Understanding the cues and characteristics that indicate and affect a cyclist's future path: A focus group study conducted in the UK and Netherlands

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ABSTRACT

Cyclists must perform continuous threat assessment when choosing the safest path through the road environment. However, different situational interpretations exist among cyclists and other road users (e.g. car drivers) regarding risk perception and the responsibilities and liabilities of each party towards mutual awareness. Automated in-car, hazard-detection technology has potential to mitigate the risk to cyclists by warning drivers or taking control of their vehicle if a collision is imminent. However, the success of such technology is predicated on its ability to make an appropriate assessment of the behaviour of cyclists and accurately predict their future trajectory, in all situations. Six focus groups involving 24 cyclists and 13 car drivers were conducted in the UK and Netherlands, with different stakeholders assembled separately. The focus groups aimed to uncover the cues that indicate a cyclist's future path and the characteristics of the environment that may affect their choice, from both perspectives. Twenty-seven cues and twenty-five characteristics were identified and categorised into 4 themes: cyclists' appearance, communications and signalling, movement and position of bicycle, and environment and conditions. Results indicated consistency between groups, but were tempered by a cultural perspective, reflecting the higher social status afforded to cyclists in the Netherlands. The findings can be used to develop classification and coding schemes for naturalistic observations and to inform the development and evaluation of in-car cyclist detection and avoidance technology.

Keywords: cyclist, driver, cues, characteristics, future path, focus group, UK, Netherlands.

1 INTRODUCTION

Accidents involving vulnerable road users (VRUs) remain a significant issue for road safety, accounting for almost 40% of road fatalities in Europe, and almost 50% worldwide (World Health Organization, 2015). Cyclists are one of the most vulnerable road users, both in terms of the likelihood of being involved in a near-miss or collision, and the potential ramifications should an incident occur (Rowe et al., 1995). For example, early data from the UK suggests that cyclists are involved, on average, in a near-miss incident every 5.59 miles (Joshi et al., 2001). More recently, Sanders (2015) found 86% of those who cycled at least annually in the US had experienced a near miss, with 20% having been hit. Furthermore, in data collected over a 4-year period, the average probability of a cyclist being seriously injured if involved in a crash was found to be almost 27% (Watson and Cameron, 2006). It is worth noting that these data are influenced by the country of origin – accidents involving cyclists in the Netherlands, for example, are likely to be much lower, relatively.

To avoid collisions, cyclists must perform continuous threat assessment when selecting and negotiating their path through the road environment, particularly in situations where they are required to share the same physical space with motorists (Salmon et al., 2013b). Identifying the 'safest path' is thus also contingent on motorists understanding the risks faced by cyclists and predicting their intended behaviour. However, evidence shows that cyclists' future paths are incredibly difficult for drivers to predict because there will be a number of possible 'safe paths' available to cyclists at any one time (Salmon et al., 2013b).

Moreover, given that the physical and cognitive demands associated with safe and efficient performance differ between road users, a car driver may interpret the same road situation differently to a cyclist (Shahar et al., 2010; Walker et al., 2011). Thus, behaviour that is deemed to be 'safe' and appropriate by one party, may be viewed or interpreted as irrational or unexpected by the other. This naturally leads to situations of conflict, particularly in environments which afford a lot of route flexibility (for cyclists) or are not specifically designed to cater for all road users' needs (Salmon et al., 2013b).

A key concept in understanding road users' interpretations is 'situation awareness' (SA) (Salmon et al., 2013b). Given their vulnerability, cyclists are more obviously influenced by environmental factors and therefore use practical, 'hands-on' knowledge about location, infrastructure, condition, time, communication and other road users to make a comprehensive assessment of the potential threats posed and determine their safest path (Salmon et al., 2013b). In contrast, motorists are less encumbered by environmental factors and this is reflected in their situational interpretation. For example, car-drivers' SA has been described as "how drivers use information from the world to combine long-term goals (such as reaching a destination) with short-term goals (such as avoiding collisions)" (Walker et al., 2013); car-drivers have also been identified as possessing "no concepts related to the sides of their vehicle" (Salmon et al., 2013b, p.16). However, it has also been suggested that cyclists overestimate their own visibility, both with and without visibility aids (Wood et al., 2009), as indeed do pedestrians (Tyrrell et al., 2004). Needless to say, it is evident that there are diverging opinions between different road users regarding the dangers faced by each party and their responsibilities and liabilities towards mutual awareness (Wood et al., 2009). Whilst such differences are inevitable and at times appropriate or necessary, the key to safe interactions between different road users is achieving a degree of compatibility and mutual understanding between their situational interpretations – so-called 'shared situational awareness' (Salmon et al., 2011; Walker et al., 2011). In the current context, a shared understanding of the threat posed to cyclists appears key to reducing the risks faced by cyclists on a daily basis.

