance of training in mirror set-up and checking.
- Factors such as rain, dirt on the mirror, and attention to other visual tasks (such as navigating using a Sat Nav) can impact processing of visual information displayed in a mirror (Cook et al., 2011).

Additional research outside of driving has shown that:

- Mirrors can distort images, and reflected objects tend to be overlooked relative to non-reflected objects (Sareen et al., 2015).
    - For instance, in photographs of real-world scenes, changes made to objects reflected in mirrors were detected more slowly and less accurately, than those objects that were in the main body of the image.
- Implications for driving and HGVs can be inferred from this – with objects reflected in mirrors being perceived differently from those viewed directly.

Summary

HGV drivers currently heavily rely on mirrors to overcome the restricted direct visual field of the cab. Previous reports and academic investigation suggest a number of risks to relying on mirrors for safe driving, including:

- Recognition rates are compromised towards mirror edges
- Mirrors may be set up incorrectly, impairing areas covered
- Mirrors can distort reflected objects
- Reflected objects tend to be overlooked in comparison to direct objects
- View can be influenced by elements such as rain and dirt

It is worth considering that in contrast, direct vision is only compromised by the last of these considerations – poor visibility caused by the elements, dirt or similar.

Indirect vision through VDUs

HGV drivers also rely on in-vehicle display units (VDUs) to provide visual information and overcome limited direct vision. However as with mirrors, risks are associated with using these devices:

- Driving performance is compromised by increasing periods of off-road glances (Borowski et al., 2014).
- When engaging with in-vehicle tasks (such as looking at a VDU), drivers take longer to acquire critical information when they return their gaze to the road (Borowski et al., 2014; Lee & Boyle., 2007).
- The resolution of camera images is sensitive to environmental conditions. For example, the image resolution of rear-view cameras is highly vulnerable to shade, making hazards less noticeable (Kidd et al., 2016).

When considering these findings, the inclination to keep adding more visual information sources to HGVs to increase the field of vision is exacerbating, not solving the problem. In contrast, direct vision is compromised by none of these considerations.

Summary

VDUs are being introduced, aiming to extend HGV drivers visual field and aid their decision making. However, the existing research suggests a number of risks related to glancing at VDUs when driving, including:

- **Increasing periods of off-road glances.**
- **Drivers take longer to acquire critical information when returning their gaze to the road.**
- **Resolution sensitive to environmental conditions.**

Note: This literature review excludes marketing research published by companies who manufacture VDUs. The review focused only on published scientific research.

Comparison of Mirrors and VDUs

Based on the findings above, it is interesting to compare and contrast the properties of mirrors and VDUs, and consider how these might influence driver identification of hazards.

Table 3. Comparison of mirror and VDU properties (adapted from Schmidt, Hoffmann, Krautscheid, Bierbach, Frey, et al., 2015).

	Mirror	VDU
Field of vision	• The law of reflection applies to mirrors. • A convex curved mirror provides the viewer with a reduced image of the object. • Mirrors can be adjusted to adapt to the users need.	• A camera records a specified field of vision which is displayed on the monitor. • Moving one's head does not alter the field of vision (though settings can be changed).
Light	• Light on the mirror, e.g. sunlight or light from other vehicles can result in glare for the driver.	• Direct light on the camera can result in artifacts – depending on the quality of the camera. • Direct light on the monitor can cause glare for the driver.
Colour	• Mirrors reflect colours well.	• The colour range of a VDU is limited.
Resolution	• The resolution of mirrors is higher than the resolution of the human eye.	• The resolution of VDUs is limited and depends on the product quality.
Time	• Mirror image changes are reflected in real-time.	• Camera image changes are depicted with a minimal time-delay. • Risk of further delay if connections are damaged.
Obscurities	• The degree of reflection can be affected by dirt, condensation, scratches, cracks or rain drops. • Further, viewing the externally mounted mirror can be affected by the above elements on the side window.	• The camera image can be affected by dirt, condensation, scratches or rain drops. • Viewing the internally mounted monitor is not affected by these elements.

What impact do such differing properties have on driver performance?

Schmidt, Hoffmann, Krautscheid, Bierbach, Frey et al. (2015) explored this, concluding that:

- Drivers perceive stationary objects as being further away when viewed in mirrors, and closer when using a VDU.
- The ability to recognise distant objects was found to decline when using VDUs as opposed to mirrors, as images of objects appeared smaller on the monitor than in the mirror.
- Drivers perceive objects to be moving more slowly when using exterior mirrors than VDUs.
- Glance duration at indirect visual information was shorter for a VDU monitor located at the height of the door panel – below the side window, and thus outside of the direct field of view*.

Schmidt et al. (2015) conclude that the overestimation of speed and the underestimation of distance when using the VDU seem to have a positive effect on road safety. For instance, when using VDUs, drivers overestimate the speed at which a car is moving, and underestimate the distance of this from their vehicle. As a result of this, larger gaps for lane changing were chosen – suggesting an (unintentional) positive effect on road safety.

* Note: The authors suggest that short glances at displays located outside of the direct field of view result from drivers being required to avert their eyes from the direct visual field which feels unsafe.

4.3.2 The Influence of Cognitive Load on Driver Performance

Cognitive load is an important avenue to explore in relation to safe HGV driving. Drivers are not only required to monitor the direct and indirect visual information available to them. They might also need to: calculate the number of drops remaining on their route or the number of miles remaining to return to base, follow a Sat Nav through an unfamiliar location, or and answer hands free calls from the office.

Academic research published in this space reveals that:

- Driving itself is a complex visual and cognitive task requiring attention to the control of the vehicle, the internal visual displays of the cab, and to the potential hazards that may occur in the external environment (MacKenzie & Harris, 2015; Stinchcombe & Gagnon, 2010).
- An increase in cognitive demand slows reactions to safety relevant information - including traffic light changes from green to amber (Fort et al., 2010).
- The multitasking required for HGV operation, including reading directions and signage, navigating road works and reading traffic signals exceeds that of human perceptual abilities (Road Safety & Transport Agency)

The below literature specifically explores the impact of cognitive demand on error detection and driver performance.

The Influence of Indirect Vision on Cognitive Load

Engstrom, Johansson and Ostlund (2005) collected data in a range of simulators and in a vehicle in real traffic. When responding to tasks on VDUs, involving identification of an 'up' facing arrow amongst 'sideways' facing arrows:

- Driver speed reduced.
- Following glances away from the road, driving position was corrected by 'abrupt and relatively large steering wheel movements'.
- Driver activation levels increased (skin conductance and heart rate).
- Drivers reported their driving performance to be worse.

This study clearly identifies the negative impact of off-road glances on driver performance.

Further findings include:

- When a driving simulator blanks out the driving scene for 1 second (similar to an in-vehicle glance away from the road), detection of changes to the speed of other vehicles is significantly reduced (Lee & Boyle, 2007).
- Driver's lane-keeping performance and reaction time to lane change signals significantly decreased when having to identify a specific arrow against other stimuli on a VDU (Wilschut, Rinkenauer, Brookhuis & Falkenstein, 2008).
- A visual search task involving target arrow identification on a 7-inch LCD touch screen whilst driving at 72km/h resulted in abrupt control movements, inconsistency of lane position and increased reaction time to braking of neighbouring vehicles (these variables were also associated with length and frequency of off-road glances) (Liang & Lee, 2010).

It might be argued that 'head-up' VDUs, located in-line with the drivers line of vision, reducing the number and duration of off-road glances, might minimise the impacts of indirect vision sources on driver performance. Liu and Wen (2004) explored this, concluding:

- 'Head up' (HUD) and 'head down' (HDD) display types showed no difference in average accuracy rate of on-screen task completion – showing that information can successfully be assimilated using either display.
- No major differences emerged between the use of the HUD and HDD on speed maintenance.
- Braking in response to an urgent event was significantly faster with the head-up as opposed to a head-down display – suggesting the location of a VDU impacts hazard detection.

The literature discussed suggests that the off-road glances required to use multiple mirrors and VDUs add to the cognitive load of drivers. This may have implications for their driving performance, as drivers need to sufficiently scan and process all relevant visual information. Such findings suggest that minimising additional visual demands is an important countermeasure. This reinforces the need to undertake the current study, and examine the influence of visual and cognitive load of HGV drivers in an experimental setting.

Previously suggested solutions include changes to the visual layout of HGV cabs such as a larger windscreen, lower driver position, improved mirror design and introduction of VDUs (Delmonte et al., 2012; Woolsgrove, 2014). However, having reviewed the existing literature, it is clear that it is important to ensure that such modifications do not:

- Mean that the driver needs to remove their eyes from the road.
- Add to the cognitive load that the driver is required to process.

Summary

The existing academic research suggests that indirect vision through the use of mirrors, and VDUs increases cognitive load, through:

- **Requiring off-road glances.**
- **Requiring processing of additional visual information.**

Consequently, processing indirect visual information has been found to result in impaired driver performance:

- **Reduced hazard detection.**
- **Abrupt steering wheel movements.**
- **Impaired lane-keeping.**

4.3.3 The Influence of Spatial Location of Visual Information on Decision Making

With the increase in use of VDUs, it is important to consider how the processing of visual information presented in a different location from its origin might be processed by a driver.

In any visually guided behaviour, it must be clear to the operational individual how the visual location of an object is linked to the physical location of the object (Cunningham, Chatziastros, von der Heyde & Bulthoff, 2001). Research has explored the influence of altering where it looks like an object is (the visually perceived location), so that it appears to be somewhere different from its actual location. Research concludes that accurately reaching out to an object in such conditions is impaired, but that individuals quickly adapt to the new visuo-motor relationship, learning from feedback (Welch, 1978).

It is interesting to consider the impact of receiving indirect visual information through the use of a camera system, where co-ordination of actions (e.g. steering) is not clearly associated with distances and locations of objects surrounding the vehicle.

Many studies have been published examining minimally invasive surgery (MIS), where a visual display unit (VDU) is the only visual interface between the surgeon and the operative field, and the natural relationship between hand and eye is disrupted (White et al, 2013). It has been observed that movements are smoother and quicker when the VDU is aligned with the operative tool, compared to when it is positioned in an offset position (White et al., 2016).

Haluck, Webster, Snyder, Melkonia, Mohler et al. (2001) stress that MIS requires different visuospatial skills and greater cognitive processing demands than open surgery (where a surgeon can directly see the site of the operation). Research in this field concludes that the effective operation of such tools relies on spatial abilities of experts requiring thorough training (Tendick et al., 2000), with Elliot (1987) concluding that large individual differences exist in spatial abilities. This research suggests that some HGV drivers may adapt to using VDUs more readily than others.

Such research is in-line with recent conclusions made by Schmit, Hoffmann, Krautscheid, Bierbach, Frey et al. (2015), who found that drivers stressed a preference for displaying visual information about the left side of the vehicle on the left-hand side of the cab, and vice-versa for information about the right side.

Summary

Though research is lacking into the impact of spatial location of visual information on driver decision making, existing findings in other contexts suggest that:

1. **Thorough (re)training is required to familiarise drivers with using devices presenting visual information from a different location.**
2. **Drivers may differ in their adaptation to using VDUs.**
3. **Processing such information requires further cognitive processing than direct visual information, which may impair decision making speeds.**

4.3.4 The Influence of Driver Eye-Height on Hazard Detection and Decision Making

Traditional HGV cabs place drivers 2.5m above the ground on average (Summerskill et al., 2015). Detailed research by Summerskill et al. (2015) on behalf of Transport for London (TfL) has explored many aspects of HGV design including the impact of driver eye-height on detection of VRUs in the vicinity of HGVs. The authors conclude that the height of the cab above the ground is the key vehicle factor which affects the breadth of direct vision, indirect vision and blind spots, influencing the ability of the driver to view VRUs that are in close proximity to the vehicle.

Specifically, the research found that:

- The higher the cab is above the ground, and the higher the driver's eye height, the further the distance from the cab that the cyclist and pedestrian can be located and still hidden from the drivers view.

These findings are demonstrated in Figure 1 – highlighting the blind spot in front of the vehicle, where pedestrians can be between 0.7m and 1.2m in front of the vehicle without being directly or indirectly visible to the driver.

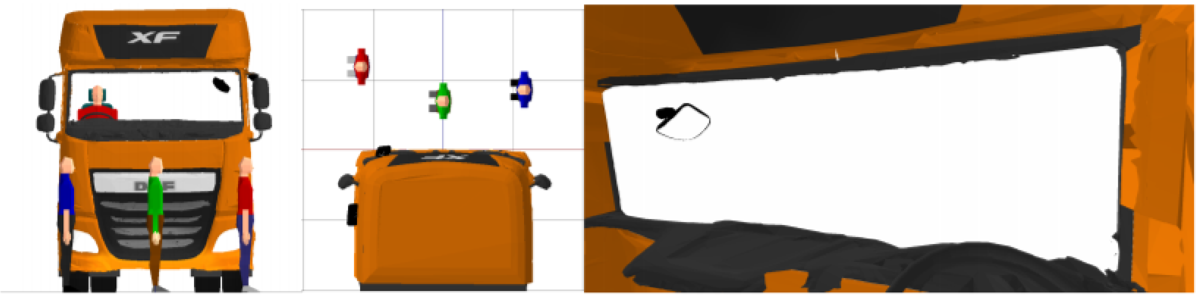


Figure 1. Pedestrians not directly visible to a driver in an average sized HGV (Summerskill et al., 2015).

Further, Figure 2 demonstrates the number and location of cyclists that can be placed around an average sized HGV cab without being seen directly through the driver’s windows.

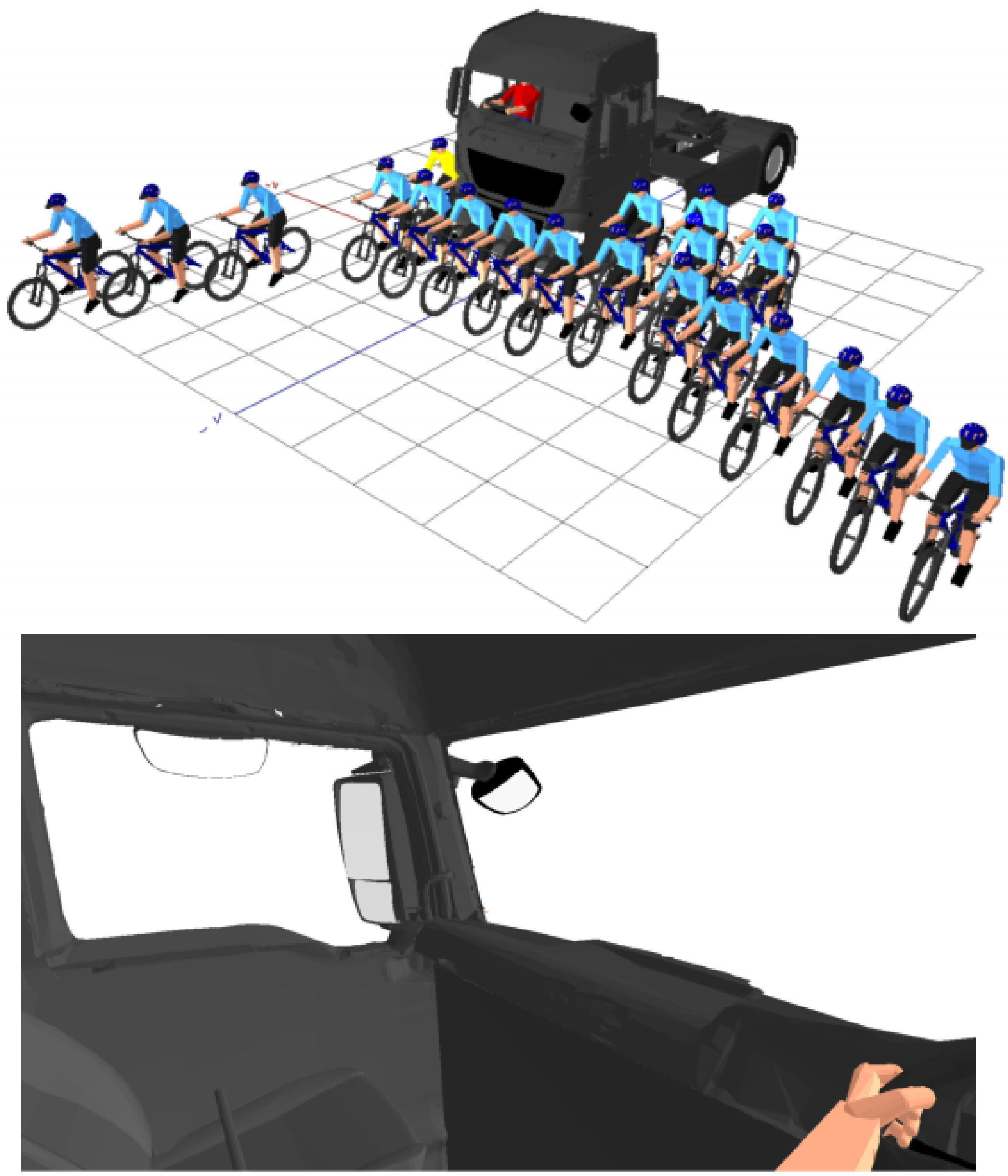


Figure 2. Cyclists not directly visible to a driver in an average sized HGV (Summerskill et al., 2015).

As would be expected, research has found that providing drivers with a wider field of view containing hazardous environmental cues, increases hazard detection (Sahar et al., 2010). Allowing drivers to have a wider visual field, as influenced by eye height makes intuitive sense with regards to hazard perception.

Summary

Research explored suggests that lower driver eye-height increases perception of VRUs in close proximity to the vehicle. Providing drivers with a larger field of view increases hazard detection, thus having the potential to reduce the number of incidents.

4.3.5 The Influence of Direct Eye-Contact on Decision Making and Hazard Perception

This project also considered the impact of direct eye-contact on decision making and hazard detection. The literature review revealed ambiguity around the benefits of eye contact between drivers and road users.

Research has stressed the importance of VRUs such as cyclists and pedestrians retaining their human appearance on the road (Walker & Brosnan, 2007).

This is because eye-tracking technology has revealed that when a cyclist appears in the line of view of a driver, attention is naturally directed straight to the cyclist's face (Walker & Brosnan, 2007). This outcome is more pronounced when a cyclist makes direct eye contact with the driver, and researchers suggest that this is because encountering a cyclist is inherently a social interaction.

However Walker (2005) concludes that:

- Cyclists' arm signals were perceived more rapidly by drivers than informal facial signals (a glance).
- Overall, arm signals and informal glances slowed down decision-making processes in comparison to no signal.
- These effects are the result of the communicative nature of both arm signals and eye-contact, eliciting extra stages of involuntary cognitive processing, and slowing driver's reactions.

Contrasting findings show that eye-contact between pedestrians and drivers can have positive implications for driving behaviour. Research has examined the impact of eye contact on driver behaviour, and found that:

- Pedestrians who stared at oncoming drivers as opposed to looking over their heads, found a significant increase in the number of drivers who stopped at a crossing (Gueguen et al., 2015).
- When pedestrians made eye-contact with the oncoming driver about 68% of drivers stopped, whereas without eye-contact 55% stopped (Gueguen et al., 2015).
- Pedestrian's smiling at oncoming drivers resulted in an increased the number of vehicle stops at crossings (Gueguen et al., 2016).

This research suggests that eye contact can have a substantial effect on social encounters resulting in stronger influences on behaviour.

Summary

Research concludes that drivers' attention is inherently drawn towards VRUs faces. However, conflicting findings currently exist regarding whether this natural social interaction enhances safe driving behaviour, or instead delays reaction times, thus compromising safety.

4.4 Literature Review Conclusions

Table 4 shows a high level summary of the research discussed in this report - highlighting the research in support of, and conflicting, the summarised findings.

Table 4. Summary of literature review findings.