1.1 Cultural Perspective

Although increasingly popular today, interest in cycling plummeted in much of the industrialised world between 1950 and 1975, when car ownership surged and cities started growing and dispersing (Dutch Bicycling Council, 2006). For many years, cities focussed on accommodating and facilitating increased car use, while largely ignoring the needs of pedestrians and cyclists (Hass-Klau, 2014). In some countries, cycling was therefore viewed as a marginal mode of transport, occasionally used for recreational purposes but rarely used for practical, everyday travel needs. Whereas such attitudes persisted, to a large extent, in the UK over subsequent decades, countries in mainland Europe, such as the Netherlands have seen interest in cycling revived to new high levels. This is due to significant changes in transport and urban planning policies in the mid-1970s, fuelled by economic, social and environmental pressures, that encouraged towns and cities to become people-friendly, favouring walking, cycling and public transport, rather than cars. Driving also became increasingly expensive and inconvenient in many European city centres, following the introduction of taxes and restrictions on car ownership, use and parking. Today, cities in the Netherlands typically provide comprehensive cycle-centric infrastructure, such as segregated cycling lanes alongside busy roads and intersections, ample bike parking, extensive rights of way and full integration with public transport. Comprehensive traffic education and training of both cyclists and motorists, complemented by regular promotional events, further boost public support and enthusiasm for cycling in the Netherlands (Pucher and Buehler, 2008). As a direct consequence, cycling is viewed in the Netherlands as a mainstream mode of transport – a safe, convenient and attractive way to get around cities that is enjoyed by everyone (male and female, and all age groups), does not require a high degree of physical fitness and is appropriate for all trip purposes (Pucher and Buehler, 2008).

In contrast, the UK appears to have continued to encourage and accommodate increased car use and ownership by expanding roadway capacity and inner city parking facilities. Cycling therefore remains a minority transport choice in many UK cities (Green et al., 2010). Nevertheless, interest in cycling is increasing in the UK – qualitative findings suggest that moral and ethical reasons as well as practical considerations are increasingly pervading and underpinning decisions about transport mode choices, with many city dwellers feeling an obligation to travel responsibly in ways that minimise the impact on the environment and maximise potential health gains: cycling is typically viewed as the most likely method to provide such benefits (Green et al., 2010). Furthermore, UK government policies now officially recognise the importance of cycling as a practical mode of urban transport in the UK, and endorse the dual objectives of raising cycling levels while increasing cycling safety (Pucher et al., 2010). Nevertheless, at a national level, cycling levels have barely changed (Aldred and Crosweller, 2015). Perceived risk is a major barrier to uptake (Horton, 2007) and experiencing or even witnessing non-injury incidents may contribute to this perception. The UK road infrastructure is also saddled with the legacy of car-centric design, with cyclists often forced to accompany motorists on busy streets without separate bike lanes or paths (or only painted lane markings) – perhaps both parties may therefore be forgiven for the frequent displays and expressions of frustration that are shared between cyclists and car drivers on a daily basis in the UK.

Needless to say, cyclists remain highly vulnerable, especially where they are required to share the same physical space as motorised vehicles – in these situations, cycling is considered anything but safe, convenient and attractive (McClintock, 2002; Pucher and Dijkstra, 2003). In Britain, this is reflected by individuals wearing safety clothing, such as cycle helmets and light-coloured or fluorescent ('hi-vis') clothing and/or accessories (belt, arm or ankle bands) (DVSA, 2015). In contrast, the relatively high numbers of cyclists in the Netherlands is seen as a major factor in mitigating risk in shared situations – Dutch car drivers expect to see cyclists and are therefore more familiar and forgiving of their behaviour.