Finding	Research Supporting	Research Against
VDUs impair driving performance through: • **Increasing number of off-road glances** • **Acting as a distraction** • **Increasing cognitive load**	Borowski et al., 2015 Engstrom et al.,2005 Fort et al., 2010 Kidd et al., 2015 Lee et al., 2007 Liang & Lee, 2010 Liu & Wen et al., 2004 McKenzie & Harris, 2015 Recarte & Nunes, 2003 Stinchcombe, 2010 Wilschut et al., 2008 Woolsgrove, 2014	Schmidt et al., 2015 • Positive impact on road safety as drivers overestimate speed through VDUs, and underestimate distance from vehicle. Cook et al., 2011 • VUDs increase the volume of space visible to the driver
Mirrors impair driving performance through: • **Distortion of reflected images** • **Increasing cognitive load**	De vos, 2001 Cook et al., 2011 Delmonte et al. 2011 Road Safety Transport Agency Sareen et al., 2010 Summerskill et al., 2015 Woolsgrove, 2014	Cook et al., 2011 • Mirrors increase the volume of space visible to the driver
Disconnected spatial location of visual information: • **Increases cognitive load** • **Slows decision making speed**	Haluck, 2001 Tendick et al., 2001	Welch, 1978 • Individuals quickly adapt to new visuo-motor relationships
Lower driver eye height from the road increases: • **Hazard detection** • **View of VRUs close to vehicle**	Summerskil et al., 2014 Summerskill et al., 2015 Sahar et al., 2010	
Eye contact between HGV drivers and VDUs increases safe driving behaviours	Walker & Brosnan, 2007 • Driver's attention naturally directed to VRUs' faces Gueguen et al., 2015 Gueguen et al., 2016	Walker, 2005 • Response to no cyclist signal was faster than to glances and arm signals

It must be noted that many papers acknowledge the utility of mirrors and VDUs while also outlining their potential negative impacts.

This review revealed numerous gaps in the literature regarding HGVs and safe driving behaviours. Key areas warranting further research include:

Comparisons of direct and indirect vision in relation to safe driving behaviours.

Examination of multiple mirrors and VDUs on cognitive load and performance.

Examination of the impact of spatial location of visual information, hazard detection and driver response.

The role of eye-contact between HGV drivers and VRUs on reaction times and safety behaviours.

5 Road User Survey

Three surveys were developed to explore perceptions of HGV drivers, cyclists and pedestrians in relation to the features of HGV design and eye contact. Survey content was informed by literature review findings and analysis survey results in turn influenced laboratory experiment design.

5.1 Survey Design

The survey was designed to build upon the key findings of the literature review, noted in Section 3. The survey spanned all research questions (see Appendix 1), and was designed to explore driver and VRU *perception and experience* of the importance of the elements being explored in this study.

See key questions which emerged from the literature review noted below:

5.2 Dissemination and Response

Surveys were disseminated in an online format (see Appendix 2) through contacts of Transport for London and Arup, as noted below:

- **HGV Drivers –** Fleet Operating Recognition Scheme (Website & eNewsletter); CLOCS (Bulletin).
- **Cyclists –** Arup Bike User Group, and broader contacts to ensure a diverse respondent group.

- **Pedestrians –** Circulated internally within TfL, Arup and more broadly to ensure a diverse respondent group.

Respondent numbers and demographics are noted below:

Table 5. Demographics of survey respondents.

Demographics		Drivers	Cyclists	Pedestrians
No. Respondents		117	129	104
Age	18-24 years	0%	5%	6%
	25-59 years	88%	93%	89%
	60+ years	12%	2%	5%
Gender	Male	98%	70%	55%
	Female	1%	30%	43%
Driving Licence	Yes	100%	91 %	94%
	No	0%	9%	6%

The sample broadly reflects cyclist & driver demographics:

- 67% of frequent cyclists are men; 19% of frequent cyclists are over 45*
- Less than 1% of HGV drivers are female; 1% of drivers are under 25; 16% of drivers are 60 or above**

**Analysis of Cycling Potential, London Travel Demand Survey 2005/06 to 2007/08; ** A Looming Driver Shortage? The Evidence Behind The Concerns, 2012.*

5.3 Survey Analysis

5.3.1 Quantitative Analysis

Quantitative survey questions were subject to a simple analysis, through calculating the percentage of each user group who agreed or disagreed with each statement.

A more detailed analysis was then undertaken to understand any group differences in responses. Differences between demographic groups were explored, as well as exploring whether cycling purpose or experience, and driver experience or industry sector they operate within impacted responses.

5.3.2 Qualitative Analysis

Qualitative responses were reviewed and grouped into categories based on the underlying theme of responses. These themes provided the framework for the analysis.

5.4 Survey Results

5.4.1 Cyclists and Pedestrians

The surveys revealed that cyclists and pedestrians hold largely consistent views regarding interactions with HGVs. Cyclists and pedestrians were assured of their anonymity, and only incentivised to take part in the study to contribute to research, thus it can be assumed that responses accurately reflect attitudes. Analysis revealed:

- The majority of cyclists and pedestrians surveyed **do not trust HGV drivers can see** them through their mirrors or VDUs.
- The majority agree that drivers who are **positioned lower to the ground can see them more easily** than those higher up.
- 86% of cyclists and 93% of pedestrians agree that drivers who have **larger windows and 'bus style' transparent doors can see them more easily** than those in cabs with solid doors.
- The majority of cyclists and pedestrians agree that being **able to make eye-contact** with HGV drivers makes them feel safer when passing a vehicle.

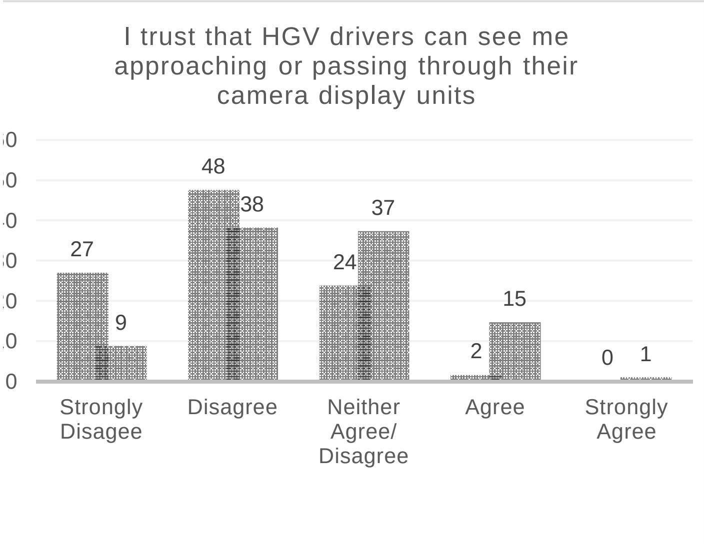
The next section describes the survey findings in detail.

Key for all graphs in this section:

- Cyclists
- Pedestrians

Direct Vision

The majority of cyclists (81%; 75%) and pedestrians (61%; 47%) surveyed do not trust that HGV drivers can see them through either their mirrors or their VDUs.



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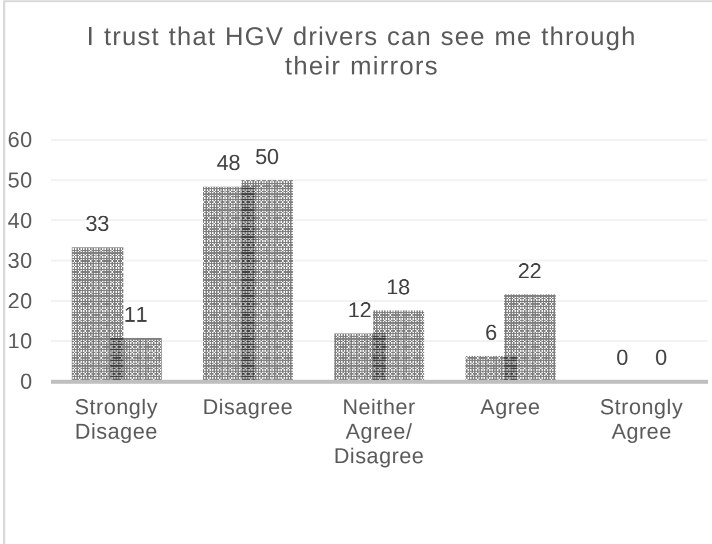


Figure 3. Percentage of cyclists and pedestrians who trust that HGV drivers can see them approaching or passing through their camera display units.

Figure 4. Percentage of cyclists and pedestrians who trust that HGV drivers can see them through their mirrors.

higher proportion of cyclists and pedestrians feel confident passing a vehicle when a driver can see them through their windows (67%), compared to 36%% when they are seen through mirrors.

Cab Design

The majority of cyclists and pedestrians agree that HGV drivers who are positioned closer to the road (lower) can see them more easily than those in higher cabs when they are positioned both in front (90%; 79%) and to the side (68%; 67%) of the vehicle. Further, 86% of cyclists and 93% of pedestrians agree that drivers who have larger windows and ‘bus-style’ transparent doors can see them more easily than those in cabs with solid doors.

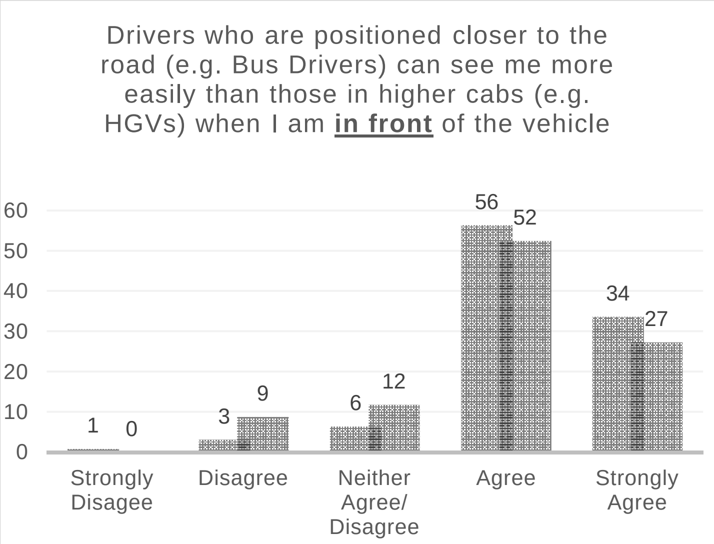


Figure 5. Percentage of cyclists and pedestrians who agree that drivers who are positioned closer to the road can see them more easily when they are in front of the vehicle.

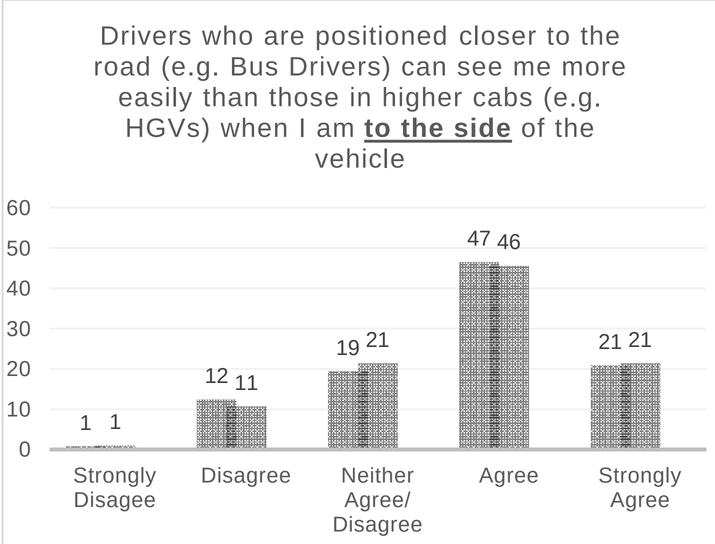


Figure 6. Percentage of cyclists and pedestrians who agree that drivers who are positioned closer to the road can see them more easily when they are to the side of the vehicle.

5.4.2 HGV Drivers

Cyclists and pedestrians were assured of their anonymity, and only incentivised to take part in the study to contribute to research, thus it can be assumed that responses accurately reflect attitudes

The survey revealed that the majority of drivers agree:

- **Mirrors provide sufficient view** of cyclists and pedestrians around the vehicle. However almost half felt that it is **sometimes difficult to recognise a cyclist** in a mirror.
- Most drivers perceive **more advantages than disadvantages** of VDU use.
- Majority **disagree that they are too high up** to locate road users.
- 41% of drivers agree that **increasing the size of windows** would support them to avoid collisions with vulnerable road users.
- Most drivers **try to make eye-contact** with road users and believe this reduces likelihood of collision.

Direct Vision: Mirrors

HGV driver's responses indicate that the majority of drivers believe that mirrors provide an adequate view of the area surrounding the vehicle. Responses suggest that there is less reliance on mirrors at the driver side of the vehicle as opposed to the passenger side, possibly because they can see directly at the driver side.

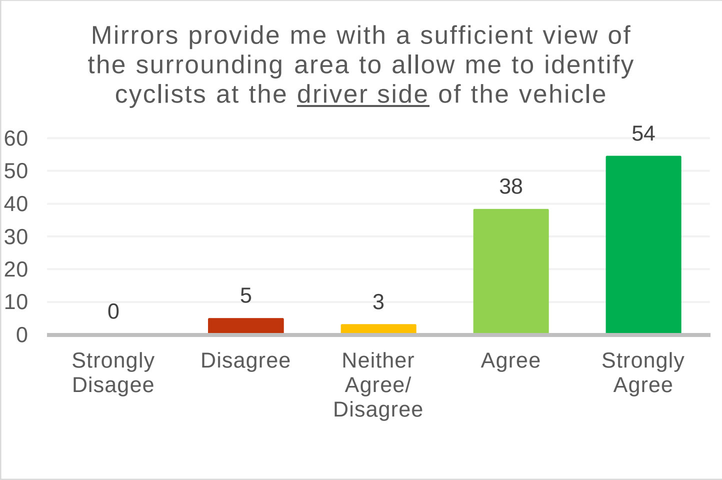


Figure 8. Percentage of HGV drivers who agree that mirrors provide them with a sufficient view of the surrounding area to allow them to identify cyclists at the driver side of the vehicle.

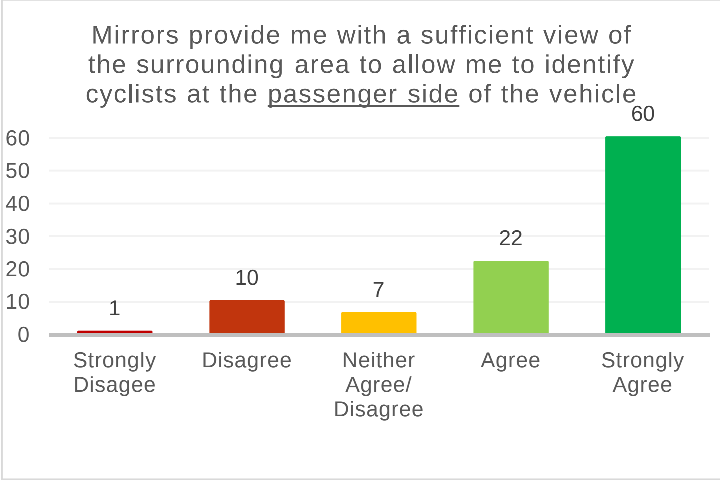


Figure 7. Percentage of HGV drivers who agree that mirrors provide them with a sufficient view of the surrounding area to allow them to identify cyclists at the passenger side of the vehicle.

HGV drivers report inconsistent views on the difficulty of recognising VRUs through their mirrors. Drivers surveyed disagree that mirrors slow down their response in comparison to direct vision. However, 39% of HGV drivers agreed to sometimes finding it difficult to recognise cyclists in mirrors while

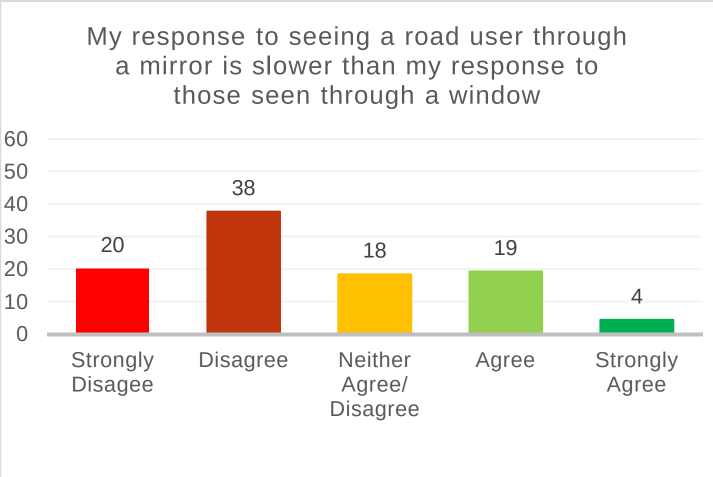


Figure 9. Percentage of HGV drivers who agree that their response to seeing a road user through a mirror is slower than their response to those seen through a window.

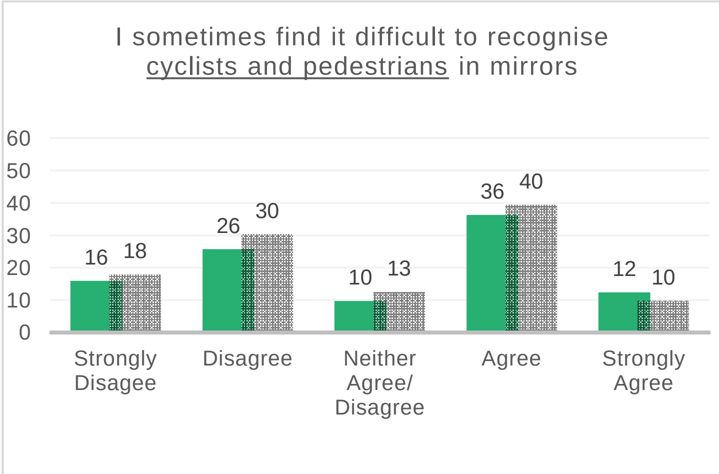


Figure 10. Percentage of HGV drivers who sometimes find it difficult to recognise cyclists and pedestrians in their mirrors.

48% disagreed with this statement.

This inconsistency might have emerged for a number of reasons. One interpretation is offered below:

- Drivers feel that *in general* they respond equally quickly to VRUs appearing in their mirrors and windows, yet when they think of *specific examples*, they are able to recall at least one instance of having difficulty recognising cyclists in their mirrors.

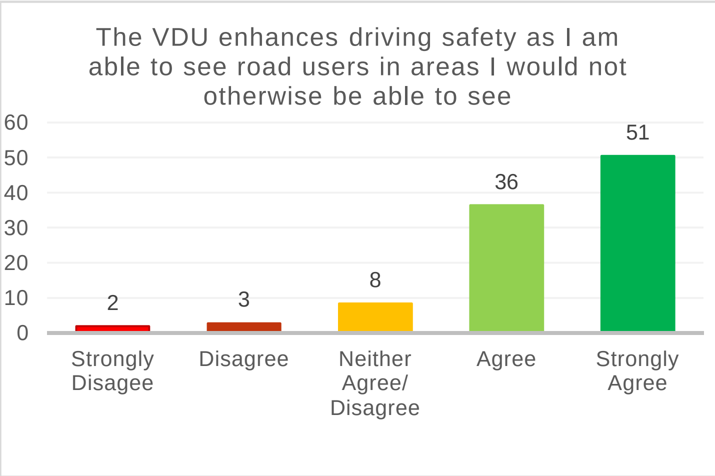
Direct Vision: Visual Display Units

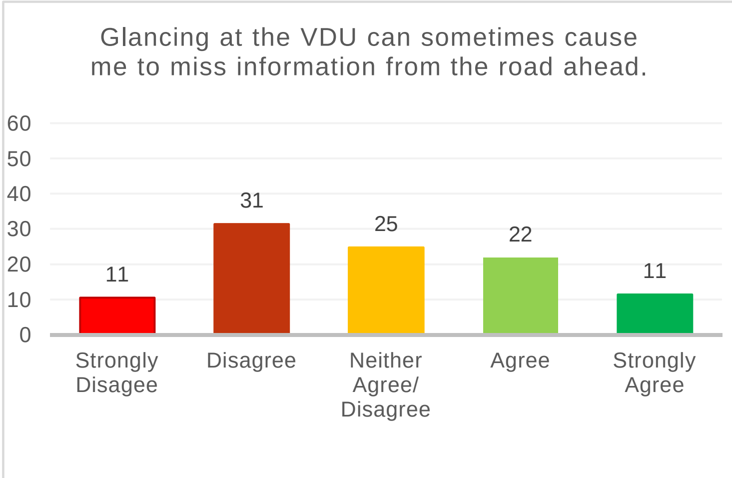
Responses indicate that majority of drivers feel that VDUs improve safe driving. Yet, 33% of drivers feel that looking at VDUs causes them to miss information from the road ahead.