1.2 Avoiding Conflict

Safety is understandably still viewed as a major barrier to cycling in less cycle-oriented cultures, and frequently cited as a reason why people choose not to cycle in traffic (Green et al., 2010; Joshi et al., 2001). In conflict situations, a consistent finding is that car drivers do not detect cyclists until it is too late to avoid a collision (Räsänen and Summala, 1998). In particular, a proportion of crashes between vehicles and cyclists have been identified as "looked-but-failed-to-see" incidents (Herslund and Jorgensen, 2003). In these situations, there is evidence that the driver of the vehicle correctly looked in the direction of the cyclist, but nevertheless failed to detect the cyclist in time to prevent the collision. This suggests shortcomings in driver attention processes (Brown, 2005), or an expectancy effect, i.e. drivers were only scanning for cars (Clarke et al., 2004, in relation to motorcyclists) – the visibility of cyclists may therefore be an important contributing factors to their crash involvement. Indeed, increasing the visibility of cyclists is frequently proposed as a method of making cycling a safer as well as an easier choice (Wood et al., 2009).

An alternative approach is to augment vehicle control using automated in-car, hazard-detection technology. Such technology has potential to mitigate the risk to cyclists by warning car drivers or taking control of their vehicle if a collision is imminent. Indeed, some cars already possess detection systems (e.g. using radar, camera, infrared sensors) that warn drivers about a hazard (such as a cyclist or pedestrian) and thereby attempt to mitigate the effects should a driver fail to take compensatory action in time (e.g. by reducing kinetic energy at the point of impact). However, these rely on the presentation of a hazard directly within the driver's trajectory and are naturally limited by the range of the sensors. Moreover, such systems are often configured to minimise false interventions, and therefore only act in case of a clear, imminent collision risk.

To increase the performance of collision mitigation systems thus requires earlier detection and/or prediction of intention. This enables *collision avoidance* in situations where the current road position and behaviour of a cyclist indicates that *future* trajectories will conflict (even if the cyclist isn't currently in the vehicle's direct line of travel). Such technology could warn drivers or take compensatory action (e.g. braking, steering, or combination of both), and would herald a shift from collision mitigation to collision avoidance. However, success is predicated on its ability to make an appropriate assessment of the threat to cyclists and accurately predict their intended behaviour, in all situations.

1.3 Overview of Focus Groups

While a cyclist's behaviour may be motivated by a number of different factors, their future path is also likely to be affected by characteristics of the environment through which they travel. Thus, successfully understanding and/or predicting the behaviour of cyclists is contingent on all parties understanding the characteristics of the road environment, and recognising and interpreting behavioural cues that indicate a cyclist's intentions (for which individual motivations may remain unknown). To explore these factors/cues, we conducted 6 focus groups, comprising 24 cyclists and 13 car drivers, with different stakeholders assembled separately. The focus groups aimed to uncover the cues that indicate a cyclist's future path and the characteristics of the road environment that may affect their choice, from both perspectives. Given that attitudes and opinions towards cycling, and therefore cyclists, are expected to differ, not only between road users but also at a national level, focus groups were conducted in both the UK and Netherlands.

2 METHOD

2.1 Participants

Six focus groups were conducted: 3 with cyclists and 3 with drivers. Cyclists were defined as people whose primary mode of daily transport (e.g. to and from work) was by bicycle; drivers were people who used a car for their primary daily transport needs. Four of the focus groups (2 with cyclists and 2 with drivers), were conducted in a meeting room at the University of Nottingham, UK, during November 2015 and February 2016. Participants were recruited via email and advertisements placed around the campus, and primarily comprised staff and students at the University. The remaining 2 focus groups were conducted at Café Bret, Amsterdam Sloterdijk, in March 2016. Participants were recruited through advertisements placed on the FietsCoalitie website (http://fietscoalitiesmartcity.nl/). All focus groups were conducted in English. Participants provided written informed consent prior to taking part and received shopping vouchers as compensation for their time and to cover travel expenses. Full demographic details for each focus group are presented in Table 1.

Table 1. Demographic details for each of the 6 focus groups.

Location	Cyclists	Drivers
Nottingham (November, 2015)	8 participants (3 male, 5 female, mean age 33 years), mean time spent commuting by bike per day 36 minutes. 5 cyclists also drove regularly.	3 participants (2 male, 1 female, mean age 47 years), mean time spent commuting by car per day 43 minutes. 1 car driver had cycled to work previously.
Nottingham (February, 2016)	6 participants (3 male, 3 female, mean age 40 years), mean time spent commuting by bike per day 47 minutes. 3 cyclists also drove regularly.	6 participants (3 male, 3 female, mean age 28 years), mean time spent commuting by car per day 58 minutes. 3 drivers also cycled regularly.
Amsterdam (March, 2016)	10 cyclists (6 male, 4 female, mean age 59 years), mean time spent commuting by bike per day 44 minutes. 2 cyclists also drove regularly.	4 drivers (3 male, 1 female, mean age 56), mean time spent commuting by car per day 34 mins per day. All drivers also cycled regularly.