The majority of drivers endorse VDUs and see more advantages than disadvantages to their use.

Figure 12. Percentage of HGV drivers who agree that VDUs enhance driving safety as they are able to see road users in areas they would not otherwise be able

Figure 11. Percentage of HGV drivers who agree that glancing at a VDU can sometimes cause them to miss information from the road ahead.

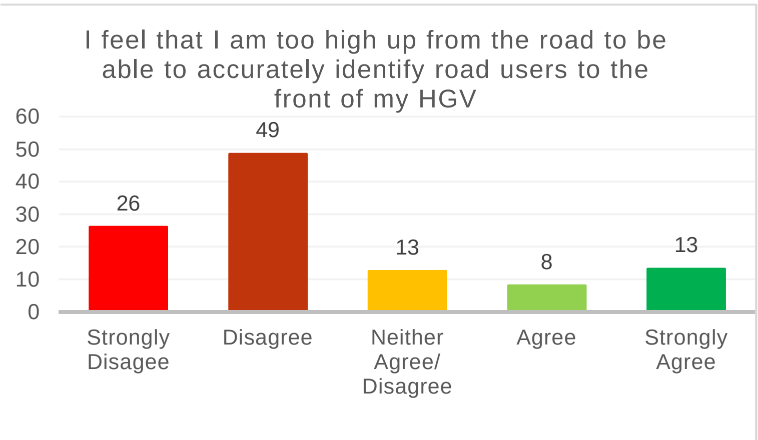




Cab Design

Drivers consistently feel that their height is no hindrance to identification of VRUs with 72% disagreeing that they are too high up to accurately identify road users to the front of the vehicle. The vast majority (78%) agree that they are easily able to make eye-contact from the cab.

Yet, responses are mixed, albeit broadly positive overall, regarding the introduction of larger windows.



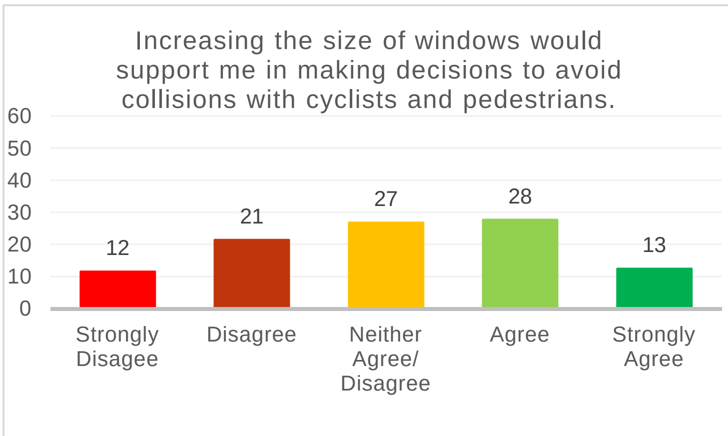


Figure 14. Percentage of HGVs who agree that increasing the size of windows would support them in making decisions to avoid collisions with cyclists and pedestrians.

Figure 13. Percentage of HGV drivers who agree that they are too high up from the road to be able to accurately identify road users to the front of their HGV.

Furthermore, it is interesting to consider that drivers indicated a preference for the safety features they are (arguably) most familiar with – i.e. blind spot cameras vs. bus style doors.

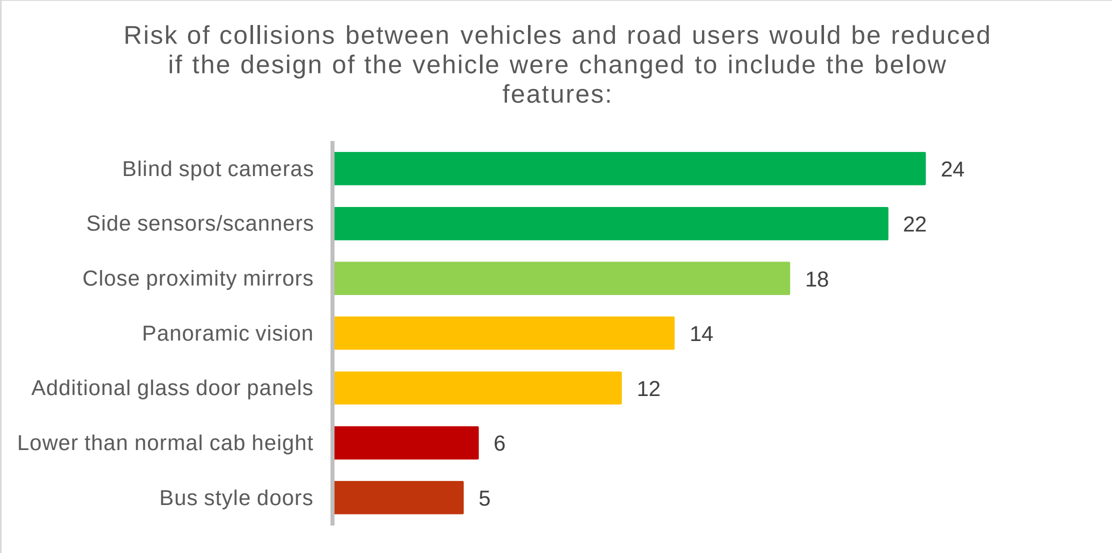


Figure 15. Percentage of HGV drivers who agree that the risk of collisions between vehicles and road users would be reduced if the design of the vehicle were changed to include additional features.

5.5 Survey Conclusions

There are clear concerns over driver safety if the design of HGV cabs were to be changed. These responses are interesting as drivers responded to a question concerning their ability to see with answers relating to their personal safety, suggesting an underlying concern.

Cyclists & pedestrians show a preference for lower cabs and larger windows while HGV drivers are satisfied with the current cab design and safety features. The below table captures the key similarities and differences derived from the survey.

Table 6. Summary of survey findings.

Feature	HGV Drivers	Cyclists	Pedestrians
Mirrors	Satisfied with current set up	Feel safer being seen directly	Feel safer being seen directly
Cab Height	Satisfied higher up	Feel safer when drivers are lower to the ground	Feel safer when drivers are lower to the ground
Windows	Mixed responses to increasing window size – majority against	Pro larger windows	Pro larger windows

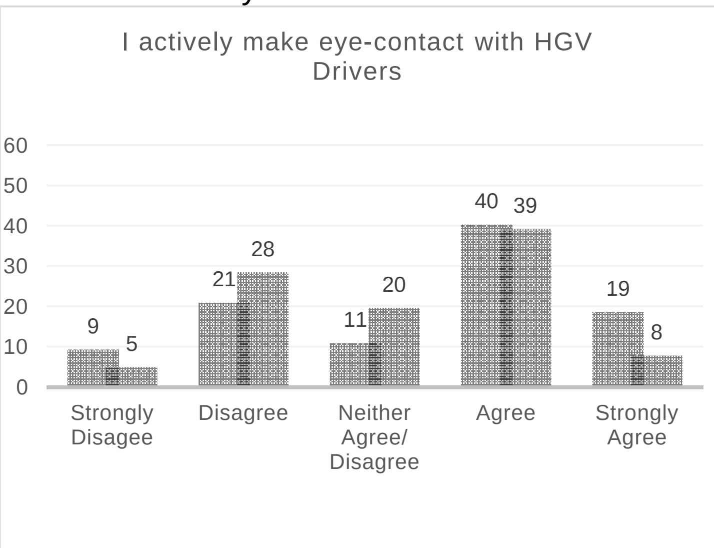
5.6 Eye Contact Specific Survey Results

The survey also considered the impact of direct eye-contact on decision making and hazard detection. The literature review revealed ambiguity around the benefits of eye contact between drivers and road users, and so the survey aimed to understand perceptions around the benefits of this.

Cyclists and Pedestrians

The majority of cyclists agreed it is important to make eye-contact with HGV drivers. 59% of cyclists and 47% of pedestrians agreed that they actively make eye-contact with HGV drivers, while 68% of cyclists and 71% of pedestrians agreed to feeling safer as a result of making eye contact.

Interestingly, Only 13% of cyclists and 3% of pedestrians agree that they are able to make eye-contact with HGV drivers through their mirrors.



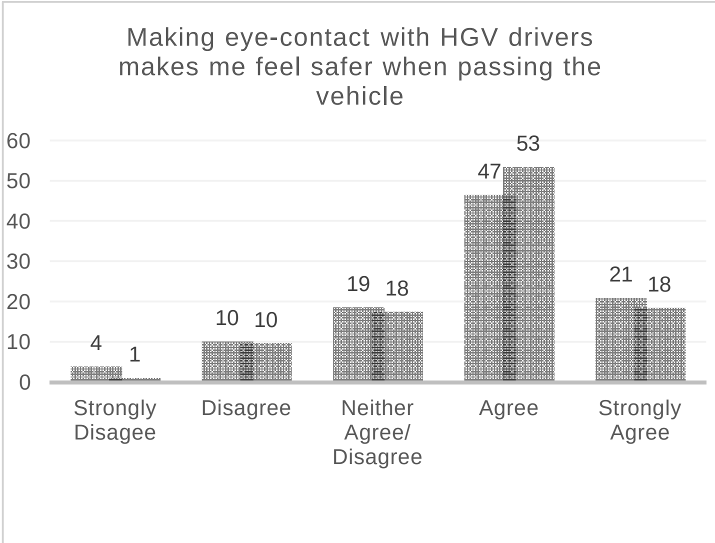


Figure 17. Percentage of cyclists and pedestrians who actively make eye-contact with HGV drivers.

Qualitative Responses

When asked whether the respondents **felt eye contact between VRUs and HGV drivers is important**, 79% of cyclists and 73% of pedestrians agreed.

Qualitative responses to this question were analysed (119 cyclist responses, 89 pedestrian responses) and divided into 3 key themes (see Appendix C for responses sorted by theme):

- Eye contact creates a *human connection and communicates behaviour*
  - 7.5% cyclists
  - 7.8% of pedestrians
- Eye contact is an *acknowledgment of one another's presence*

Figure 16. Percentage of cyclists and pedestrians who agree that making eye-contact with HGV drivers makes them feel safer when passing the vehicle.

    - 39% cyclists
    - 42.6% of pedestrians
- Making eye contact with HGV drivers is *impractical and dangerous*
    - 17% cyclists
    - 8.9% of pedestrians

As in qualitative research, some respondent's comments crossed themes:

- *Human connection* and *acknowledgment of presence*
    - 8% of cyclists
    - 4.5% of pedestrians
- *Acknowledgment of presence* and *impractical and dangerous*
    - 1% of cyclists
    - 3.4% of pedestrians

Theme Descriptions

Eye contact creates a human connection and communicates behaviour

Cyclists and pedestrians noted that human interaction/eye-contact facilitates a human connection between cyclists and HGV drivers. Respondents suggested a link between making eye-contact and communication. Further, some respondents noted that they really valued such interactions. Examples of participant comments include;

"There is something human about it – something polite, something helpful. It is about creating a mind-set of consideration and concern, which requires human contact"

"It's about mind-set. People may see me through a video camera, but not feel that human connection to me. Instinctively, it just seems better for me that drivers are able to make human contact in their work and so remember that they are interacting with living breathing people, not representations on a screen."

"Eye contact can help inform decision making process as a driver, to confirm intentions on either part (i.e. letting someone pass or vice versa)."

Eye contact is an acknowledgment of one another's presence

Many participants described making eye-contact as important because it was reassuring to see the driver and to know (from making eye-contact) that the driver had seen them. This reassurance was explicitly stated and alluded to through comments about awareness and mutual recognition. This awareness was suggested to lead to safer outcomes and feelings of safety among participants. Representative participant comments include;

"It acts as acknowledgment that they have seen me"

"If I know they've seen me, I feel safer"

"I feel safer to know they are aware of me, especially if they are manoeuvring / reversing."

Making eye contact with HGV drivers is impractical and dangerous

In this theme respondents stated the difficulties with achieving eye-contact and the dangers of being in a position where making eye-contact with a HGV was possible. Some respondents felt that making eye-contact was ambiguous in its effects. For example one respondent states;

"It takes my eyes off the road in front - in central London, a lot can happen in front in half a second!"

"I can't predict what action they'll take, whether they've seen me or assume I'm safe to overtake."

"It's important but not entirely meaningful - just because they seem to be looking at you doesn't mean they're paying you any attention, or have even consciously registered you. It's still of primary importance for the cyclist safety to not end up in a dangerous road position (regardless of whether it was the cyclist or driver that creates the situation) and to have an awareness of potential hazards so you can avoid them, like if an HGV starts pulling right at a junction the are probably swinging wide for a left turn and you should stay well away."

Group Differences

Overall more men than women completed the surveys. There were no sizable gender differences identified, however, a higher percentage of female cyclists (70%) did not trust that they could be seen through mirrors in comparison to males (40%). This trend was replicated in the pedestrian survey where 69% of women did not trust they could be seen through mirrors in comparison to 58% of men.

Additionally, 79% of female cyclists felt safer passing a vehicle having made eye-contact with the driver whereas only 61% of male cyclists felt this way. This might be explained by an inherent gender difference that has been consistently found between men and women – in that women engage in more eye contact across a variety of situations (Exline, 1963; Radtke & Stam, 1994).

Among cyclists, there were no sizable difference between those who cycle to commute and those who cycle for leisure. With regards to cyclist experience one clear difference in perception was identified.

A higher number of cyclists who have been cycling for less than 5 years (80%) agree that making eye contact with HGV drivers makes them feel safer, where only 62% agree who have been cycling for 5 years or longer. This difference might be as a result of negative experience or making eye contact and still being involved in a near-miss, or generally worsening attitudes towards HGVs as cyclists have been on the roads for longer.

HGV Drivers

The majority of HGV drivers indicated that they try to make eye contact with road users and feel that they are able to.

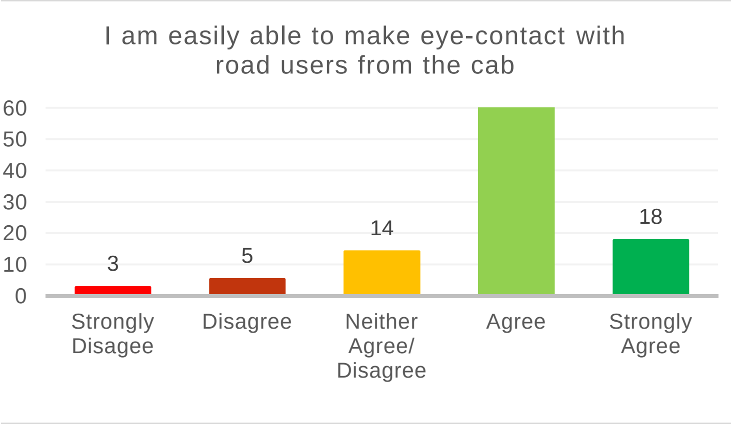


Figure 18. Percentage of HGV drivers who agree that they are easily able to make eye-contact with road users from the cab.

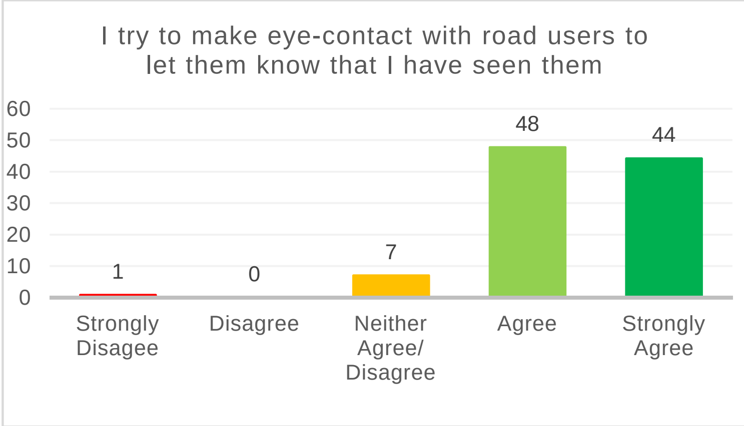


Figure 19. Percentage of HGV drivers who agree that they try to make eye-contact with road users to let them know that they have seen them.

Qualitative Responses

The vast majority of HGV drivers view eye-contact with cyclists and pedestrians as positive and important. Responses have been grouped into three themes:

1. Beneficial in *combination with cyclist training*
   - 5% of responses
2. Eye Contact is an *acknowledgement of one another's presence*
   - 86% of responses
3. Making eye contact is *impractical and dangerous*
   - *9% of responses*

The vast majority of respondents think that making eye contact with VRUs is important particularly in establishing awareness of presence between drivers and road users – they see it as transactional rather than empathetic.

These themes are described below:

Eye-contact is beneficial in combination with cyclist training

- 5% of comments suggested that eye contact can be beneficial but stressed the importance and need of training cyclists for road use. Comments included references to Legislations, Insurance, Training, Certification and a shared responsibility among road users.

"Cyclist need to be trained to a specific level before using main roads and should have at least 3rd party insurance and their bicycles should be subject to regular maintenance safety checks"

"No amount of safety aids on the vehicle make a difference if the pedestrian or more especially cyclists don't take responsibility for their own actions. Better training and awareness of traffic around them would be a greater help"

"Cyclists in particular must be forced into obeying road traffic law, especially in busy towns and cities. In my opinion cyclists should also be forced to undertake a degree of training and carry some form of insurance before being allowed to use the streets in busy towns and cities, although I appreciate that this would be hard to enforce."

"It is the vulnerable road users that need to change the way they behave and (in the case of cyclists) some form of legislation be imposed so that they can be answerable for the ways they use the roads and treat traffic signals and other vehicles."

Eye Contact is an acknowledgement of one another's presence

- 86% of responses reflect the importance of eye contact in facilitating an awareness of presence with vulnerable road users. Responses stress the importance of "being seen" and the consequent safety implications.

"So that both HGV drivers and cyclists and pedestrians are aware of each other for safety reasons"

"It lets both sides know they are both aware of each other's position"

"Because it makes us aware of each other's presence"

Making Eye Contact with HGV Drivers is dangerous and impractical

- The Category represents 9% of responses where drivers mainly refer to the difficulties, danger and impracticality of making eye contact with cyclists and pedestrians.

"If they (VRUs) can't see a big lorry I doubt if they will see my eyes"

"[Making eye contact] is very difficult for the cyclist when they are riding at speed and normally on the passenger side of your vehicle from the rear.

"Nearside door windows will give cyclists a false sense of security. For the driver they will only offer limited field of vision, and there are also issues if they prevent the nearside window from being lowered. On my vehicle there are no blind spots on the nearside. I also have a frenzel (sic) lens which is very good. These should be designed into the window glass"

Other observations

- **Safety**

It is important to note that when the survey asked drivers about the importance of eye-contact between VRUs and drivers, responses often answered a different question. A number of comments focused on the perceived risk to driver safety that accompanies the introduction of low entry cab design. It would be interesting to undertake further research to understand if drivers might be more supportive of such a design if their safety was assured.

"With lower cabs there is the safety aspect for the driver in the event of a rear end collision with another LGV especially on a motorway or other fast (road). With a low cab, the driver is at head height with the floor of a trailer and would probably receive severe if not fatal injuries"

"Additional side windows pose a safety flaw as the passenger window cannot be opened. If a HGV overturned on the driver's side they have no means of escape."

- **Eye contact creates a human connection and communicates behaviour**

It is interesting to note that this theme did not emerge from driver responses. Only 1 driver commented in line with this theme; see below:

"I think eye contact is very important- some kind of language which is used consciously or subconsciously to quickly make a decision on the road and for some more issues"

Note. This comment was made by a male who works in the construction sector, and has been driving for between 10 and 15 years.

Group Differences

With one exception, all respondents were male. 78% of drivers had over ten years' experience driving HGVs.

A larger percentage of drivers from the waste industry (66%) agree that increasing the size of windows would provide a better view of VRUs than construction drivers (44%). The number of actual drivers who agree with this statement from the construction industry is 31, more than the entire number of waste drivers overall. Due to the variation in distribution of drivers per industry, percentages of agreement or disagreement become inflated.