2.2 Design and Procedure

Each focus group lasted approximately one hour. Discussions were structured around two activities, which were conducted in the same order for each group:

1. 'Post-It' Note Exercise. Participants were asked to imagine that they were cycling or driving (as determined by the primary mode of transport – car or bicycle – of group members) and write down any cues that they felt *indicated* a cyclist's/their behaviour, and characteristics of the road environment, which they felt may *affect* a cyclist's/their behaviour.

2. Video Excerpt. Participants were played a short video excerpt, lasting approximately 5-10 minutes, showing an example of a cyclist's journey (captured from either a cyclist's or driver's perspective in the UK or Amsterdam, as relevant) and were asked to identify any cues or characteristics, either visible or inspired by the video. This activity built on the 'post-it' note exercise with the aim of stimulating the generation and discussion of further ideas.

2.3 Analysis

The discussions were audio-recorded and later transcribed in full. The 'post-it' notes were also collected for subsequent analysis. Transcripts and data from the 'post-its' were analysed using nVivo software (version 10, QSR International). A simple coding scheme of 'cues' and 'characteristics' was used during the analysis. Cues were defined as reported behaviours which indicate a cyclist's intentions regarding future path selection to other road users. Characteristics were defined as features identified within the road environment which affect a cyclist's future path and therefore could be used to predict intentions.

Focus groups are a good method for generating a lot of information. While it is possible to make frequency counts of the cues and characteristics codes that were identified, this does not necessarily reflect the importance or significance of the cues/characteristics in cyclist path prediction, rather just the frequency with which they were discussed within the groups. Instead, findings are therefore presented as revealed and discussed qualitatively. Quotes from the focus group participants are used to support and elucidate findings where appropriate.

3 RESULTS AND ANALYSIS

The cyclists and drivers in the focus groups identified 27 behavioural cues which were considered relevant in indicating or influencing a cyclist's future path (see Table 2) and 25 environmental characteristics which were thought to affect a cyclist's future path (see Table 3). The cues and characteristics were grouped into 4 themes that emerged during the analysis – cyclists' appearance, communications and signalling, movement and position of bicycle, and environment and conditions – and are discussed below.

Table 2. Behavioural cues identified by focus groups that indicate cyclists' intentions, grouped into themes.

Cues to indicate cyclists' intentions		Nottingham		Amsterdam	
		Cyclists	Drivers	Cyclists	Drivers
Cyclist's Appearance	Clothing (esp. 'high-visibility')	✓	✓	✓	✓
	Helmet	✓	✓	✓	
	Lights	✓	✓	✓	✓
	Other equipment (e.g. large back-pack)	✓	✓	✓	
	Type of bicycle (racing, city, tricycle, recumbent)	✓		✓	✓
	Bicycle condition / branding				✓
	Status of cyclist (tourist, student, professional, sports)		✓		✓
	Age of cyclist		✓	✓	
	Number of cyclists together (groups vs individual)		✓	✓	
	Facial behaviour (Mind wandering/visual behaviour)				✓
	Social behaviour/stop talking				✓
Communication and Signalling	Hand/arm signals to indicate direction	✓	✓	✓	✓
	Hand/arm signal to indicate annoyance	✓		✓	
	Eye contact/regarding each other	✓	✓	✓	✓
	Head/body movements	✓	✓		✓
	Use of bell	✓		✓	
	Speech / Shouting	✓		✓	✓
	Physical contact (e.g. kicking car, bang on roof)			✓	✓
	Secondary task engagement (e.g. using mobile phone)			✓	✓
Movement and Position of Bicycle	Position of cyclist in lane/road	✓	✓		✓
	Bike movements	✓			
	Speed/change in speed of bicycle	✓	✓	✓	✓
	Stop, start behaviour / hesitation	✓			✓
	Stop pedalling / free-wheeling				✓
	Swerving		✓		
	Posture/stability		✓		✓
	'Ghost-riding' (local knowledge)			✓	✓

Table 3. Environmental characteristics identified by focus groups which affect cyclists' behaviours, grouped into themes.