5.7 Eye Contact Specific Conclusions

At this stage in the project, it was decided to refine our research questions, focusing specifically on those that we were confident we could answer empirically via laboratory experiments. Questions posed include:

- Does direct vision improve: (i) reaction times (ii) hazard detection, iii) driving accuracy?
- Does spatial location of visual information impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?
- Does driver height proximity to the road / road users impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?

Does visual cognitive overload impact on (i) reaction times (ii) hazard detection, iii) driving accuracy? It was agreed that eye contact whilst an emotive topic was a potential distraction from these questions. It was also agreed that the research questions below would require a dedicated study to investigate them properly:

- Does direct eye-contact impact on (i) reaction times (ii) hazard detection, iii) driving accuracy?

- Does direct eye-contact create feelings of empathy?

Investigation of the importance of direct eye-contact was halted at the end of the second project phase and subsequently receives no further mention within this paper.

6 Laboratory Experiments

Based upon the findings of both the literature review and surveys, three control experiments and two main experiments were designed and conducted. These experiments, conducted in a bespoke laboratory setting, aimed to establish whether there is a safety benefit from seeing VRUs directly (through windows), as opposed to indirectly (through mirrors) when driving an HGV.

6.1 Experimental Set Up

In order to assess the extent to which safety can be improved by increasing direct vision of the area surrounding the cab, a virtual environment was used to simulate specific controlled events between HGVs interacting with VRUs.

The experiments were designed and set-up as follows:

- The experiment was designed so that the driver had control over the path of their vehicle, and their behaviour impacted whether collisions took place.
- Participants sat on a height-adjustable driving seat.
- The projected images of the virtual environment were the only source of light or visual information.
- Participants controlled steering using a steering wheel that provided feedback similar to that which you would experience whilst driving on a real road.
- Participants drove through a small virtual city, designed using a grid system (see Figures 20 and 21). The grid system provided ‘choice points’ in which drivers were instructed to stop, move off and take turns. These ‘choice points’ offered the opportunity for a hazard to present itself i.e. VRUs would enter the scene, that if not detected could result in a collision.

The cyclists and
pedestrians used in the experiments were approximately 1.7m and 1.75m high respectively. These heights are based on previous TfL commissioned reports which used an average male biker (50th percentile = 1.74mm) and pedestrian (50th percentile = 1.76mm). Using average heights is essential to ensure that this research is applicable to the general population.

- Drivers were able to look freely at the scene either directly (through front and side windows), or indirectly (via mirrors).
- Mirrors were setup to adhere to the minimum viewing requirements set out in Directive 2003/97/EC13. Mirrors were also setup to be ‘dirt-free’ to provide the best case scenario for indirect vision. This meant that any observed differences between direct and indirect vision could be attributed to differences in viewing method rather than any difference in viewing quality.
- HGV cab measurements were not matched to specific Traditional and Low-Entry designs, but rather were based on the collective measurements of a large number of commercially available HGV models as documented in Summerskill et al. (2015). These measurements were used to determine the key optical characteristics for both a low entry/high visibility and traditional/low visibility cab. The resulting HGV cab measurements used in the experiment can be found in Table 7.

Table 7 HGV Cab Measurements

	TRADITIONAL	LOW ENTRY

	DESIGN	DESIGN
EYE HEIGHT	2.5m	2m
SIDE WINDOW VISUAL ANGLE (OPTICAL ANGLE FROM EYE TO BOTTOM OF SIDE APERTURE)	17.95° (40% Occlusion)	37.38° (Glass side door)
FRONT BLIND SPOT SIZE (FOR A 1.75M VRU)	0.69m	0.0m
SIDE BLIND SPOT SIZE	1.3m	0.0m
FRONT WINDOW SIZE	0.9m x 1.67m	0.9m x 1.67m
SIDE WINDOW SIZE	0.66m x 0.8m	1.1m x 0.8m

Note: only the side window increased in actual size. The front windscreen size was constant, but the blind spot was eliminated because the driver's virtual eye height

was lowered.

Figure 22. Example of the view of the same stimulated driving environment in the (A) Traditional Cab, (B) Low Entry Cab.

While the experiments and conditions varied, the basic experimental activities took place as follows:

- The driver's task was to safely navigate the city by following the signage. At junction points the driver was instructed, via on-screen signage, on the direction they needed to go (left, right or straight ahead) and whether they needed to "Go" or "Stop". Instructions were given prior to the experiment starting, explaining what they were expected to do.
- The driving task required intermittent monitoring and attention to the road and their surroundings.
- When approaching a junction or crossing, participants were able to see Stop/Go signs approximately 8 seconds away. When they were 4 seconds away the Stop/Go sign either flipped to 'Stop' or remained 'Go'.
- When moving forward (with foot off the brake) driving speed accelerated up to 15mph for all participants to ensure that speed was consistent across all participants. This speed was selected as the DfT state that the average driving speed in London between 7-10am is 14.6mph.
- The experiment was set-up so that participants pressed the pedal to brake and released the pedal to accelerate.
- The three control experiments were conducted using the 'low entry' cab characteristics as this allowed us to compare the best form of direct vision (stimuli in front or side window) with indirect vision (stimuli in any of the mirrors) without any additional confounds (such as change in eye-height). The control experiments were designed as follows:

6.2 Experimental Design

Our experiments were designed to investigate the extent to which use of VDUs, mirrors and/or direct vision impact road safety requires precise measurement of gaze behaviours (how the driver moves their head and eyes to sample information from the world) and also measurement of the resulting steering behaviours with respect to moving objects in the world. There is no way to safely measure such behaviours in a real-world in a way that is as accurate and reliable as laboratory methods The facilities within PACLab allowed us to simulate the same core perceptual experience for the driver whilst systematically varying the key visibility characteristics and precisely recording steering, braking and gaze (head and eye) behaviours in relation to the scene (including key features such as road edges and other moving objects). It was necessary to conduct static control experiments with all participants to calibrate their response times. This allowed subsequent analysis of the impact of direct or indirect vision.

A series of experiments were designed to ensure that each set of findings built upon the understanding and interpretation of its predecessor(s).

1. First, we conducted a series of short, highly controlled trials, to obtain baseline reaction times for the difference between seeing visual stimuli directly or indirectly, when all other influencing factors were equal.
2. We then tested reaction times driving through a virtual town with no VRUs. This enabled an assessment of how dividing attention between driving and detecting stimuli impacts reaction times.

3. We then added VRU interactions to the experiments. We sought to understand how driving traditional vs. low entry cabs impacted driver behaviour in close proximity to VRUs.

4. Finally, we built on experiment 3 by further increasing the cognitive load upon the driver, adding an odd numerical pairings distractor task.

6.2.1 Control Experiment 1 – Visual Search While Stationary

We conducted a series of short, highly controlled trials, in order to obtain baseline reaction times between seeing visual stimuli directly or indirectly, when all other influencing factors were equal.

Initially participants were static i.e. not driving through the simulated environment, in order to measure reaction times under 'best case' conditions with no additional load due to driving (e.g. divided attention due to navigation). Participants responded as quickly as they could to the stimuli (using 'paddle' style buttons located conveniently under the fingers when the hands were on the steering wheel) to stimuli which appeared in the front or side window (direct vision), or in any of the mirrors (indirect vision).The timing of the stimuli's appearance was unpredictable, requiring the participant to conduct an ongoing visual search. Participants then conducted the visual search activity whilst carrying out the moving navigation task used in the main experiments.

We conducted the visual search experiments with a high salience stimuli (blue dot) and a low salience stimuli (grey dot) to examine whether differences between detecting the stimuli through direct or indirect vision, changed when the stimuli was hard to spot (see Figure 23).

Research Design: Real World Comparison

A real world example of this could be a cyclist wearing a high visibility jacket and who can be seen equally quickly, either directly through the window or indirectly through a mirror. Yet greater differences in reaction times between direct and indirect viewing may occur when the cyclist wears low visibility clothing.

Participants conducted the 'visual search' activity 48 times to provide ample data, with 6 stimuli (blue or grey dots) appearing in each area of vision i.e. front and side widows, and all mirrors. At least 2 seconds elapsed between each stimuli appearing but this varied slightly to make their appearance irregular and unpredictable.

6.2.2 Control Experiment 2 – Visual Search Whilst Navigating

In the second version of the visual search control experiment, participants were required to conduct the navigation task in addition to detecting the appearance of visual stimuli. This meant that participants had to monitor the road and navigate,

Figure 23 Control Experiment 1 – Visual Search Design. This figure shows a visual search for a blue dot (A), and a grey dot (B).

while responding to stimuli, which is arguably comparable to every-day driving.

In this version of the control experiment, both high and low salience stimuli appeared i.e. blue and grey dots.

6.2.3 Control Experiment 3 – Pedestrian Visual Search Whilst Navigating

In addition to how 'visible' a VRU is (i.e. wearing high-vis clothing or not) it was decided that size was an important factor to examine. Mirrors affect how we see things, and people or objects can appear smaller, even when the exact same distance from the vehicle, depending on whether you see them directly (through a windscreen) or in a mirror. In short, mirrors make stimuli appear smaller and this could impact a driver's ability to and speed of detection.

To examine whether the effect of optical size impacted on reaction time, we conducted a third control experiment (see Figure 24). Pedestrians appeared as you would see them in the real world – smaller in mirrors vs. through the windscreen and side window (scaled based on the optical effect of the mirror). As in the second control experiment, the drivers would navigate the town while responding to any pedestrians using the paddles.

6.2.4 Main Experiment 1 – VRU Interaction

The control experiments (1, 2, 3) explored whether seeing stimuli directly (through windows) impacted upon reaction times in comparison to seeing stimuli indirectly (through mirrors).

The main experiments went on to assess the impact of driving a traditional cab vs. a low entry cab (See Figure 25 and Table 8 for detail). A traditional cab offers drivers less opportunity to see VRUs directly through their windows, as they are seated higher up from the road, with small side door windows. Comparably, the low entry cab offers drivers greater opportunity to see VRUs directly through their windows, as they are seated closer to the road, with larger windows in their side doors.

Figure 25 Cyclist passing in VRU Interaction Experiment. This figure shows the driver view in A) Traditional Cab; B) Low Entry Cab

As previously described, participants followed a sign-posted route. The task was to successfully navigate the route, while responding to any VRUs that appeared. Responding to and avoiding collisions with VRUs was a sub-task so as not to make this the focus of the activity.

> Research Design: Real World Comparison
>
> As in a real life driving scenario, the task meant that participants had to intermittently monitor *both* the road and their surroundings while driving and navigating.

During the main experiments, a range of events involving VRUs took place. These events were designed to be in line with typical VRU and HGV interactions based on data. In Europe, two manoeuvres have been found to be primarily responsible for VRU KSIs (TRL, 2016): (1) At crossings where vehicles are pulling off; (2) At left turn junctions. These interactions were simulated in our experiment, in addition to a number of scenarios where VRUs and HGVs typically interact safely. All participants experienced at least 5 key events with the potential for a collision to occur (stared scenario from the list below), as well as distractor events where VRUs passed safely which served to make the experiment unpredictable.

The VRU and HGV interactions simulated are presented below -

Cyclists:

1. **A cyclist coming up the inside of the lorry on a left turn when the lorry *is starting from a stopped position* ***
2. **A cyclist coming up the inside of the lorry on a left turn when the lorry *is in motion* ***
3. A cyclist, who turns or crosses the junction before the driver (cannot collide with).

Pedestrian:

4. **A pedestrian walking in front of a stopped lorry when the lorry is about to accelerate ***
5. A pedestrian crossing the road further ahead of the vehicle.
6. A pedestrian crossing in the blind spot-spot when the vehicle is stationary at a ‘Stop’ sign.
7. A pedestrian appearing but not crossing the road.

Drivers were instructed by variable signage within the simulation as to whether to stop or proceed at a junction as this, again, more closely replicates a real world driving context. The simulator also automatically accelerated drivers to 15 mph to prevent participants from driving cautiously in an attempt to reduce the complexity of the driving task.

The table below highlights the viewports in which each of the three VRUs who moved in a way meaning they were at risk of being involved in a collision were visible.

Table 8. The source of visual information for detecting the presence of a VRU at the point of passing close to the HGV, either up the inside or to the front.

VRU scenario	A cyclist coming up the inside of the HGV on a left turn when the HGV *is starting from a stopped position*		A cyclist coming up the inside of the HGV on a left turn when the HGV *is in motion*		A pedestrian walking in front of a stationary HGV when the HGV is about to accelerate	
Cab Type	Traditional HGV	Low Entry HGV	Traditional HGV	Low Entry HGV	Traditional HGV	Low Entry HGV

Windscreen						•
Side Window		•		•		
Class II	•	•	•	•		
Class IV	•	•	•	•		
Class V	•	•	•	•		
Class VI					•	•

Note: The virtual environment was calibrated to ensure that regardless of how far away a driver stopped from a crossing/at traffic lights, the pedestrian or cyclist would step-out at the same distance from the cab each time. This was important to consistently test how drivers controlled the vehicle in relation to road users, regardless of where they stopped their vehicle in relation to a stop sign. The specific distance depended on the type of event.

6.2.5 Main Experiment 2 – Adding Cognitive Load

In Main Experiment 1, it was important to ensure that we were measuring the effect of seeing VRUs either directly through greater window size in the low entry cab, or indirectly, through mirrors in the traditional cab. We designed an experiment free from potentially confounding variables that might influence reaction time, such as bad weather affecting visibility, dirty mirrors, or having to read a Sat Nav.

In the real-world there are many potential distractions and we generally do not experience the best-case driving conditions examined in Main Experiment 1. Conditions such as poor visibility, or the distraction of having to read a Sat Nav have the potential to impact on our ability to detect and respond to hazards.

Accordingly, we added an element of cognitive load to Main Experiment 1 so as to more accurately replicate real world driving conditions. A small visual display unit (VDU), similar to a Sat Nav, was positioned at the bottom of the windscreen simulation (see Figure 26). This VDU displayed a pair of digits, which changed every 2 seconds.

Participants were required to check the digits, and respond when both of the digits were odd e.g. “1, 3”, or “7, 5”, by clicking a red button on the steering wheel. They carried out this task while continuing to navigate through the town, and were asked to prioritise this task equally with the other tasks they were carrying out, i.e. driving, navigating and avoiding hazards.

This task was designed as it required participants to intermittently make off road glances to look at the VDU, and dedicate cognitive attentional resource in order to try and get the task right. Participants were therefore forced to trade-off between getting the odd pairings distractor task correct or focusing on navigating the town safely.

In addition to measuring collisions with VRUs, data was also collected in Control Experiment 2 on correct and incorrect responses to the odd pairings distractor task.

This task was designed to ensure that we could quantify the potential impact of the additional cognitive load, and incrementally vary the degree of this. Hence the use of a simple maths task where it was possible to ascertain whether drivers were completing the task conscientiously or merely responding at random to reduce the cognitive load they were experiencing.

Figure 26 Control Experiment 2: Odd Pairings Distractor Task Design

This task is broadly comparable to the kind of simple speed-distance-time equations drivers must make to ensure they make delivery times, obey speed limits, and navigate in congested areas.

Research Design: Real World Comparison

When driving in real life, cognitive load is impacted by a range of inputs drivers are required to process. Examples include:

- Diverting ones gaze to a Sat Nav, and processing the instructions
- Listening to a quiz on the radio and working out the answers, using attentional resources
- Hearing your phone ringing and wondering who wants to speak to you, and what for
- Working out how many drops you have left to deliver, in how many hours

6.3 Experiment Participants

6.3.1 Participant Demographics

Table 9 shows the participants who were recruited to take part in each experiment.

We decided to test regular drivers (holding a Cat B and B1 license), for our experiment. This was a conscious decision to ensure:

- We explored ‘typical’ human reactions to stimuli appearing directly, or indirectly via mirrors.
- We did not want reaction times and VRU interactions to be skewed or distorted by training, learned behaviours and past experience.
- Our conscious decision to assess professional drivers separately ensures that, as well as focusing on generic reaction times, the research can be applied to new and trainee drivers.

In addition to testing regular drivers, we also tested 11 qualified HGV drivers. This was important to:

- Examine whether 'experts' exhibited different visual and driving behaviours in our simulation.
- Explore how extensive training and experience may support professional drivers to react to VRUs appearing in their mirrors, through using learned behaviours e.g. monitoring mirrors more frequently.

Table 9. Participants by Experiment

Experiment	Participants
Control Experiment 1 – Visual Search While Stationary	30 Drivers (mean age = 28.6 years, age range = 21-48yrs) 11 HGV Drivers (mean age=45.9 years, age range = 27-59yrs)
Control Experiment 2 – Visual Search Whilst Navigating	
Control Experiment 3 – Pedestrian Visual Search Whilst Navigating	
Main Experiment 1 – VRU Interaction	
Main Experiment 2 – Adding Odd Pairings Distractor Task	30 participants (mean age = 29.53, age range = 20-50)

6.3.2 Recruitment

Participants were recruited through advertisements issued to key contacts of Transport for London, the University of Leeds, and Arup.

Participants were informed of the high level aims of the project – exploring the safety benefits of direct vision. Detailed research aims were not shared until after the completion of the experimental series. This was so as not to bias the behaviour of drivers. All participants were paid £30 for their participation in the experiment.

It should be noted, however that the professional drivers recruited were highly invested in performing well due to:

1. Their understanding of the arguments around HGV re-design.
2. The fact that these drivers chose to travel to the University of Leeds to undertake this research in addition to their day job.

An example advert is shown in Figure 27.

Figure 27. HGV Driver Advertisement.

6.3.3 Motion Sickness

Simulator sickness is a common occurrence (Brooks et al., 2010). This impacted on the full experiment completion rate of the participants noted above.

Participants	**Dropout rate**
30 Drivers (mean age = 28.6 years, age range = 21-48yrs)	30 participants successfully completed the experiment. (Note. 33 were initially involved, and 3 participants were unable to complete the experiment – 9% drop out rate)
11 HGV Drivers (mean age=45.9 years, age range = 27-59yrs)	5 HGV drivers could not complete the experiments (45% dropout rate)
30 participants (mean age = 29.53, age range = 20-50)	5 drivers could not complete the experiments (17% drop out rate)

Research demonstrates that motion sickness is more common in older participants (Brooks et al., 2010). This explains the heightened dropout rate in the HGV driver group.

Motion Sickness should be a major consideration for future experiments: Whilst all eleven of our HGV drivers completed our series of (short) control tasks, unfortunately many were beset by motion sickness during the longer periods of driving. Whilst

University of Leeds expected some motion sickness issues, we did not expect it to preclude anyone from doing the study so are surprised by the 45% dropout rate from HGV drivers. This raises important issues for any future laboratory work into Truck-VRU interaction. Potential explanations:

- **Age:** HGV drivers were generally considerably older than the normal drivers, which is considered a risk factor for experiencing motion sickness.
- **Experiment Design:** Another issue lies in experiment design. Anecdotal reports of the sickness cause were Starting/Stopping, and sharp turns. Since the primary aim of our experiment was to examine pull-offs and left-turns, it would have been difficult to examine our research question without these aspects central to the design, but future designs could consider short trial-style experiments (rather than continuous periods of driving) which may avoid the cue conflict associated with Starting/Stopping by fading out/in the display instead.

6.4 Results

To establish the effect of seeing a visual stimuli or VRU through either direct or indirect vision, the following data was recorded for all experiments.

- Time from the visual stimuli appearing to the driver responding.
- Mean reaction time – On average how much faster or slower were participants to respond to seeing stimuli through different direct or indirect means

Statistical analysis was conducted in order to investigate whether the observed trends in the data were systematic, and what they meant in terms of any potential difference between direct and indirect vision for driver reaction time.

6.4.1 Control Experiment 1 – Visual Search While Stationary

30 Participants (mean age = 28.6 years, range = 21-48yrs) took part in the experiments. As previously described, these participants responded using paddles as quickly as they could to acknowledge stimuli appearing either the windows or mirrors.

In this stationary version of the task, participants did not have to navigate through the virtual town environment and were focused on responding to the stimuli.

The results (as presented in Figure 28 and 29) clearly show that:

- **A high salience stimuli (i.e. a blue dot) was reacted to significantly more quickly (p<.001) than a low salience stimuli (i.e. a grey dot).**
- This is likely because the grey dot was hard to detect using peripheral vision (whereas the blue dot was visible enough), so detecting the low- salience dot required the participant to actively search, which is a slower process.
- However these results do not show a large difference between viewing a stimuli directly or indirectly.

Interestingly, Figure 28 also shows that reaction times are generally faster in right hand mirrors than those on the left hand side. These findings can be interpreted as follows:

- In our experiment, drivers only had two right hand mirrors to look at (II R, IV R), so dealing with that side of the visual field was quicker (i.e. you only need two eye movements).
- On the left side of the visual field drivers had the side windscreen and three mirrors (V, II L, IV L), so the left side may have taken longer to scan.
- During normal driving it is assumed that the split between left and right viewports is fairly equal. In our current experiment it is probable that participants did not divide their scanning time proportionately between the right and left viewports in line with the visual scenes available to them.
- Therefore, drivers may have spent less (too little) time looking at each left hand viewport and were thus slower to react to stimuli appearing here.

6.4.2 Control Experiments 2 and 3 – Visual Search Whilst Navigating

These experiments required participants to respond to both high or low salience stimuli, and pedestrians, while also steering and navigating through the simulated town.

The overarching findings, as demonstrated in Figure 30 and 31 were as follows:

- **Participants responded most quickly to pedestrians and slowest to low salience (grey dot) stimuli. This difference was significant ($p < .001$).**
    - This is likely due to the size of the pedestrians. This inference can be made as the Class IV mirrors where the pedestrian appeared smallest compared to other mirrors or direct vision, had a slower response reaction time on average compared to the high salience (blue dot) stimuli.
- Participants responded significantly more quickly ($p<.001$) to visual stimuli (both pedestrians and high/low salience dots), seen through direct vision (windows) compared to indirect vision (mirrors).
- Reaction times to stimuli seen through the front windscreen were equivalent (to the high salience, blue dot) or faster (to the low salience, grey dot) when driving (Control Experiment 2), than when stationary (Control Experiment 1). Furthermore, the reaction times to stimuli seen through mirrors (indirect vision) were slower when driving, particularly in the mirrors furthest from the driver.

- An explanation for this is that when driving, one's gaze tends to be focused on the road ahead (Wilkie & Wann, 2003; Wilkie et al., 2010). Detecting and reacting to stimuli ahead of you should therefore be faster since that is where your gaze naturally falls. In contrast mirrors are not within your direct line of sight and so they will require shifts of gaze to detect appearing stimuli.

- In general, participants responded more slowly to stimuli appearing in their mirrors, as opposed to those appearing through the windscreen. This benefit was less evident when comparing mirrors to side windows.
  - This suggests that the direct vision benefits present whilst driving primarily reside for stimuli viewed through the front windscreen rather than the side window (where benefits were less clear). This will be explored in more detail in the Implications Section 6).

Figure 31.

Demonstrating overall mean reaction to high salience (blue) stimuli, low salience (grey) stimuli and pedestrians presented through direct or indirect means (windows or mirrors) while stationary.

6.4.3 Main Experiment 1 – VRU Interaction

The primary measure of performance in Main Experiments 1 and 2 was whether or not the participant collided with a VRU when they appeared in the simulation. It was important to have a clear comparable measure in this experiment to determine the impact of driving a traditional vs. low entry cab.

In total, the non-HGV participants collectively experienced 46 collisions and there were large differences in collision rates when driving the traditional vs. low entry vehicle.

The overarching findings, as demonstrated in Figure 32 were as follows:

- **A significant difference in the number of collisions occurred when a pedestrian was seen through a windscreen (driving a low entry cab) compared to indirectly through mirrors (driving a traditional cab).**
    - No significant difference was found in the number of collisions occurring in traditional cabs vs. low entry cabs occurring when the driver was not instructed to 'Stop', and a cyclist appeared to the side of the vehicle. In this scenario cyclists could be seen through side windows in the low entry cab, compared to mirrors in the traditional cab.
    - This suggests that in this simulation at least, direct vision does not reduce the chance of colliding with a cyclist. Within the parameters of this experiment it has not been possible to ascertain why, however the findings can be interpreted as resulting from the faster movement of cyclists vs. pedestrians and will be discussed in the conclusions of the report.
- When driving in a traditional cab 43.3% of participants experienced at least one collision with a VRU (35 collisions in total).
- When driving in a low entry cab 26.7% of participants experienced at least one collision (11 collisions in total).
- The number of collisions also depended on the type of VRU event.
    - More participants collided with a VRU when they were not instructed to 'Stop' and the VRU was a cyclist.
- **The greatest difference in number of collisions between the traditional vs. low entry cab was when a pedestrian crossed in front of the vehicle. The number of participants who collided with a VRU dropped from 26.7% to 3.3% once they saw the pedestrian through their windscreen (low entry design cab) rather than their mirrors (traditional design cab).**

6.4.4 Main Experiment 2 – Adding Cognitive Load

To understand the impact of cognitive load on driving performance it was necessary to measure performance on the odd pairings distractor task (the number of correct vs incorrect odd number pairing detections). Across Experiment 2 as a whole, performance on the odd pairings distractor task was as follows:

- The average correct detection of odd pairings across the whole experiment was 85% - this reflects overall good performance and that participants were giving it ample attention to perform well.
- Performance varied between the static and moving trials in the experiment (see Figure 33):
    - Average correct detection when static i.e. not driving was 92%
    - Average correct detection when driving was 80%
    - This differing level of performance tells us that the odd pairings distractor task was not too easy, and required attention. Furthermore, the reduced performance when steering (driving), demonstrates that participants were making a ‘cognitive trade off’ in order to give enough attention to the road as well as the distractor task.

Whilst measuring odd pairings distractor task performance provides us with an insight into task difficulty and whether or not a cognitive trade off was taking place, it does not tell us what effect a cognitive load has on drivers' responses to hazards and VRUs.

> Research Design: Real world comparison
>
> Cognitive load is the total amount of mental effort being used by our working memory. In simple terms, it is how hard your brain is working and how much pressure different tasks are placing on it to perform. When driving, it is rare, if not impossible to experience no distractions. Things going on in the streets around you, other vehicles, people talking to you, the radio – all of these things will impact your cognitive load and subsequently influence driving performance.

It was, vital, therefore, to consider the differences when driving traditional vs. low entry cabs, with the addition of a distraction. This ensures that results more accurately reflect driving in the real world.

Visual Search While Stationary

Findings for the static reaction time test to visual stimuli appearing across a range of view ports (mirrors and windows) in the low entry cab with the added odd pairings distractor task were as follows (see Figures 34 and 35):

- Reaction times to visual stimuli slowed in general when the distractor task was present.
- Participants responded considerably faster to high salience visual stimuli (blue dots) compared to low salience visual stimuli (grey dots).
  - This difference between high and low salience visual stimuli (blue vs. grey dots) was statistically significant ($p<.001$).
- **However, as in Control Experiment 1, there was no significant difference between reaction times to visual stimuli seen through direct vision (windows) compared to indirect vision (mirrors), while static and carrying out the odd pairings distractor task.**
  - Interestingly, there also appeared to be an interaction between salience and seeing stimuli through windows vs. mirrors. Direct vision reaction times were actually on average slower than indirect vision reaction times, and more variable for low salience visual stimuli (grey dots) when an odd pairings distractor task was present.

- Since the windscreen and side windows take up much larger regions of the visual field than the mirrors, they actually require a lot more eye movements (therefore, time and effort) to make a complete scan for a low-salience stimuli, whereas the mirrors might only need a single glance. When participants have the added visual load of looking intermittently at the distractor task, it appears that they compromise by spending less time making the effort to scan the larger regions of the visual field, so detection performance is impaired on the large windscreen. You do not see this effect with high-salience circle, since the contrasting colour supports easy detection in the windows (especially the front), without the need to expend effort scanning the area.

Visual Search Whilst Navigating

The odd pairings distractor task was then conducted while participants were driving the low entry cab through the virtual environment, thus providing perhaps the most authentic real-world experience of driving. The results for this element of Main Experiment 2 were (see Figures 36 and 37):

- Reaction times to visual stimuli slowed in general when the odd pairings distractor task was present (just as they did in the static version of the experiment).
- Participants were quicker in their reaction times to pedestrians, and were slowest when responding to low salience visual stimuli.
- Unlike in the static trial, there was a significant difference between mean speed of response to all visual stimuli (pedestrians, high-salience blue dots and low salience grey dots).
    - This shows that when moving, with added distraction and cognitive load, drivers were faster to recognise and respond to visual stimuli and hazards when they saw them directly through windows compared to

through their mirrors indirectly.

Figure 37. Demonstrating overall mean reaction times to high salience and low salience stimuli (blue or grey dots) presented through direct or indirect means (windows or mirrors) while navigating and carrying out the odd pairings distractor task.

Overall, the odd pairings distractor task increased reaction time to visual stimuli and VRUs by approximately 30%. This was between an 0.19 and 0.76 second increase in reaction time depending on the specific condition – with indirect vision of low salience stimuli (grey dots) being the slowest.

VRU Interaction

Interestingly, when driving a traditional vs. low entry cab, the impact of these reduced reaction times played out when interacting with VRUs. The results for this element of Main Experiment 2 were (see Figure 38):

In terms of collisions:

- **Participants experienced 107 simulated collisions in total in Main Experiment 2 following the addition of the odd pairings distractor task. By way of comparison, 46 collisions occurred in Main Experiment 1.**
- 68% of participants collided with a VRU in the simulated direct vision condition.
- 64% of participants collided with a VRU in the simulated indirect vision condition.
- As in Main Experiment 1, a higher number of participants collided with a VRU when they were not instructed to ‘Stop’, and the VRU was a cyclist.
    - This increased from approximately 30% of participants colliding in Main Experiment 1, to 60% in Main Experiment 2.
    - Interestingly, this did not vary between conditions in the traditional and low entry cabs, suggesting that in this simulation at least, direct vision does not reduce the chance of colliding with a cyclist. This will be discussed in the conclusions of the report.

Figure 38. Demonstrating percentage of participants who experienced a collision across three events while carrying out the odd pairings distractor task: (inside cyclist with driver stopped); (inside cyclist with driver going); (front pedestrian with driver stopped).

- **For pedestrians, direct vision brought significant benefits. Collisions with VRUs dropped greatly from 52% when seen indirectly through mirrors (driving a traditional HGV), to 12% when seen directly (driving a low entry HGV), even when carrying out the odd pairings distractor task – a 40% reduction (see Figure 39).**
    - Statistical analysis demonstrated that this difference was significant –

      further cementing the potential benefits of direct vision.

Figure 39. Demonstrating the percentage of participants colliding with at least one pedestrian during the navigation task, during Main Experiment 1 (no odd pairings distractor task) and Main Experiment 2 (with the odd pairings distractor task).

6.4.5 HGV Driver Results

Control Experiments – Visual Search

In addition to testing regular drivers (those holding a Cat B and B1 license), we also tested 11 current HGV drivers (mean age=45.9 years, range = 27-59yrs) to examine whether professional drivers exhibited different visual and driving behaviours (see Figures 40 and 41 for results). The findings were as follows:

- **HGV drivers generally demonstrated the same response trends as non-HGV drivers.**
- For the static control experiment:
    - Similar to the non-HGV drivers, there were significant differences in mean reaction time between the high and low salience stimuli ($p<.001$).
    - Similar to the non-HGV drivers, there were no large differences in mean reaction time to stimuli appearing directly (through windows), or indirectly (through mirrors).
- For the driving control experiment:
    - Similar to the non-HGV drivers, there were large differences in mean reaction time for both high vs. low salience stimuli (blue vs. grey dot), and direct vs. indirect vision (windows vs. mirrors).
- **Both HGV and non-HGV drivers were better at detecting visual stimuli when seeing them directly i.e. through a window, when they are driving.**
- **Interestingly, the HGV drivers <u>were slower on average</u> to react to the visual stimuli than non HGV drivers in the control experiments.**
- **No reliable differences were found in reaction times to stimuli appearing directly / indirectly <u>when stationary</u>. However, reaction times to stimuli appearing directly / indirectly were significantly different <u>when driving</u>.**
    - A possible reason for increased reaction times overall is that the HGV drivers were on average 17 years older than the control participants. Older adults generally have slower reaction times (Birren & Schaie, 2001; Welford, 1984). This does however raise important questions around the age of the professional driving population and what this means for collisions. This interesting additional finding will be discussed further in the conclusions on this report.

Figure 40. Demonstrating the mean reaction time of HGV Drivers to high salience (blue) and low salience (grey) stimuli presented through direct or indirect means (windows or mirrors) while stationary.

To explain these findings simply, Figure 41 shows that there are no reliable differences between Indirect and Direct vision when not driving (static). Any apparent differences visible on the graphs are due to noise/chance. This is reassuring, as it shows that participants were able to respond to stimuli appearing in the simulated mirrors. Therefore, we can conclude that the differences in reaction time when stationary (Figure 40), and when driving (Figure 41) are present because participants were having to drive, not because participants were fundamentally unable to detect things in our simulated mirrors.

Main Experiment 1: VRU Interaction

<u>HGV Driver Findings</u>

Only seven HGV drivers completed both cab design conditions due to a high dropout rate (37%) caused by participants experiencing motion sickness. Unfortunately older adults are more prone to simulator sickness, and the HGV driver group were on average 17 years older than the control group.

The small numbers make it difficult to make strong inferences about the relative collision performance for Low-entry and Traditional cabs. The six HGV-driver participants experienced only two collisions between them: one collision during the traditional cab (indirect vision) condition with a cyclist, and one collision during the low entry (direct vision) condition with a pedestrian.

Without further testing of HGV drivers it is not possible to draw robust conclusions from these results, since a random sample from the control group could have led to similar patterns of behaviour.

It should be noted that the professional drivers recruited were highly invested in performing well due to their understanding of the subject and arguments around HGV re-design. This may have caused them to be particularly attentive to VRUs appearing in their mirrors. They also had significant experience in using mirrors to monitor blind spot-spots, and the degree to which training and experience can compensate for reduced reaction times is a critical issue for future investigation (see future directions section).

6.5 Simulation Survey

Following the experiments, we surveyed participants to better understand their experience of the simulated driving set up (see questions in Appendix 6).

The simulation revealed that:

- The majority of participants felt ‘immersed’ during the simulation.
- The significant majority of participants agreed that we are investigating an important road safety issue, and that there should be more research in the area.
- 58.6% of participants experienced motion sickness

  - Simulator sickness is a common occurrence, and is more likely in older participants (Brooks et al., 2010). This was reflected in the current study, with the older HGV Driver participants experiencing this more frequently. This is investigated further later in the report.
  -
- 34.5% didn't think that the behaviour of pedestrians mimicked real life.
  - This is likely because the experiment intentionally simulated a disproportionate high number of risky VRU behaviours in comparison to real life. This was important to allow us to explore how varying cab design would impact driver behaviour in such interactions within the timeframe of the experiment. If VRUs has not behaved in such a fashion we could have seen many hours of simulated driving with no collisions

- 48.2% felt the simulation 'adequately represented the core aspects of driving'. 27.6% disagreed, 24.1% felt neutral about this statement.

The qualitative comments reveal that those who disagreed, did so for a range of reasons:

- **Experimental design:**
  - *'It would be more realistic if the driver was to sit in the shell of an actual cab'*
  - *'May be good to also have indicators on the wheel, as often when I indicate that's another reminder to check my blind spot'*
  - These considerations are useful for future experimental design.

- **Distractions:**
  - *'[when driving in real life] there are far more distractions going on - music from the stereo, the two way radio, camera systems fitted have to be viewed, and also noise from proximity sensors are all distractions and that is only IN the cab, there is of course also a great deal more distractions outside to contend with.'*
  - *'I think with more traffic around during the simulation would be a better representative from a drivers point of view.'*
  - These comments highlight that driver behaviour would likely be further impaired if the experiment took place in a more realistic scenario – with the driver required to cognitively process a range of visual and auditory stimuli.

Challenges that the driving task did not authentically replicate real-world driving experiences were expected. The objective of this study was to provide statistically significant data on the impact of direct/indirect vision to reaction times – not to provide a wholly genuine driving experience. We have succeeded in this ambition and a good level of fidelity was achieved in the laboratory experiments. Ultimately, due in part to the ethical constraints placed on such research, there is no practicable alternative to simulation.

6.6 Experimental Conclusions

Three control experiments and two main experiments were designed and conducted.

These experiments aimed to establish whether there is a safety benefit associated with seeing VRUs directly (through windows), as opposed to indirectly (through mirrors) when driving HGVs.

Visual Searches While Stationary

- A high salience stimuli (i.e. a blue dot) led to considerably faster reaction times (RTs) than a low salience stimuli (i.e. a grey dot).
- Reaction times did not differ significantly when viewing stimuli directly through windows vs. indirectly through mirrors <u>when not driving</u>.

Visual Searches Whilst Navigating

- Participants responded more quickly to pedestrians seen through direct vision (windows) compared to indirect vision (mirrors).
- Viewing a pedestrian directly resulted in reaction times that were approximately 0.7 seconds quicker than indirect viewing.
- Reaction times of both non-HGV drivers and HGV drivers to **stimuli seen through mirrors (indirectly)** were **slower when driving** as opposed to when stationary, particularly in the mirrors furthest from the driver (Class V and VI).
- Reaction times to **stimuli seen through windows (direct**) were **faster when driving** as opposed to when stationary.
    - When driving, one's attention is focused on the road ahead to anticipate future steering requirements (McKenzie & Harris, 2005). Detection of stimuli directly through the windscreen is improved as your gaze is naturally directed here, while detection of stimuli in the visual periphery (mirrors) is impaired since gaze is not focused there.
- In general, participants responded more slowly to stimuli appearing in their mirrors, as opposed to those appearing through the windscreen. This benefit was less evident when comparing mirrors to side windows.
    - This suggests that the direct vision benefits present whilst driving primarily reside for stimuli viewed through the front windscreen rather than the side window (where benefits were less clear).

HGV driver differences

- HGV drivers were slower on average to react to the visual stimuli in the control experiments.
- This is likely due to the fact that the HGV drivers were on average 17 years older. It has been demonstrated consistently that reaction times increase with age (Birren & Schaie, 2001; Welford, 1984).

VRU Interaction

- Increased direct view of pedestrians (through the windscreen in a low entry cab) resulted in significantly fewer participants colliding with pedestrians than when relying on an indirect view (Class VI mirror in a traditional cab). This was true with and without the addition of the odd pairings distractor task.

  - These results align with the previous finding that participants respond more quickly to pedestrians seen through direct vision (windows) compared to indirect vision (mirrors).
  - Across the main VRU Interaction Experiments (with and without the odd pairings distractor task) participants took approximately *double* the response time to detect stimuli presented in the Class VI mirror (where the driver needs to look to detect pedestrians indirectly) as opposed to that presented on the front windscreen.

- Viewing cyclists passing on the inside of the vehicle directly (through the side window in the low entry cab) did not result in fewer collisions than when viewing them indirectly (through mirrors in the traditional cab).
  - This might be because the cyclist was travelling quickly, passing the cab at a quicker rate than the pedestrians passed in front of the vehicle. The cyclist appeared in the side window for a short amount of time, and so the potential benefit for direct vision would be less than for pedestrians crossing in front of the windscreen.
  - Drivers need to voluntarily look to the side windows (turning their head and eyes) in order to detect the presence of a VRU, taking time and delaying responses. This suggests that increasing direct vision through the side windows may not provide the same degree of benefit as increased direct vision through the windscreen.

7 Implications

Reaction Times

Viewing a pedestrian directly resulted in reaction times that were approximately 0.7 seconds quicker than indirect viewing.

At slow (15mph) driving speeds this would equate to 4.7m of extra travel before braking, more than enough to collide with a pedestrian crossing in front of the vehicle. Even at 5 mph (pulling off speed) this still equates to 1.5m of extra travel. Any collision with an HGV, even at 5mph has the potential to be fatal.

Speed	Extra Travel
15 mph (24kph)	4.7 meters
10 mph (16kph)	3.1 meters
5 mph (8kph)	1.5 meters

This increased stopping distance could make the difference between a collision, and halting at a safe distance, particularly in an urban environment.