Characteristics which affect cyclists' behaviours		Nottingham		Amsterdam	
		Cyclists	Drivers	Cyclists	Drivers
Environment and Conditions	Lane layout / infrastructure / hardware provision		✓	✓	✓
	Traffic prioritisation rules/legal responsibility			✓	✓
	Type of road environment		✓		
	Curve / bend in the road	✓	✓		
	Road going downhill / gradient	✓			
	Junctions		✓		
	Joining of cycle lane and road	✓			
	Quality of cycle lanes				✓
	Width of the road		✓		✓
	Road markings	✓	✓		
	Central reservation	✓			
	Traffic lights (not stopping)		✓	✓	
	Roadworks		✓		
	Cars parked at side of road / in road	✓	✓	✓	
	Other obstacles		✓		
	Manoeuvring (reversing) / parking cars			✓	
	Pedestrian crossing	✓		✓	
	Other motorised vehicles (e.g. scooters, pedelecs, trams)		✓	✓	✓
	Static traffic / queues	✓			
	Density of traffic, busyness	✓	✓		
	Gap in traffic		✓		
	Flow of traffic upstream		✓		
	Presence of other cyclists/pedestrians (esp. tourists)			✓	✓
	Day of week		✓		✓
	Time of day		✓	✓	✓

4 DISCUSSION

The cues and characteristics identified in the focus groups were categorised into four 'themes' that emerged during the analysis. These are discussed below, supported by examples. Each section begins with a brief explanation of each theme.

4.1 Cyclists' Appearance

Cyclists' appearance refers to any physical features of the rider and/or bicycle that are independent of the environment through which they travel but provide a clue to behaviour. This is typically by evoking memories of learned behaviour or stereotypical attributions made by the observer. Features may be unintended or consciously selected to demonstrate a particular value or attitude.

In both the UK and Netherlands, cyclists felt that their clothing and cycling equipment were very important in establishing and maintaining their status as road users and making others aware of their presence. However, there was conflicting evidence of how this was put into practice, with many UK cyclists reporting that they always wore highly reflective clothing (vest, jacket etc.) and a cycle helmet. In contrast, Dutch cyclists rarely chose to wear a helmet or high visibility clothing within the city, although in other situations (e.g. on racing cycles, or for younger children), the use of helmets was more common and encouraged (*"It is not common to wear a helmet for your everyday cycle, but when you go fast cycling, we all wear a helmet"*). In both the UK and Netherlands, cyclists were aware that wearing a helmet may influence driver's behaviour (*"one of the things I've read is that actually motorists take more care when they see that you haven't got a helmet" – NL cyclist*). However, Dutch cyclists generally did not support the wearing of high visibility clothing (*"I think 'high vis' is a means of shouting"*), and considered this (and the wearing of helmets) to be a barrier to cycling if enforced. Nevertheless, Dutch cyclists were aware of the increased visibility of light colours and indicated that they would be wary of this when replacing items of clothing – *"if I have to buy a new rain jacket, I would try to look at what colour or if it has reflective stripes or not".*

Cyclists from both countries agreed that the use of lights was important for making other road users aware of their presence, particularly during evening or night-time cycling, although recognised that regulations stipulating the use of lights were rather relaxed (*"you may wear your lights on your clothing"*). The use of lights invited further debate amongst Dutch cyclists, who considered their dual purpose – 'to see' and 'be seen' – suggesting that the utility of lights varied between town and city. Cyclists in the UK often adopted enhanced lighting techniques (e.g. flashing lights, *"very bright…aircraft-style headlights"*) to ensure that they were noticeable. However, these were often selected without due consideration of their impact on other road users. For example, although *"much more noticeable"*, motorists commented that flashing lights were very distracting, and only served to highlight an individual cyclist at the expense of all other road users; furthermore, bright lights could be dazzling.

There was evidence that drivers often identified stereotypes amongst cyclists, based solely on their appearance, and this influenced their expectations of behaviour and future paths. This was prevalent in both the UK and Netherlands, although expectations conflicted to some extent, particularly in the UK, illustrating the divergence in drivers' opinions. Key aspects of appearance that led to the identification of stereotypes were the type of bicycle and cyclists' attire. All groups differentiated between racing bikes commanded by Lycra-clad enthusiasts, and traditional upright cycles, associating higher speeds and more predictable behaviour with racing bikes. Views from car drivers were not always so favourable: *"I have met aggressive guys in Lycra…you think they'd know how vulnerable they are but they don't and they can be really aggressive".*

Dutch drivers also differentiated between tricycles, recumbent bicycles, city bikes and electric bikes, associating higher risk with electric bikes and attributing this to cyclists who have failed to successfully adapt their behaviour to the higher speeds achievable with these bicycles. The adoption of electric bikes by older cyclists was also blamed for higher perceived accident rates and less predictable behaviour amongst this cohort of riders.