The pedestrians in our experiment appeared 0.63 meters in front of the vehicle, and we observed fewer collisions when pedestrians were viewed Directly compared to Indirectly (as discussed below).

Collision Rates

Collision rates were reduced in the low-entry HGV set-up, in comparison to the traditional cab set-up across the three key VRU events that were examined:

- A cyclist coming up the inside of the HGV on a left turn when the HGV is starting from a stopped position.
- A cyclist coming up the inside of the HGV on a left turn when the HGV is in motion.
- A pedestrian walking in front of a stopped HGV when the HGV is about to move off (the Stop sign turns to Go).

The event where we found the biggest reduction in collision rates was the pedestrian condition.

Here, the proportion of drivers who collided with the VRU dropped from 27% (eight participants) to 3% (only one participant) - because the driver could view the pedestrian through their windscreen as opposed to only via their mirrors.

This is particularly noteworthy given that recent trends suggest that pedestrian-HGV collisions, particularly at the front of the vehicle are a prevalent cause of fatalities in London.

When cognitive load was added in the form of the odd pairings distractor task, the percentage of drivers who collided with a VRU at some stage during their driving task dropped from 52% in the traditional cab (13 participants out of 25) to 12% in the low entry cab (only 3 participants).

This suggests that when a cognitive task increases in difficulty, i.e. driving with additional distractions, the ability to directly view a pedestrian in front of the vehicle (as in a low entry cab) becomes even more beneficial.

These findings collectively have strong implications for reducing pedestrian collisions and KSIs. As previously stated, driving without any distraction is near impossible and at any point in the day drivers can experience increased demands on their cognitive processing. Day time or rush hour driving requires the navigation of busy roads and lots of people, and night time driving in darkness will likely lead to mental compensation to navigate safely despite reduced visibility. The 40% decrease in collisions with VRUs as demonstrated in our research in the odd pairings distractor task clearly demonstrates the potential benefit of direct vision to VRU safety.

Given the continual and ever increasing preference of both manufacturers and vehicle owners installing more technology into vehicles, it is arguable that distraction and experience of cognitive load placed on drivers will increase in coming years. Our research implies that with these additions comes the increased likelihood of a collision due to increased reaction times. It may not be possible or desirable to prevent technology being added to HGVs, but the negative, potentially lethal consequence of this could be mitigated through HGV cab re-design and enhanced direct vision.

8 Recommendations for Next Steps

A number of questions have emerged from the current study, which would benefit from further exploration in the near future.

Salience

An outstanding question is how salience (visibility) of VRUs affects an HGV driver's capacity to detect them and then respond appropriately. In our study drivers were considerably slower in the reaction time task when the stimuli had low-salience (grey stimuli vs. bright blue stimuli). Similar effects have been reported within a real-world driving context, with Wood et al. (2003) concluding that only 5% of darkly clothed pedestrians were identified at night, in the presence of the glare of oncoming headlights. Our findings, in combination with this study suggest that if VRUs are wearing dark colours, particularly during night time conditions, the probability of slow detection (and therefore increased chance of collision) is higher.

We removed this potential confound from our experiments by equipping both our cyclist and pedestrian with only one set of clothes (therefore one level of saliency), however, it would be valuable to examine the effect of salience in its own right. Exploring how different levels of VRU salience interact with the ability to view a VRU directly vs. indirectly has the potential not only prompt cyclists to 'dress for safety' on the roads, but also improve our understanding of why VRU collisions occur. These findings indicate that our fundamental ability to detect someone can be influenced simply by what they are wearing – make them more salient and the probability of a collision can be reduced. These experiments indicate that when a VRU is wearing dark clothing it becomes increasingly important that the VRU is viewed directly rather than indirectly. Further improved understanding of the true nature of these matters may prevent future incidents and build the case for changes to both HGV design and cyclist behaviour.

Examining the benefits of the side window

The current experiments do not reveal conclusive evidence regarding the benefits of direct vision through a side window.

Looking through the side window (and away from the desired direction of travel) may aid VRU detection, but it could also have a negative impact on the driver's ability to stay on track when driving at greater speed. It has been demonstrated that driving ‘where we look’ and ‘where we steer’ are tightly coupled (we ‘look where we want to steer’ but also ‘steer where we are looking’; Wilkie & Wann, 2003; Wilkie et al., 2010). This may have implications for the use of direct vision through glass-doors since looking directly at a VRU requires large turns of the head, and so could impair the driver's ability to maintain their current direction when driving at speed. We believe that further research may be needed better define all components of the optimum cab design – a side window or glass door panel will not allow a driver to see what is approaching from behind him, only to better observe what is adjacent.

It should be noted that the observed benefits of direct vision through the front windscreen were present even at low speed. It may, similarly, be the case that direct vision through the side door has most benefit at slow driving speeds when there is a VRU moving alongside the HGV (in a fixed position relative to the HGV). Further research is required to understand the potential benefits of direct vision through side windows.

Driver Distraction

In our simulation adding a cognitive load resulted in slower reaction times for both direct and indirect vision conditions, but with a greater number of simulated collisions under indirect vision conditions.

We designed the odd pairings distractor task to simulate core components of driver distraction (i.e. requiring the driver to look, think, and respond to a secondary task). Specifically the task (an odd pairings distractor task) added a gaze load (looking at something other than the road ahead), a visual load (reading and comparing the two digits), and the motor load (responding by pressing the button). It is currently unclear if each component is important in reducing the driver's capacity to respond rapidly and appropriately to the appearance of a VRU or whether certain aspects of the task were more disruptive than others. In particular we would like to understand whether certain cognitive tasks are particularly problematic when relying on indirect vision to detect VRUs. These factors may be influential in evaluating the potential impact of introducing further information to the HGV driver via VDUs. Whilst there are potential benefits in terms of reducing/removing blind spots and warning drivers of VRUs, there are also potential costs of the driver looking away from the road.

There are other types of cognitive distraction that we have not examined that may also have an impact on VRU detection via Indirect vision: for example verbal, auditory and spatial loads that map to common in-vehicle distractions (e.g. talking hands free on the phone, listening to the radio, examining a GPS map etc.). For example, it might be predicted that a driver's ability to be spatially attentive to the scene could be diminished if they must conduct a task involving spatial cognition (such as altering the view of a camera displayed on an in-cab VDU). There are currently proposals to add a variety of warning signals to warn drivers of VRU in close proximity to their vehicle, however, each warning signal will add to the already significant cognitive load placed upon the driver.

Future research should provide a solid underpinning of future policy decisions around the use and deployment of in-cab devices (such as warning signals and in-vehicle information systems). Rather than relying upon accident statistics, the experimental setup described in the current report would be ideal for examining the safety implications of these systems BEFORE they are deployed in actual working vehicles.

Driver Experience, Learning and Training

Experienced professional HGV drivers exhibited the same pattern of reduced reaction times when responding to stimuli viewed directly vs. indirectly. However, it emerged from our findings that the reaction times of HGV drivers were slower than the non-HGV driving population. We believe that this was because the HGV drivers were on average 17 years older than our non-HGV drivers and there is evidence to indicate general age-related declines in reaction times.

It is possible, even probable, that HGV drivers use their experience to compensate to some degree for reduced reaction times due to indirect vision and increase age when detecting and avoiding VRUs. Unfortunately, there are always limits to such compensation, especially as the cognitive demands of driving environments increase. For example Raw et al. (2012) demonstrated that older adults can compensate fairly effectively (by slowing down) but their ability to compensate started to fail once they were forced to drive at faster speeds.

The average age of HGV drivers reflects the fact that there is currently a national shortage of trainee HGV drivers. Research that examines how best to train individuals to obtain expert driving skills when using the latest cab-designs could have huge implications for optimising HGV training and improving road safety. This is an avenue of research that would have vital economic benefits and practical importance for the haulage industry.

VRU Behaviour

In addition to the proposed future work exploring cab design and HGV driver training, it is essential to also consider VRU behaviour given that this can also influence the likelihood of a collision. Many HGV drivers commented in the survey (Section 4) that VRUs require education and training to safely navigate the roads around HGVs.

It would be interesting to explore VRU decision making regarding their interactions with HGVs:

- When they make the decision to step out in front of a HGV
- When they cycle up the inside of a HGV, particularly at a junction

Are these decisions informed by variables such as the speed at which the vehicle is moving, their distance from the vehicle, or the eye contact they make with the driver? Do VRUs understand the limits of vision for someone driving a HGV, do they think they can be seen when they can't.

An understanding of existing decision making behaviour would support the design of the most effective communication to the public, or even training for cyclists to bring about lasting behaviour change.

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10 Appendices

Appendix 1: Research Questions

Set 1 Research Questions:

1. Does direct vision improve: (i) reaction times, (ii) hazard detection, and (iii) driving accuracy?
    - Not just when driving.
    - Not just in response to VRUs.
2. Does spatial location of visual information impact on (i) reaction times, (ii) hazard detection, and (iii) driving accuracy?
3. Does driver height proximity to the road / road users impact on (i) reaction times, (ii) hazard detection, and (iii) driving accuracy?
4. Does visual cognitive overload impact on (i) reaction times, (ii) hazard detection, and (iii) driving accuracy?

Set 2 Research Questions:

1. Does direct eye-contact impact on (i) reaction times, (ii) hazard detection, and (iii) driving accuracy?
2. Does direct eye-contact create feelings of empathy?
    - Do feelings of empathy impact on (i) reaction times, (ii) hazard detection, and (iii) driving accuracy?

Appendix 2: Survey Questions

10.1.1 HGV Driver Survey

HGV Driver Survey

Page 1: Introduction

Thank you for taking the time to complete this survey on road safety. We are interested in understanding your views on the role of eye-contact on safety outcomes between HGV drivers and vulnerable road users (VRUs) such as pedestrians and cyclists. We are also interested in better understanding HGV drivers' attitudes towards vehicle elements such as mirrors, visual display units (VDUs) and the design of the vehicle. We ask that in completing this survey you think about your recent and general experiences of operating a HGV. Your responses will provide us with valuable information regarding road safety and interactions between road users. This survey is not intended to change or influence your driving behaviour. Currently the impacts of making direct eye-contact with VRUs are **UNKNOWN** and we stress the importance that participants **DO NOT** carry out new or unsafe road behaviours as a result of this survey.

All responses are entirely confidential and you will not be identifiable. The survey should take approximately 10-15 minutes to complete. Thank you for time and cooperation. If you have any questions please contact lucy.philips@arup.com.

I understand the purpose of this survey and consent to my answers being used confidentially and anonymously as part of the data analysis.

Page 2:

Age:

Gender:

Years driving Heavy Goods Vehicles (HGVs)?

Do you drive the same of differentvehicles each day?

What type(s) of vehicle(s) do you drive as part of your job?

If you selected other, please specify:

What Industry do you work in?

What are your typicalDriving routes:

Do you drive the same routes daily?

Page 3:Mirrors

I use al mirrors available to me.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I consider some mirrors more important than others for safe driving.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

If 'agree' or 'strongly agree', please rank the mirrors in order of importance:

Please don't select more than 1 answer(s) per row.

	1	2	3	4	5	6
Class I (Interior rear view mirrors)	☐	☐	☐	☐	☐	☐
Class II (Main exterior mirrors)	☐	☐	☐	☐	☐	☐
Class III (Main exterior mirrors)	☐	☐	☐	☐	☐	☐
Class IV (Wide angle mirrors)	☐	☐	☐	☐	☐	☐
Class V (Close proximity mirrors)	☐	☐	☐	☐	☐	☐
Class VI (Front mirrors)	☐	☐	☐	☐	☐	☐

Depending on road conditions (traffic, speed of travel, urban/rural roads) I rely on certain mirrors more than others.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

If 'agree' or 'strongly agree', please select the mirrors that you feel are most relevant for certain conditions:

Please don't select more than 6 answer(s) per row.

	Class I (Interior rear view)	Class II (Main exterior)	Class III (Main exterior)	Class IV (Wide angle mirrors)	Class V (Close proximity mirrors)	Class VI (Front mirrors)
Heavy traffic	☐	☐	☐	☐	☐	☐
Speed of travel	☐	☐	☐	☐	☐	☐
Urban roads	☐	☐	☐	☐	☐	☐
Rural roads	☐	☐	☐	☐	☐	☐
Duel carriage way driving	☐	☐	☐	☐	☐	☐
Motorway driving	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐

If other, please add details below:

I check that all mirrors are set up accurately before driving the vehicle.

It is crucial to set up mirrors to my needs accurately before driving.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

The vehicle's mirrors provide me with a sufficient view of the surrounding area to a low me to identify:

Please don't select more than 1 answer(s) per row.

	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
Cyclists at the front of the vehicle	☐	☐	☐	☐	☐
Cyclists at the driver side of the vehicle	☐	☐	☐	☐	☐
Cyclists at the passenger side of the vehicle	☐	☐	☐	☐	☐
Cyclists at the rear of the vehicle	☐	☐	☐	☐	☐
Pedestrians at the front of the vehicle	☐	☐	☐	☐	☐
Pedestrians at the driver side of the vehicle	☐	☐	☐	☐	☐
Pedestrians at the passenger side of the vehicle	☐	☐	☐	☐	☐
Pedestrians at the rear of the vehicle	☐	☐	☐	☐	☐

There are too many mirrors on my vehicle to keep track of when monitoring cyclists and pedestrians around my vehicle.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

There are blind spots around my HGV.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I sometimes find it difficult to recognise cyclists in my mirrors.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I sometimes find it difficult to recognise pedestrians in my mirrors.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

My response to a road user seen through a mirror is slower than my response to those seen through a window.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Assessing the specific location of a road user and responding to it is more difficult through mirrors.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Page 4: Visual Display Units

Is your vehicle fitted with a visual display unit (VDU), allowing you to see a camera-view of a blind spot on your vehicle?

How many VDUs are located in your HGV cab?

How many cameras do they present images from?

Who positioned these devices?

The VDU enhances driving safety, as I am able to see road users in areas I would not otherwise be able to see.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I find the VDU easy to use.

I ensure my VDU is set up appropriately- a lowing me a clear view of my blind spots before I begin my journey.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I frequently look at the VDU while driving.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Glancing at the VDU can sometimes cause me to miss information on the road ahead.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I get distracted by the presence of the VDU in the vehicle.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I find it difficult to accurately locate road users in relation to my vehicle based on a VDU screen.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I can think of a time I have failed to recognise cyclists in my VDU.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I can think of a time when I have failed to recognise pedestrians in my VDU.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

My responses to road users as seen in VDUs are slower than my responses to those seen through a window.

Page5: Window

Increasing the size of windows would provide me with a better view of cyclists and pedestrians.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Increasing the size of windows would support me in making decisions to avoid co lisions with cyclists and pedestrians.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I am more likely to accurately identify road users through my windows than through my mirrors.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I am more likely to accurately identify road users through my windows than through my VDU.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I am more likely to accurately identify road users through my mirrors than through my VDU.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I feel that I am too high up from the road to be able to accurately identify road users to the front of my HGV.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I feel that I am too high up from the road to be able to accurately identify road users to the sides of my HGV.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Do you think that a lower driving position would alow you to enable you to more easily detect other road users.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Page 6: Eye-Contact

I try to make eye-contact with road users to let them know that I have seen them.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

43 When I make eye contact with other road users I:

Please don't select more than 1 answer(s) per row.

	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
Proceed with my route, confident that they are aware of my vehicle	☐	☐	☐	☐	☐
Want them to understand that I am about to make a manoeuvre	☐	☐	☐	☐	☐
Believe that the risk of us co liding is reduced	☐	☐	☐	☐	☐
Value the social interaction	☐	☐	☐	☐	☐

In a situation where I have not been able to make eye contact with road users around me I:

Please don't select more than 1 answer(s) per row.

	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
Proceed with my route or manoeuvre	☐	☐	☐	☐	☐
Wait for the pedestrian to acknowledge my location before proceeding with my route or manoeuvre	☐	☐	☐	☐	☐
Feel that there is no increased likelihood of collision	☐	☐	☐	☐	☐

I avoid eye-contact with road users in the vicinity of my vehicle.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I notice when road users make eye-contact with me.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

I am easily able to make eye-contact with road users from the cab.

Strongly Agree	Agree	Neither Agree or Disagree
Disagree	Strongly Disagree	

Risk of collisions between vehicles and road users would be reduced if the design of the vehicle were changed to include the below features (select from list):

Page 7: Qualitative Questions

Prior to driving, do you have a standard routine for checking the vehicle vision characteristics? (E.g. correct seating position, mirrors adjusted and clean, VDU working, etc.)

Do you think eye-contact between cyclists/pedestrians and HGV drivers is important? If so, why?

When walking or cycling, do you seek to make eye contact with HGV drivers you encounter?

Any other comments?

Page 8: Thank you

Thank you for taking the time to complete this survey on road safety. Your responses will provide us with valuable information regarding road safety and interactions between road users.

This survey is not intended to change or influence your driving behaviour. Currently the impacts of making direct eye-contact with Vulnerable Road Users are **UNKNOWN** and we stress the importance that participants **DO NOT** carry out new or unsafe road behaviours as a result of this survey.

Alle responses are entirely confidential and you will not be identifiable.

Thank you for time and cooperation, if you have any questions please contact:
lucy.philips@arup.com

10.1.2 Pedestrian Survey

VRU - Pedestrians Survey

Page 1: Introduction

Thank you for taking the time to complete this survey on road safety. We are interested in understanding your views on the role of eye-contact on safety outcomes between HGV drivers and more vulnerable road users such as pedestrians and cyclists. We ask that in completing this survey you think about your recent and general experiences of trave ing in close proximity to the road. Your responses wi provide us with valuable information regarding road safety and interactions between road users. This survey is not intended to change or influence your walking behaviour. Currently the impacts of making direct eye-contact with HGV drivers are **UNKNOWN** and we stress the importance that participants **DO NOT** carry out new or unsafe road behaviours as a result of this survey.

A responses are entirely confidential and you wi not be identifiable. The survey should take approximately 5 minutes to complete. Thank you for time and cooperation. If you have any questions please contact lucy.phi ips@arup.com.

I understand the purpose of this survey and consent to my responses being used confidentia ly and anonymously to inform this research.

Page 2: Pedestrian survey

Age:

Gender:

Do you have a driving licence?

If yes, how regularly do you drive?

Please rate the fo lowing statements:

Please don't select more than 1 answer(s) per row.

	Agree Strongly	Agree	Neither Agree or Disagree	Disagree	Disagree Strongly
I trust that HGV drivers can see me through their mirrors	☐	☐	☐	☐	☐
I feel confident passing a vehicle when a driver can see me through their mirrors	☐	☐	☐	☐	☐
I feel confident passing a vehicle when a driver can see me directly through a window	☐	☐	☐	☐	☐
I trust that HGV drivers can see me approaching or passing through their camera display units	☐	☐	☐	☐	☐
Drivers who are positioned closer to the road (e.g. bus drivers) can see me more easily than those in higher cabs (e.g. HGVs) when I am in front of the vehicle	☐	☐	☐	☐	☐

Drivers who are positioned closer to the road (e.g. bus drivers) can see me more easily than those in higher cabs (e.g. HGVs) when I am to the side of the vehicle	☐	☐	☐	☐	☐
Drivers who have larger windows and ‘bus-style’ transparent doors (e.g. bus drivers) can see me more easily than those in cabs with solid doors (e.g. HGVs).	☐	☐	☐	☐	☐
HGV drivers ignore cyclists and pedestrians.	☐	☐	☐	☐	☐
I actively make eye-contact with HGV drivers.	☐	☐	☐	☐	☐
Making eye-contact with HGV drivers reassures me that they are aware of my presence.	☐	☐	☐	☐	☐
Making eye-contact with HGV drivers makes me feel safer when passing the vehicle	☐	☐	☐	☐	☐
I have noticed that HGV drivers often try to make eye-contact with me.	☐	☐	☐	☐	☐

I make eye contact with drivers through their mirrors.	☐	☐	☐	☐	☐
I make eye contact with HGV drivers specifica ly through their mirrors.	☐	☐	☐	☐	☐
I make the same amount of eye contact with HGV drivers regardless of whether I am cycling, walking or driving	☐	☐	☐	☐	☐

When walking, do you seek to make eye contact with HGV drivers you pass or who pass you?