UK drivers had a particularly negative perception of young, teenager cyclists: *"If they're 18 with a BMX and…headphones in, you think: 'Oh God'", "I've seen them [cycling] down the middle of the road texting"*. In the Netherlands, stereotypical attributions were generally more consistent between cyclists and drivers, and centred on journey purpose and motivation. In particular, car drivers in the Netherlands were more inclined to give a wide berth to cyclists who were tourists. It was also evident that Dutch cyclists changed their behaviour in the presence of tourist car drivers, especially those boasting British or German number plates.

Cyclists' posture, stability and control of their bicycle were viewed by car drivers as indicators of cycling skill, and thus predictors of behaviour. These also affected drivers' confidence that the cyclist was going to behave predictably, or not: *"you can just see they're going to be a bit wobbly so you're going to have to give them a bit more room"*.

4.2 Communications and Signalling

Most cyclists consciously employed physical actions to indicate behaviour (e.g. using arm or hand signals to indicate their future path); many also chose to express their attitudes and opinions with physical displays (e.g. using arm or hand signals or shouting to indicate annoyance at car drivers or pedestrians). Drivers were also attendant to other signs, e.g. visual scanning patterns and head movements, indicative of 'mind-wandering', which may suggest that the cyclist is not fully engaged with the cycling task. Hand and/or arms signals were recognised by all parties as the foremost cues to indicate future paths and were used extensively. However, UK cyclists expressed concerns about the visibility of such signals in some situations (e.g. during the evening or night-time). Nevertheless, cyclists from both countries also recognised that in certain situations it could be difficult or dangerous to indicate with their arms, for example, while braking or manoeuvring: *"if it's a difficult road situation you can't just take your hand off whenever you want to, you have to think about controlling the bike first and indicate second"*. This demonstrates where prior experience as a cyclist can improve a driver's awareness and understanding of their behaviours.

An increasing trend towards cyclists engaging in secondary tasks while cycling – notably using a mobile phone – was highlighted by drivers in both countries. Drivers explained that this further limited cyclists' ability to make appropriate and timely arm and hand signals, particularly to indicate direction. Dutch drivers further recognised that in groups, cyclist would often be conducting conversations, and tourists may be sightseeing while cycling: in these situations, cyclists may be cognitively or visually distracted from the road situation.

Head and upper body movements were consistently identified as important cues by all groups. While there was general consensus that the direction of the head movement conformed with the cyclist's intended direction of travel (*"if someone moves their head to the left, they probably will go left"*), it was also recognised that cyclists would conduct more head movements and over-the-shoulder checks when travelling in heavier traffic conditions, and thus moving their head could indicate that a cyclist is attempting to improve their situational awareness generally, or may indicate that they are specifically preparing to change their road position or undertake a manoeuvre in *either* direction.

Making eye contact was also discussed as a means of communication between cyclists and drivers, although recognised as being highly dependent on context (e.g. whether driver and cyclist could actually see each other). Cyclists often attempted to make eye contact before pulling out at a junction, or in *"strange"* situations, to confirm that car drivers had seen them (*"it's catching someone's eye and making sure that they have seen you and don't move on until you've checked that"*). In other situations, drivers attempted to make eye contact with a cyclist to ensure that they had seen them and to confirm their intention, particularly if the driver's trajectory crossed the cyclist's path, although some drivers felt that the responsibility for making eye contact lay solely with the cyclist.

In certain situations, sound was considered a viable alternative to making eye contact – Dutch cyclists in particular recognised that using sound also meant that cyclists could keep their eyes *"on the road"*. A common example was ringing a bell, although all cyclists suggested that this was more typically employed to indicate their presence to pedestrians, rather than cars. Cyclists also used speech, but again this was more often intended to capture the attention of pedestrians. Examples of shouting at car drivers were also cited, although these tended to be as expressions of annoyance, especially following a near-miss incident. Dutch drivers were also attuned to changes in the pattern of talking between cyclists who were travelling in groups, recognising that if cyclists stopped talking, a change in behaviour/manoeuvre was imminent: *"stop talking, if they are in company…they stop talking because they have to concentrate"*. Several extreme, physical methods of attracting the attention of drivers were also mentioned by Dutch cyclists. These included kicking a car or banging on its roof, and were more likely to be employed in situations of annoyance. Hand and arm signals were also used by cyclists in both nations to express annoyance (*"if it's an idiot I will use my middle finger every now and then"*).

4.3 Movement and Position of Bicycle

Observable changes in the movement, position and stability of the bicycle, either through conscious actions (e.g. selecting road position and speed) or unconscious behaviour (e.g. swerving, instability), also provide good indicators of behaviour; these are also potentially influenced by the road environment (lane structure, road condition etc.). In situations where cyclists shared the same physical space as cars, the position that they adopted in the road was considered a very strong indicator of future paths, by all groups. Moving out into the road, in combination with an arm indication, was considered by most participants as a clear indication that a cyclist was about to turn right (in the UK). Similarly, proximity to kerb, i.e. adopting a position close to the kerb was considered to be an indication that a cyclist was about to make a left-turn (in the UK).

Road position was also associated with confidence and assertiveness, from a cyclist's point of view, with several cyclists commenting that they took a more assertive road position, to take control from drivers (*"I will actually try to occupy the same space as a car, so I'll drive almost in the middle of the path" – UK cyclist*). Cyclists believed that this forced drivers to make an exaggerated overtaking manoeuvre to pass them. However, it was recognised that this potentially put cyclists at greater risk and had the potential to annoy drivers. Car drivers also tended to interpret a cyclist's road position in terms of their confidence.

Dutch cyclists were very aware of their visibility when manoeuvring through busy, slow moving traffic, particularly regarding their tendency to become lost in a car's blind-spot. Several cyclists therefore explained that they consciously moved to ensure they remained visible to drivers: *"I sometimes know I'm in the dead-spot [blind-spot] and I move a bit to make sure I'm in their rear-view mirror", "when I try and pass him, I go to his rear-view mirror and then go around"*.

Speed was also a common indicator of behaviour, highlighted by all groups. Drivers understood reductions in speed (indicated by cues such as stopping pedalling) as an indication that a cyclist intended to change direction, and thus if a cyclist maintained their speed at a junction, interpreted this to indicate that they would be travelling straight ahead. From a cyclist's perspective, speed influenced other behaviour. For example, road position may differ depending on speed: *"especially when I'm on my race cycle, that drivers don't anticipate me going that fast, so I have to take a defensive stance"*. Dutch drivers also highlighted other speed-related cues associated with cyclists (such as hesitation, stop/start behaviour, free-wheeling) as indication of an imminent change in behaviour, although recognised that this lacked a specific interpretation (*"They could do something but you don't know yet what"*). Additionally, it was commented that this behaviour could be influenced by the environment through which they were travelling.

4.4 Environment and Conditions

Physical and temporal attributes of the environment also influence the behaviour of cyclists (e.g. road infrastructure, other road users, time of day, inclement weather etc.). In the UK, much of the cycling network has been realised by allocating a proportion of the existing roadway to cyclists (highlighted with solid or broken white lines), typically without physical demarcation and often without exclusivity. While this is a relatively cost effective method to retrofit the extensive UK roadway infrastructure with designated cycle paths, it nevertheless fails to address the fundamental intention of segregating road users. Consequently, UK cyclists often share the same physical space as motorists, even when travelling in cycle lanes; moreover, motorised vehicles can legally encroach on cycle space. This frequently presented a problem to both parties. For example, obstacles in the roadway (e.g. drains, potholes, puddles) could cause problems to cyclists, particularly where these existed within designated cycle lanes in the UK. Furthermore, cycle lanes may suddenly start or stop thereby redirecting cyclists to or from the main carriageway. As a result, British cyclists may be required to suddenly and unexpectedly move into the main carriageway. Whereas UK drivers acknowledged this behaviour during the discussions, they explained that during routine driving, they did not attend to specific obstacles to predict behaviour, but rather attempted to build a holistic picture of the entire road environment and all significant road users. There was a feeling that for drivers it was more a subconscious awareness which guided their behaviours.