Why?

Do you think eye contact between pedestrians and HGV drivers is important?

Why?

When driving a car or motorbike, do you seek to make eye contact with cyclists and pedestrians?

Why?

Page 3: Thank you

Thank you for taking the time to complete this survey on road safety. Your responses wi provide us with valuable information regarding road safety and interactions between road users. This survey is not intended to change or influence your walking behaviour.

Currently the impacts of making direct eye-contact with HGV drivers are **UNKNOWN** and we stress the importance that participants **DO NOT** carry out new or unsafe road behaviours as a result of this survey.

A responses are entirely confidential and you wi not be identifiable. Thank you for time and cooperation, if you have any questions please contact lucy.phi ips@arup.com.

10.1.3 Cyclist Survey

VRU - Cyclists Survey

Page 1: Introduction

Thank you for taking the time to complete this survey on road safety. We are interested in understanding your views on the role of eye-contact on safety outcomes between HGV drivers and more vulnerable road users such as pedestrians and cyclists. We ask that in completing this survey you think about your recent and general experiences of trave ing on the road. Your responses wi provide us with valuable information regarding road safety and interactions between road users. This survey is not intended to change or influence your cycling behaviour. Currently the impacts of making direct eye-contact with HGV drivers are **UNKNOWN** and we stress the importance that participants **DO NOT** carry out new or unsafe road behaviours as a result of this survey.

A responses are entirely confidential and you wi not be identifiable. The survey should take approximately 5 minutes to complete. Thank you for time and cooperation. If you have any questions please contact lucy.phi ips@arup.com.

I understand the purpose of this survey and consent to my responses being used confidentia ly and anonymously to inform this research.

Page 2: Cyclists survey

Age:

Gender:

Do you have a driving licence?

If yes, how regularly do you drive?

How long have you been cycling on the roads?

How many cycle journeys do you make each week?

Do you cycle the same or different routes each day?

What are your reasons for cycling?

If you selected Other, please specify:

Please rate the fo lowing statements:

Please don't select more than 1 answer(s) per row.

	Agree Strongly	Agree	Neither Agree or Disagre e	Disagree	Disagre e Strongly
I trust that HGV drivers can see me through their mirrors	☐	☐	☐	☐	☐
I feel confident passing a vehicle when a driver can see me through their mirrors	☐	☐	☐	☐	☐
I feel confident passing a vehicle when a driver can see me directly through a window	☐	☐	☐	☐	☐
I trust that HGV drivers can see me approaching or passing through their camera display units	☐	☐	☐	☐	☐

Drivers who are positioned closer to the road (e.g. bus drivers) can see me more easily than those in higher cabs (e.g. HGVs) when I am in front of the vehicle	☐	☐	☐	☐	☐
Drivers who are positioned closer to the road (e.g. bus drivers) can see me more easily than those in higher cabs (e.g. HGVs) when I am to the side of the vehicle	☐	☐	☐	☐	☐
Drivers who have larger windows and 'bus-style' transparent doors (e.g. bus drivers) can see me more easily than those in cabs with solid doors (e.g. HGVs).	☐	☐	☐	☐	☐
HGV drivers ignore cyclists and pedestrians.	☐	☐	☐	☐	☐
I actively make eye-contact with HGV drivers.	☐	☐	☐	☐	☐
Making eye-contact with HGV drivers reassures me that they are aware of my presence	☐	☐	☐	☐	☐

Making eye-contact with HGV drivers makes me feel safer when passing the vehicle	☐	☐	☐	☐	☐
I have noticed that HGV drivers often try to make eye-contact with me.	☐	☐	☐	☐	☐
I make eye contact with drivers through their mirrors.	☐	☐	☐	☐	☐
I make eye contact with HGV drivers specifica ly through their mirrors.	☐	☐	☐	☐	☐
I make the same amount of eye contact with HGV drivers regardless of whether I am cycling, walking or driving	☐	☐	☐	☐	☐

When cycling, do you seek to make eye contact with HGV drivers you pass

Why?

Do you think eye contact between cyclists and HGV drivers is important?

Why?

When driving a car or motorbike, do you seek to make eye contact with cyclists and pedestrians?

Why?

Page 3: Thank you

Thank you for taking the time to complete this survey on road safety. Your responses wi provide us with valuable information regarding road safety and interactions between road users. This survey is not intended to change or influence your cycling behaviour.

Currently the impacts of making direct eye-contact with HGV drivers are **UNKNOWN** and we stress the importance that participants **DO NOT** carry out new or unsafe road behaviours as a result of this survey.

A responses are entirely confidential and you wi not be identifiable. Thank you for time and cooperation, if you have any questions please contact lucy.phi ips@arup.com.

Appendix 3: Pedestrian Survey Analysis

61% of Pedestrians do not trust that drivers can see them through their mirrors. 77% feel confident when they can be seen directly through windows whereas only 31% feel confident that they can be seen through their mirrors. Only 16% trust that HGV drivers can see them approach through their VDUs. Majority agree that drivers who are positioned closer to the road can see me more easily than those in higher cabs when they are to the front (80%) and side (67%) of the vehicle. Furthermore 91% agree that drivers who have larger windows and 'bus style' doors can see them more easily than those in cabs with solid doors. 75% agree that making eye-contact with HGV drivers reassures them of their presence and 72% agree that this makes them feel safer. Only 3% of pedestrians agree to actively making eye contact with HGV drivers through their mirrors.

Qualitative Pedestrian Responses.

Question 7. When walking, do you seek to make eye contact with HGV drivers you pass or who pass you?

Yes	No
• 50.5% of pedestrians agree that when walking they make eye contact with HGV drivers who pass while 49.5% Disagree. • This result is interesting as almost half of pedestrians seek eye contact and the other half does not. • Furthermore it does not reflect an earlier question regarding making eye contact where 32% disagreed to making eye contact while 48% agree and 20% neither agreed nor disagreed. • These findings highlight the ambiguity of this issue with regards to pedestrians. • This inconsistency is worth noting as it may be that pedestrians are not often in situations where they encounter HGVs.	• Of those who report making eye contact reasons for doing so are to create **awareness, recognition and reassurance.** • An interesting response to emerge was "I work on a site with a lot of HGVs and its part of the advice issued by my employer" suggesting that making eye contact is encouraged within some industries. • Responses that were against making eye contact included reasons such as lack of necessity, feasibility and never thought to do it. • Respondents draw on the practicalities of achieving eye contact with HGVs from their positions as pedestrians for instance "Can't usually see them to make eye contact because they are so high and moving too quickly past me".

Question 8. Do you think eye contact between pedestrians and HGV drivers is important? If so, Why?

The majority (72%) of pedestrians feel that eye contact between HGV is important. When asked to expand on why respondents felt eye-contact between HGV drivers and pedestrians is important**, responses covered safety, human interactions, awareness and recognition as well as unimportant or dangerous.**

Awareness	Human Connection	Not Important
• **Awareness and Recognition as a result of eye contact emerged as an important category. Most responses, suggested awareness and recognition by HGV drivers through eye-contact was important.** • **Many responses stated being seen by drivers instilled confidence and confirmation that drivers had seen pedestrians.** • **For example "*Confirmation that the driver has acknowledged your presence*".** • **Responses suggest that driver awareness of pedestrians is important for road safety and eye-contact facilitates this recognition** • **Responses suggested Safety as a reason why eye-contact between HGV drivers and pedestrians was important.** • **Respondents reasoned that making eye-contact with HGV drivers generates feelings of safety, responses included "*would make me feel safer"* and *"I would feel***	• Eye Contact was said to create a human connection for instance; "*To know that we have seen each other. Makes us more human".* • This idea was supported by another's response "*Its about mindset. People may see me through a video camera, but not feel that human connection to me. Instinctively, it just seems better for me that drivers are able to make human contact in their work and so remember that they are interacting with living breathing people, not representations on a screen."* • However, it should be noted that a 'human connection' was referred by few respondents.	• Approximately 28% of responses, were against the importance of eye-contact between HGV drivers and pedestrians. • Qualitative explanations suggest that making eye-contact with HGV drivers is not possible "*There are too many pedestrians crossing at once for an HGV driver to make eye contact with them"*. • It was further suggested by one respondent that eye-contact can serve as a distraction to the driver. *"If every pedestrian tried to make contact with the driver, the driver would be too distracted to actually operate the vehicle".* • The theme of this section suggests that eye-contact between HGV drivers and cyclist is not usually possible and if so it can detract from road safety.

safer crossing if I knew they could see me". • **It was further suggested by respondents that making eye-contact reduces risks of accidents for example one response states; "*it surely helps reduce the likelihood of an accident if you have seen each other***		

A category of responses has been labelled 'Un-Themed' as it contains a variety of responses, both positive and negative that do not fit in with the previously discussed themes. Comments suggest that the circumstances under which eye-contact is made is important for safety outcomes. This can be seen in comments such as "mostly No but depends on the circumstances". Respondents suggest a variety of circumstances that may influence the role of eye-contact ranging from pedestrian behaviours and conditions to HGV and other drivers such as cars and motorcycles. "It's no more important than with car, motorbike, cyclist or other road user".

Question 9. When driving a car or motorbike, do you seek to make eye contact with cyclists and pedestrians? If so, Why?

Yes	No
• **The majority of respondents reported yes to seeking to make eye-contact with cyclists and pedestrians.** • **Reasons include facilitating awareness and interactions with VRUs.** • **Within this category there appears to be different reasons for making eye contact although they are related.** • **The majority of participants state that eye contact facilitates an awareness between road users and that this awareness has important safety implications.** • **A small proportion of respondents refer to a subtle, communicative act that eye contact creates. Stating things**	• 66% of pedestrians agreed that when driving a car or motor bike do you seek to make eye contact while 34% Disagreed. • Of the responses against seeking eye-contact as a driver, reasoning included concentrating on driving and the road ahead. • Some respondents suggested certain road traffic conditions where making eye-contact was possible such as Zebra crossings but stated the difficulty of making eye-contact in a moving vehicle. • To sum up one participant stated *"A host of reasons - distance, practicality,*

like *"I can understand their intentions better"* and *"It helps me read their intentions".* • **Unlike those against making eye-contact this category of responses suggests a mutual understanding between drivers and VRUs as a result of making eye-contact. Comments include *"so they know I have seen them"* and "*If I see that a pedestrian or cyclist is about to move into my path, I try to make eye contact to ensure they know my intention not to stop".*** • **Hence within the support for making eye contact category it appears two different understandings of eye-contact have emerged. Overall in these category reassurance, recognition and communication emerged from the collected responses as reasons for making eye-contact with VRUs from the perspective of a driver. However the way people understand these concepts in light of eye-contact varied**	*numbers, positioning. More importantly the need to drive the vehicle and monitor other motorised vehicles which pose more of an immediate threat on the road."* This line of reasoning is similar to that of the previous section

Appendix 4: Cyclist Survey Analysis

81% of Cyclists surveyed do not trust that HGV drivers can see them in their mirrors. 47% do not feel confident that a driver can see them in their mirrors as they pass the vehicle. More than half of respondents, 51% feel confident passing a vehicle when they can be seen by the driver directly through the windows. 73% disagree that HGV drivers can see cyclists approaching through their VDUs. 89% Agree or Strongly Agree that drivers who are positioned closer to the road can see better than those in higher cabs. 86% Agree that drivers who have larger 'bus style' doors can see them more easily than those in cabs with solid doors. 64% actively make eye contact with HGV drivers and 73% feel reassured that by making eye contact with drivers they are reassured of their presence. 68% report to feeling safer passing the vehicle after making eye contact. 14% agree to actively making eye-contact with HGV drivers through their mirrors.

Qualitative Cyclist Responses

Question 11. When cycling, do you seek to make eye contact with HGV drivers you pass? Why?

Responses can be categorized into For and Against making eye contact with HGV drivers.

For	Against
• In the 'For' category responses generally indicate support for making eye-contact with HGV drivers to ensure respondents have been seen by the driver. • One participants states *"Making eye contact reassures me that the driver has seen me and therefore will take more care i.e. be more conscious that I am on the road and drive/manoeuvre more considerately and less brashly."* • This comment illustrates the general consensus among the 'For' category. • Many respondents feel that making eye-contact with HGV drivers makes drivers aware of their presence and ensures their safety	• The 'Against' category contradicts this conclusion. • In this instance respondents outline the difficulties and dangers of making eye-contact with HGV drivers. • For example; "*Rarely in a position where it's practical, HGV windows/mirrors are often higher than my normal sight line".* • Furthermore one participant notes the dangers of taking one's eyes off the road *"takes my eyes off the road in front - in central London, a lot can happen in front in half a second!"*

Question 12 Do you think eye contact between cyclists and HGV drivers is important? Why?

Analysis of Q12: Although only 56% report to making eye contact with HGV drivers 81% believe that making eye contact with HGVs is important. Qualitative responses to this have been divided into 3 categories; Of little importance, Human Interaction and Awareness.

Awareness	Human Interaction	Not Important
• Many participants described making eye-contact as important because it was reassuring to see the driver and to know (from making eye-contact) that the driver had seen them. • This reassurance was explicitly stated and alluded to through comments about awareness and mutual recognition. • This awareness was suggested to lead to safer outcomes and feelings of safety among participants. Comments include; *“It acts as acknowledgment that they have seen me”* *“If I know they've seen me I feel safer”*	• Another category to emerge was the Human Interaction eye-contact facilitates between cyclists and HGV drivers. • Respondents stated a link in making eye-contact and creating a human interaction and what such a connection evokes. • The value of this human interaction was further suggested by participants. • For instance one participant wrote; *“There is something human about it – something polite, something helpful. It is about creating a mind-set of consideration and concern, which requires human contact”* • However, this category represented 11% of responses.	• In the ‘Of Little Importance’ category respondents stated the difficulties with achieving eye-contact and the dangers of being in a position where making eye-contact with a HGV was possible. • Some respondents felt that making eye-contact was ambiguous in its effects. • For example one respondent states; *“It’s important but not entirely meaningful- just because they seem to be looking at you doesn’t mean they’re paying you any attention, or have even consciously registered you. It’s still of primary importance for the cyclist safety to not end up in a dangerous road position (regardless of whether it was the cyclist or driver that creates the situation) and to have an awareness of potential hazards so you can avoid them, like if an HGV starts pulling right at a junction the are probably swinging wide for a left turn and you should stay well away.”*

Question 13. When driving a car or motorbike, do you seek to make eye contact with cyclists and pedestrians? Why?

For	Against
• Majority of respondents agreed that when driving they seek eye-contact with cyclists and pedestrians. • Comments elaborating on this have been grouped into categories; Recognition, Not Important and Safety. • Responses indicate that drivers make eye-contact with pedestrians and cyclists to let them know that have been seen and recognised. Comments would suggest that this a two way stream of communication, for instance one participant wrote; "*Mutual understanding of each other's presence*" and another *"It helps to assure both parties that have noticed each other and are paying attention."* • From responses collected it appears that making eye-contact is seen as a method of communicating with pedestrians and cyclists to let them know they have been seen on the road. • Comments suggest the benefits of being recognised through eye contact.	• Respondents also have highlight the safety implications of making eye-contact for example one participant states*; "As both a truck, car, motorcycle and bicycle driver and rider I know what it's like on both sides of the fence here. Whatever I can do in whatever capacity I can do it to make all of our journeys safer, I will. When I'm driving, if I actively seek out cyclists and pedestrians and I can see they're looking at me, we both know where we are and we're safer for it*." This comment illustrates the perceived importance of making eye-contact for safety outcomes. • As with the previous questions some participants feel that eye contact between drivers and VRUs is not important. Stated reasons for this include the dangers of taking eyes off the road and the circumstances.

Appendix 5: HGV Survey Analysis

The general trend in the data is that most drivers are satisfied with the current use and functionality of mirrors.

Mirrors & VDUs	Windows.	Vehicle Height
• 51% agree that mirrors are sufficient for providing visibility at the rear of the vehicle. • Very similar trend when asked about pedestrians (88%, 87%) and 50% at rear. • 78% agree that there are blind spots. 67% disagree that there are too many mirrors to keep track of when monitoring VRUs. • Interestingly 48% of HGV drivers agreed to sometimes finding it difficult to recognise cyclists in mirrors while 46% disagreed with this statement. • Suggesting that among HGV drivers there are differences in effects/ demands of mirrors but 46% disagree and 78% disagree that responses are slower to road users seen in mirrors than windows • 87% agree that VDUs enhance driving safety by making road users who would otherwise be invisible to them, visible. • 72% frequently look at the VDU when driving. • There is disagreement in attitudes regarding the risks of VDUs,	• Regarding increasing the size of drivers windows responses are split. • 41% of HGV drivers Agree that increasing the size of windows would support them in making decisions to avoid collisions with cyclist and pedestrians while 30% disagree. • 32% agree to be more likely to identify road users through windows than mirrors and 36% disagree. • Furthermore 41% agree that increased window size would support drivers in making decisions to avoid collisions with • VRUs while 33% disagree.34% are more likely to identify road users through their windows than through mirrors. • 45% of Drivers are more likely to identify road users through windows than VDUs while 28% disagree.43% agree to being more likely to accurately identifying road users through windows than VDUs. • It would appear that there are two categories within HGV drivers for and against larger windows.	• The majority of drivers are satisfied with the current height of vehicles with 72% disagreeing that they are too high up to accurately identify road users to the front of the vehicle. • When drivers cannot make eye contact 39% Disagree that there is no increased chance of collision while 24% agree. • 19% of HGV drives value the social interaction as a result of making eye contact. • The vast majority (78%) agree that they are easily able to make eye-contact from the cab.

43% disagree that VDUs cause drivers to miss information and 33% agree.		

Any Other Comments:

When asked to provide any other comments, a trend emerged where HGV drivers stated the importance of training cyclists to be eligible for the roads. Respondents made an argument for educating cyclists. Some comments suggest that lowering vehicle windows is not a safety precaution and by adding VDUs it increases the distraction faced by drivers. HGV drivers also provided qualitative comments on the design of cabs, raising the following perceived risks: VRUs experience false sense of security as a result of larger windows, Driver distraction by numerous mirrors and VDUs, Reduced driver safety as a result of lowered cab.

"Nearside door windows will give cyclists a ***false sense of security****. For the driver they will only offer limited field of vision, and there are also issues if they prevent the nearside window from being lowered. On my vehicle there are no blind spots on the nearside. I also have a* ***fresnel lens*** *which is very good. These should be designed into the window glass"*

Eye contact creates a human connection and communicates behaviour	Eye contact is an acknowledgment of one another's presence	Making eye contact with HGV drivers is impractical and dangerous	Un-themed
1. There is something human about it - something polite, something helpful. It is about creating a mindset of consideration and concern, which requires human contact. 2. If they know I am a human they won't squish me 3. It helps to form a relationship between you and the driver 4. They mentally clock you're in front of them and to give you a second to get away. 5. Make them aware what we want to do (straight on or turning etc.) 6. It makes both of us realise each other is a human 7. It reminds them both that they are human beings sharing a road 8. Once I catch their eye, I can give an indication of where I'm going and they usually acknowledge it. If they don't, I don't do whatever it was that I was indicating. 9. You can read each other's intent and make gestures.	1. It's reassuring 2. It's vitally important!! No matter what technology is used to improve vision, a HGV driver will always have some blind spots. On that, cyclists must understand that making eye contact is vitally important so they are not cycling in mentioned blind spots. 3. If I can see the driver, and I can see that the driver can see me, we know where each of us is and are less likely to get in each other's way. 4. Mutual awareness of each other's presence 5. If you can see someone's eyes - you know they can see you. What both cyclists and HGV drivers do after that is what matters 6. It depends on the circumstance but I know HGV drivers have loads of different checks to make before the manoeuvre, and I don't think you can take it for granted that they will have been looking in your direction and seen you otherwise. 7. Yes- as it is one form of confirming and receiving reassurance that each actor has acknowledged the presence of the HGV and Cyclist on the road. 8. So that they know you are there. 9. Reassurance they see me and therefore will let me pass/not run me over. 10. Reassurance, acknowledgement, understanding and awareness that you are there and seen as a person 11. It helps to reassure cyclists 12. So they acknowledge you 13. It confirms that each are looking out for each other, and aware of each other's presence on the road. 14. To gauge whether they have seen me.	1. Eye contact is difficult to achieve 2. I don't think it is worst cyclists time to attempt to make eye contact with HGV drivers, as HGV drivers are a lot further from the road than other drivers and much harder to look 3. It is too difficult and the opportunity passes too quickly. 4. Need to be aware of all around not just focusing on one individual 5. At a distance and through glass it would be impossible to be absolutely certain that they'd seen you. Better to just avoid being in a position of danger in relation to an HGV. Getting into a position where it's even possible to make eye contact is almost certainly going to be a position of danger. If you go to the side of a lorry with the hope of making eye contact and then the driver happens not to look at you or notice you would be in a very dangerous place. 6. I think if people are focusing on eye contact they are focusing their senses on something largely irrelevant and of little value. For example, a cyclist could be seeking eye contact but by doing so is distracting their other sense of surroundings, potentially causing an accident or worse. Actively seeking eye contact is dangerous for all road users. Focus on your surroundings and respect other road users around you (all road users!) 7. It takes eyes off other hazards and generally can only be done easily in slow face-to-face traffic flows. 8. Because you can't guarantee it. it's more important that the cyclist assesses the situation and then makes a decision on what to do	1. Eye contact shouldn't make any difference to what road users actually do (physical indication is more important, eye contact can help) 2. It makes me feel they are accountable for their next actions as they have looked directly at me. 3. If i know they've seen me i feel safer . 4. Because if a driver has seen a cyclist then it is less likely there will be an accident. 5. When at lights I feel more confident that I will be avoided if I have made eye contact. 6. But I have to say that I have seen no evidence of drivers changing their attitude because of having made eye contact 7. Because the ambiguity of right of way still remains. 8. It's important, but not entirely meaningful - just because they seem to be looking at you doesn't mean they're paying you any attention, or have even consciously registered you. It's still of primary importance for cyclist safety to not end up in a dangerous road position (regardless of whether it was the cyclist or driver that creates the situation) and to have an awareness of potential hazards so you can avoid them, like if an HGV starts pulling right at a junction they are probably swinging wide for a left turn and you should stay well away!

	15. For mutual recognition 16. Sometimes you can judge if HVG drivers have seen you 17. It acts as an acknowledgement that they have seen me 18. To know whether they've seen me 19. Eye contact triggers recognition and the conscience (where one exists). 20. recognition that one another are there, and makes you safer/more diligent 21. To know they have seen each other. 22. They realise you are there and bear you in mind even when they can't see you after 23. It would reassure me that they have seen me and reassure them that I am paying attention to them 24. I feel safer to know that I have made the driver aware of my presence. 25. Because HGV drivers need to know that cyclists and pedestrians exist. 26. Promotes awareness and confidence. 27. it's important as a means of acknowledgement 28. Making eye contact at least implies that both of us are aware of each other 29. To increase awareness of each other 30. confirmation that they have seen me if they look at me directly 31. Making eye contact is the only way of making sure a driver has seen you - if not, you may need to reposition yourself. 32. It is about awareness. As long as the other knows the person is there they can both use the road safely. 33. Eye contact is not the be all, being seen is the important thing. 34. to ensure they acknowledge my presence 35. if you can see them, they can see you 36. It is the only way to know for certain that the HGV drivers have seen you.	9. Eye contact with car drivers makes me feel safer. I'm not sure how I'd make eye contact with an HGV driver. 10. I think it is unlikely to happen on regular occasions and think it is safer to concentrate on watching the HGV itself to judge where it is going 11. You can't assume that a driver has seen you just because you can see the driver in the mirror. 12. Maybe from their perspective but inner city cycling does not allow you to 13. I think you need to challenge what is alleged to take place when a cyclist "makes eye contact" with a vehicle beside or behind her or him, because I seriously don't think it actually happens. 14. Because I'm busy looking everywhere. More over position my bike is more important than eye up HGV drivers 15. The reality of cycling in London is that space in limited. We are always going to at some point have to filter through traffic, as not all roads have dedicated (protected) cycle lanes. 16. It is hard to make eye contact 17. Yes, I believe it is important but it's not very easy to achieve and that is why I try to find other ways to make my way out of traffic. 18. Eye contact doesn't guarantee anything. They either see me or they don't, making eye contact doesn't mean they've noticed me more. 19. It gives a false sense of security to the cyclist. The best thing cyclists can do is to stay behind a HGVs. 20. I think potentially it is, and I do make eye contact when crossing the roads. However, I find it more difficult on the road, especially when you are on the side of a vehicle.	9. If I can't see them through the mirror, then they can't see me, but if I can see them in the mirror, it doesn't mean they have seen me unless there's been eye contact 10. Because you don't need to look at someone's eyes to see they are there. If someone is in bright clothing, they are easily seen, no eye contact necessary. I think it is more important for cyclists to be bright and eye catching rather than seeking to make eye contact with HGV drivers 11. To avoid accidents 12. Safety 13. I think eye contact would be a useful extra safety measure, but the most important thing for cyclists is to be very wary of HGVs. 14. Only way to be safe! 15. Safety but not crucial 16. Safety 17. If HGV drivers can claim 'sorry mate I didn't see you as I have a blind spot' and if judges accept that as an excuse, then there is no incentive for drivers to be more cautious. The blind spot 'get out of jail card' must be made something of the past. 18. To manage traffic flow. 19. As it makes the cyclist feel safer. 20. I am also an HGV driver - it is very important for me to know that a cyclist is taking the hazards associated with an HGV seriously; eye contact is the primary method of achieving this. 21. I think it can help. But I wouldn't put too much emphasis on this. I think separating cyclists and

	37. To ensure a shared knowledge that you have seen each other 38. Best way to determine recognition of each other 39. Eye contact helps ensure that drivers are aware of cyclists and indicates that both have taken account of the others road position 40. Acknowledgement of each other presence 41. To improve the chance of being seen. 42. So you can have confidence they have seen you 43. To reassure the cyclist they have been seen. 44. Makes sure that everybody is aware of everybody's presence 45. Acknowledges awareness of each other presence, and drivers are more likely to yield. 46. Confidence that HGV drivers can see me would make me feel safer.		HGVs (i.e. with dedicated cycle lanes) is way more important 22. Only when in front of them to make sure they have seen me. Not when behind or passing. 23. I have never thought about it
1. Yes, it makes sure that you've seen each other. It also tells me if the driver is looking to make a manoeuvre. I never assume I've been seen. 2. Mutual understanding of each other's presence, agree who goes first 3. Mutual exchange of awareness, and it is possible to convey information e.g. driver might wave me on or I could signal they can proceed 4. as with all road users, it's reassurance that you have been seen and that drivers will not pull out in front of you 5. It is the only way to know that you have been seen by a HGV driver. It also makes it more personal, so as a cyclists and as a driver you treat each other with more respect 6. it is the only way you can be sure you have been seen, is by noting the human reaction of eye contact. 7. When a driver makes eye contact with me, I feel more confident that they are aware of my position. They are less likely to turn into me. 8. Human nature to acknowledge through eye contact. 9. With eye contact, both cyclist and driver are making clear they are aware of each other's presence, so can take appropriate action to ensure the interaction of cycle and HGV can be safer. 10. If they see you they can take into account and move or make turns accordingly			
	1. To ensure both know they can make out the presence of the other. This applies at traffic lights but in general traffic it is key to keep my eyes on the road.		

Table 2: Pedestrian responses to Question 8. Do you think eye-contact between pedestrians and HGV drivers is important? If so, why?

Eye contact creates a human connection and communicates behaviour	Eye contact is an acknowledgment of one another's presence	Making eye contact with HGV drivers is impractical and dangerous	Un-themed
1. Its about mindset. People may see me through a video camera, but not feel that human connection to me. Instinctively, it just seems better for me that drivers are able to make human contact in their work and so remember that they are interacting with living breathing people, not representations on a screen. 2. to communicate each other's intention 3. again to try to make them aware of your presence. Also to get an idea or instruction as to what each are likely to do next 4. Increases pedestrian feeling of safety 5.it is a way of signalling intentions	1. So that HGV drivers register that someone is there 2.Reassurance for me that they have seen me and are going to slow down 2. It lets me know they've seen me. 3. I think eye contact between pedestrians and any moving vehicle at a point of danger is important. I know the rule of the road is to give way to pedestrains at pedestrian crossings - but unless I know a driver has seen me at that pedestrian crossing (i.e. we've made eye contact) there is no way I'm going to start bibmbling out into the road	1. My natural assumption is that as I am on the pavement, it is up to me to ensure I don't step out into the road in front of an HGV 2. Pedestrians are particularly hard to see and HGV drivers expect for them to wait until their manoeuvre is complete 3. HGV Drivers have a lot to consider when driving. They should most definitely anticipate pedestrians and cyclists but I appreciate that they can't always see (blind spots) and also cyclists are unpredictable and often	1. I don't feel that actual eye contact between the 2 parties is not necessary. I expect drivers to look out for pedestrians and as a pedestrian, I assume that drivers can't see me so I take the necessary pre 2. Rarely get a chance to make it cautions. 1. Because it is an unreasonable expectation to expect all people to behave to "objects" (be they people, vehicles or

6.Would make me feel safer 7.Communication	when I've got 50 tonnes of truck bearing down on me. That's just stupid. 4. It makes them aware of my presence 5. it 100% validates that they know you are there, rather than presuming they see you 6. Having spent time in a HGV I understand how difficult it is for drivers to see everything particularly behind them or next to the cab..on that, if eye contact can be maintained then this eliminates the chance of a collision 7. Safety - awareness of one another 8. It ensures both parties are aware of each other. This helps to determine which party is going to have priority when moving passed one another 9. So I know they know I'm there 10. I would feel safer crossing if I knew they could see me 11. Hopefully it means they've seen you and will drive more carefully as a result 12. Only way you can both ensure presence 13. To reassure both parties that they have seen each other 14. To confirm that they are aware of my presence 15. To confirm I have been seen 16. Makes it clear each person has seen each other and will act accordingly 17. So both are aware of the other 18 .Exchange of awareness and information 18. To make HGV drivers aware that pedestrians are around, that they are vulnerable, and that we need to share space. 19. It raises levles of confidence and awaerness of each others needs 20. it surely helps reduce the likelihood of an accident if you have seen each other 21. It shows the HGV driver is aware of the pedestrian 22. If you are seen then the driver is aware of your location	don't follow the basic road rules 4. It's no more important than with car, motorbike, cyclist or other road user 5. If every pedestrian tried to make contact with the driver, the driver would be too distracted to actually operate the vehicle. 6. Because it detracts from HGV drivers concentrating on other road users 7. There are too many pedestrians crossing at once for an HGV driver to make eye contact with them 8. It can be hard to know whether or not a driver has seen you, particularly if they are more isolated from the road.	people in vehicles) in the same way beyond simple rules (such as the current highway code) and some common sense. I would prefer that "dehumanising" my fellow pedestrians was possible and that people walking obeyed some sensible guidelines such as we do when driving, rather than trying to de-organise an essentially working system with relationship type behaviours. 2. Not Necessary 3. It just slows everything down a bit - no eye contact I don't walk in front.... 4. never had a problem 5. as above 6. Because you're on the side of the road and should only be in 'contact' with them when crossing at a red light or zebra crossing 7. it's less important than for cycling, usually will cross roads at traffic lights 8. To avoid accidents 9. At crossings it's good to know you've been seen 10. When crossing roads it is important 11. See above 12. Safety 13. See response to 7 above 14. The same standard should be for all drivers not just HGV. Probability for accidents is the same 15. they should focus on the road 16. Yes it probably helps

	23. It reassures you that you have been seen (as a pedestrian) 24. So that they can see I am there 25. Promotes recognition and awareness 26. It shows that they are aware of my presence 27. To ensure they know you are there 28. So we both know that they've seen me 29. So I know they've seen me (and they know vice versa) 30. Reassures both parties and reduces accidents 31. I think it would improve the chances of being seen. 32. Confirmation that the driver has acknowledged your presence 33. They know who is near them 34. for both to make sure we are aware of each other 35. To ensure that each road user is aware of each other during transit / motion 36. You would receive acknowledgement that they have seen you 37. So they know pedestrians are there and won't run them over. 38. You can be sure they have seen you then		17. same as above 18. Inter-visibility. 19. mostly No but depends on the circumstances 20. safety 21. Never given it much thought 22. Never really thought about it. 23. See above 24. See above 25. As above 26. I have never thought about it
11. To know that we have seen each other. Makes us more human 12. Establishes confidence that they are aware of you 13. I would hope they would be more likely to stop and give way when appropriate. Would hopefully make them more aware of pedestrians			
	39. Is important if the pedestrian is looking to cross in front of a hgv. Don't think it is if just walking along pavement 40. No the most important, but I think it can work as an additional precaution on top of being careful, not as guarantee for safety. 41. ONLY when crossing the road		

HGV Table of responses to Question 50: Do you think eye-contact between cyclists/pedestrians and HGV drivers is important? If so, why?

Awareness	**Against Eye-contact**	**Un-themed**
1. Yes as it makes everybody aware of each other 2. As both parties have seen each other and know it 3. VERY AS YOU NEED TO MAKE THEM FEEL SAFE IN THE FACT THAT YOU HAVE SEEN THEM 4. yes to acknowledge your presence 5. yes then you know of each others presence 6. Yes, they know you're there if you make eye contact 7. Yes. People acknowledge there is another person present and are aware of them 8. yes if poss,confirms to all awareness of each other. 9. Yes, so both of you have confirmed your presence. 10. yes.so we are all aware of one another 11. Yes it is so people know and acknowledge that you are present 12. Yes , so all are aware of each other 13. so driver and cyclist are aware of each other 14. Yes so we see each other 15. Yes so you are both aware of each other. 16. So that they are aware you are there and that makes it safer for everyone 17. Yes, it ensures they are aware of my position and that I have seen them	1. No as they are so unpredictable and push their luck even when they have seen you and you have seen them 2. Very difficult for the cyclist when they are riding at speed and normally on the passenger side of your vehicle from the rear. Pedestrians always depends on their position 3. No if they can't see a big lorry i doubt if they will see my eyes 4. No 5. No 6. no 7. NO - NEITHER TAKE A BLIND SPOT BIT OF NOTICE,ESPECILALY CYCLIST 8. No 9. No	1. People don't like to make eye contact it's a fundamental flaw 2. Driver and cyclists need to b aware of each other as cyclists don't acknowledge as they have music in there ears

18. yes, they know your there 19. so you know they are there 20. Yes, the cyclist/pedestrian needs to know I have seen them. 21. Very , to make each other aware of you been there 22. Yes let's you know they have seen you and you have seen them. 23. Yes. Eye contact is non verbal communication to ensure each Road user is aware of each other 24. Yes as this will enhance both parties awareness of each others intentions 25. Yes, acknowledged intentions as it allows a physical and mental interaction between users 26. It's important you both Make eye contact to demonstrate you have both seen each other 27. So that every one what way you are going 28. yes so every one knows where they are going 29. So we both know what manoeuvre each will take 30. You both recognise the need to interact for safety sake 31. Yes, to ensure they have seen me and recognise that I am moving or am going to turn 32. Yes very. It is all about sharing a space no matter what size you are and making sure the vulnerable user is safe and gets priority 33. i think is important because you then shown them you have seen them so then you can give them room 34. Yes 35. Yes to reduce accidents 36. yes because hopefully cyclists will take care 37. Yes 38. Yes. Reduces likelihood of collision 39. room 40. yes, greatly lessens risk of collisions 41. yes 42. yes less chance of collision 43. very important! for everyone safety 44. Because it shows u that u have been seen before any manoeuvre and u have seen them! 45. Yes it puts u at ease 46. Yes because you both have acknowledged each others vehicles		

47. As I know if eye contact is made I see you You see me 48. Yes is important for each one safety 49. Yes, as it confirms you are aware of each other 50. Yes 51. think making eye contact makes others think about your intent to perform a manoeuvre 52. Yes. It gives an understanding that you're both aware of each other. 53. Is important to know I was seen when I manovering to avoid any collision 54. Because it makes us aware of each others presence 55. yes its very important 56. yes 57. makes both parties aware of each other 58. makes people aware 59. so they can see you 60. becouse you let them know you have seen them... 61. YES. it helps drivers pedestrians and cyclists to go along safely together 62. Safety of all 63. To know they aware of my presence 64. So they can understand what I am about to do 65. Yes. It let's both sides know they are both aware of each others position 66. You no wher thay are and thay no wher you are 67. They see you and you see them 68. Yes it helps 69. yes but hgv drivers have been educated to the max, it is now time to test, certify and educate the cyclists & pedestrians 70. So that you can get across to them what you are about to do. 71. Understanding of each other 72. Yes so that both hgv drivers and cyclists and pedestrians are aware of each other for safety reasons 73. yes i gives everyone a clue as to there intentions 74. yes 75. yes 76. Yes so the drive and vulnerable Road user are aware of each other present 77. Yes because it means they have acknowledged you and know you are there 78. Yes		

79. I think eye-contact is very important- some kind of language which is use consciously or subconsciously to quick make a decisions on the road and for some more issues 80. if both parties have seen each other, both should watch what the other is intending to do 81. Yes, reassure them that I have noticed them. 82. Yes, other road users and pedestrians can see what your intentions are 83. It is important for both parties to recognise that they are there 84. Yes 85. yes		
1. Yes but you can only make eye contact if the cyclist or pedestrian wishes to do the same. You can make a lorry cab as low as you like and entirely out of glass but if cyclists and pedestrians remain unaware of the dangers around them there will still be collisions. It is the vunerable road users that need to change the way the behave and (in the case of cyclists) some form of legislation be imposed so that they can be answerable for the ways they use the roads and treat traffic signals and other vehicles. 2. It does help as you have aknoweged each others presence. However it doesn't mean you know for sure what each other will do. 3. yes and no 4. yes so that if a left turn is going to be done or any other manovere other than straight is being made everybody has to be aware 5. Yes, as this lets each other know that you are aware of each other, BUT i always treat them with caution, as you can never tell what that might do, i.e walk out infront of you 6. Yes - I wish cyclists would take more notice of large vehicles around them - they don't look		

Appendix 6: Simulator Experience Questionnaire

Simulator Experience Questionnaire

Page 1: Introduction

Thank you for taking the time to take part in our experiment.

We are interested in finding out more about how you found the experience.

Before you begin the survey we ask that you provide your name and email address so that we may link your survey responses with your experimental data. Your personal information wil not be used in any other way.

The results of this survey wil remain entirely confidential and you can opt out at any time before submission by closing the browser. The survey should take approximately 5-10 minutes to complete. If you have any questions please contact M.Skelton@leeds.ac.uk

Ethics approval has been granted by the School of Psychology Research Ethics Committee

Ethics Reference Number: 16-209
Approval Date: 02-08-2016

☐ I have read and understood the information about the study and I agree to take part. I understand the purpose of this survey and consent to my answers being used confidentially as part of the data analysis. I also understand that data can not be withdrawn after submission but I can opt out at any time by simply closing the browser.

Please provide your participant code to allow us to link your responses with your experimental data

Date experiment completed *Optional*

Page2:Experience

Please indicate the extent to which you agree with the following statements, where 1 indicates disagree and 7 agree.

I felt comfortable during the Simulation

I felt immersed during the Simulation:

I felt motion sickness during the Simulation

The simulation adequately represented the core aspects of driving:

The behaviour of cyclists mimicked real-life experience:

The behaviour of pedestrians mimicked real life experiences:

This experiment is addressing an important road safety issue:

There should be more research into this issue:

I felt I could better detect and respond to participant in the "Direct Vision" cab (lower eye height & larger side window) compared to the "Indirect Vision" cab:

Are you a qualified HGV driver?

Have you experience driving a *high vision* cab?

If Yes, please indicate the extent of your agreement with the following statement: the "Direct Vision" cab condition felt similar to lower eye height cabs I have driven (e.g. the Mercedes Econic).

Please note below the model of cabs you typically drive.

Page 3: Future Participation

If you have any comments that you think will be valuable for future experiments, please enter them below:

If you are happy to be contacted for participation in future studies, please indicate below.

Page 4: Thank you

Thank you for taking part in this follow-up survey. Please get in touch with Meg Skelton with any questions.