In contrast, cyclists in Amsterdam benefitted from an extensive proprietary cycle network ("we have 500km of cycle paths in the centre"), which often segregated cycles and car drivers with physical barriers. Nevertheless, there were still many physical attributes of the road environment generally that were expected to influence cyclists' behaviour, such as gradient, bends in the road, road markings, as well as other road furniture, such as traffic lights. In addition, the presence of other road users, particularly cars – parked, queued, or simply in high numbers – influences cyclists' selection of future paths. In Amsterdam, the high proportion of tourists was recognised as a major factor influencing behaviour by both cyclists and drivers.

The time of day, and day of the week, were also identified as important by both cyclists and drivers. This affected the type and number of road users in an environment, resulting in adaptations of behaviour from both parties. Moreover, the same road users are likely to behave differently at different times of the day and days of the week (e.g. work-day rush-hour compared to weekend leisure activities).

In both countries, all groups discussed 'rules of the road', and each party's responsibilities. In the UK, there were conflicting opinions over whether cyclists should adhere to the same rules as drivers and also acknowledgement that a lack of knowledge on the part of drivers can make situations even more dangerous. In the Netherlands, there is a much stronger cycle-centric attitude and higher numbers of cyclists, with comments from NL participants reflecting this imbalance – *"80% of the traffic in Amsterdam is from cyclists"* (in reality, the proportion of cyclists is actually expected to be lower than this). Dutch car drivers' comments reflected the higher numbers of cyclists – *"when driving a car, you expect cyclists everywhere, every corner"*, but also reflected annoyance and irritation at their behaviour – cyclists often *"take the* *priority"* at junctions and *"make the rules"*. While cyclists generally felt that they obeyed the rules of the road, they were also willing to concede that *"we have rules, but we have also our own rules"*. In many circumstances, Dutch cyclists felt able to make an independent assessment of the road situation and choose what action to take, often in spite of instruction to the contrary; the most common occurrence of this type of behaviour was at traffic lights. Frequent cyclists in Amsterdam were also aware of situations where traffic lights could be avoided by taking a slightly longer route (so-called 'Ghost Riding'): *"you always take another route…we call it ghost riding, riding on the other side, and then you cross normally on the place where there are no traffic lights. Because you are familiar with the city, you try and avoid the red lights"*. Dutch drivers and cyclists both conceded that *"trams in Amsterdam, they are absolute kings of the road"*; this is also reflected in the traffic rules.

5 CONCLUSIONS

The cyclists and drivers in the focus groups identified 27 cues and 25 characteristics which were thought to affect a cyclist's future 'safe' path (Salmon et al., 2013b). Cyclists tended to focus on their own visibility, hand signals and road position. While drivers acknowledged all of these factors as indicators of behaviour, they tended to focus more on the negative aspects of cyclist behaviour and on differences in their use and understanding of the road environment. Drivers were also more inclined to profile cyclists according to dress, age, purpose of trip and other social factors, using this to predict stereotypical behaviour, although several drivers acknowledged that it was important to treat all cyclists with the same level of caution, irrespective of appearance and other external factors. Both cyclists and drivers identified similar characteristics of the road environment that were likely to affect cyclists' future paths, but drivers thought that they made a more holistic assessment of the entire environment and how it changed moment-by-moment, rather than focussing on individual aspects. Although there was consistency between the UK and Netherlands, it is noteworthy that attitudes were tempered by a cultural perspective, reflecting the larger number of bicycles, better cycling infrastructure and higher social status afforded to cyclists in the Netherlands.

The findings have several applications. Firstly, as part of the PROSPECT project (PROSPECT, 2015), they will be used to inform the development and evaluation of new in-car cyclist detection and avoidance technology. Such technology could also improve the performance of current Autonomous Emergency Braking (AEB) systems. Early recognition of cues can improve the understanding and prediction of the cyclist's intention. This will help to correctly predict the collision risk, which will lower the false alarm rate, and therewith increase the performance of the system.

The research also provides valuable insight into cyclist behaviour at a more general level. This can be used to support education and training, as well as informing road policy, road design and vehicle design (both automotive and bicycle). The data can also be used to inform future behavioural studies, for example, naturalistic observations and conflict investigations – by identifying a series of easily recognisable visual cues to cyclists' behaviour (wearing helmet, using lights, arm signals, head movements etc.), it is possible to develop classification and coding schemes for naturalistic observations. This is likely to dramatically reduce the skill, time and effort required to analyse typically large data-sets, leading to a better understanding of near-miss and accident events, and ultimately reducing the risk to cyclists. Needless to say, in all cases, further validation work is required to confirm the relationship between identifying possible cues and understanding the exact behaviours they are indicating.

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