Autonomous Vehicles, Car-Dominated Environments, and Cycling: Using an ethnography of infrastructure to reflect on the prospects of a new transportation technology

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Abstract

With growing concerns about air pollution and congestion, getting more people to move around cities by bicycle is gaining more attention than at any point over the past 50 years. At the same time, the spread of autonomous vehicles (AVs) is being positioned by some as a solution to these same problems. This raises interesting questions about the possible trajectories AVs could take when they become part of the traffic landscape of a street. Will they entrench existing hierarchies of use? Or will they help facilitate the expansion of cycling and other non-motorised forms of mobility? To begin to think about this question, the paper considers what a street is and how different users within a street environment share and cooperate. It then moves on to explore the technologies involved in the development of AVs and the challenges involved in their use on environmentally complex urban streets. With rules being central to how AVs operate, the fact that rules can mean different things to different people, and that they are both formal and informal, matters. To show why this matters, examples from an ethnography of infrastructure involving 81 adult road users are used to illustrate the ambiguities involved in making sense of the appropriate way to make a right-hand turn when cycling in a country that travels on the left. How AVs are programmed to deal with such ambiguities will have profound effects on the kind of infrastructural settlements that come to dominate how people share the street. These are judgements that will have important consequences for the development of cycling in the many places with car-dominated transport environments.

Highlights

- Streets are amalgams of materials, regulations, people and normative patterns of use
- AVs could entrench existing inequalities, or facilitate new ways of using streets
- Rules can mean different things to different people, they can be formal and informal
- Moral judgements shape the infrastructural settlement of streets

Keywords

Autonomous vehicles, cycling, infrastructure, sharing, rules, intelligence,

1. Introduction

In recent years there has been a tremendous resurgence of interest in cycling as a way of getting around cities. In many of the richer parts of the world cycling is recognised by planners, public health officials, and even politicians as an important tool for combating a wide range of urban and social problems. These range from traffic congestion, air pollution and climate change, to obesity and lack of physical activity, as well as social isolation and the erosion of social capital. Cycling is a key means of creating more liveable people-centric neighbourhoods. What had been thought of by many as an outdated technology overtaken by automobility is being – in effect – re-inserted into the fabric of cities. This re-discovery of the bicycle as a means of urban transportation is being fostered by all sorts of technological and infrastructural innovations. Whilst the dominant form of the bicycle has remained remarkably stable over the last century, recent decades have seen a host of new ways of organising how cycling is done. These range from design elements like bike lanes, cycle traffic lights and shared streets, to bike hire schemes (docked and dockless), cycle cafes, and smartphone navigation apps to name just a few examples (Pucher and Buehler, 2008; Aldred and Dales, 2017; Parkin, 2018b).

Many of these innovations involve altering how streets get used and shared among different types of road users. Urban streets involve a complex mix of people driving, cycling, walking and in some cities motorbiking, scootering, skateboarding, and more. Exactly how these different road users interact and share the common space of the street is open to enormous variation. Design and regulation matter. But as the journalist Tom Vanderbilt (2008:6) writes, streets are far 'more than a system of regulations and designs', they are 'places where people, with only loose parameters for how to behave, are thrown together on a daily basis'. How streets are shared amongst different transport modalities is dynamic though not necessarily fair nor inevitable. In many cities automobiles and other motorised vehicles crowd out other road users. The innovations listed above work to carve out spaces for those cycling, and in doing so generate alternative patterns of sharing street spaces. This raises interesting questions for the advent of autonomous vehicles (AVs) in cities. Proponents of AVs claim that they will make streets more efficient, productive and safe (Alessandrini, et al., 2015; Fagnant and Kockelman, 2015; Herrmann, et al., 2018). These benefits, however, appear incommensurable. So it is worth asking, would the arrival of such vehicles crowd out other ways of moving around cities as earlier forms of automobility did? Or will they allow for new, more equitable configurations of sharing with a greater plurality of road users? Put another way, will they work against efforts to encourage cycling among

urban inhabitants, or will they encourage patterns of road use that further enable the recent upsurge in urban cycling[1].

What follows reflects on the above questions. Focusing on the idea of streets as spaces of sharing where people – employing a range of transport modalities – coordinate and cooperate as they travel between destinations, it is argued that how AVs impact existing mobility systems will depend on their interpretation of formal road rules as well as how they relate to existing informal norms of use. To make this argument the next section examines in more detail what is involved in thinking about streets as spaces of sharing and how navigating a street does not just involve coordination but also cooperation. Second, what an AV is and how they are likely to operate in urban environments is considered. The third section explores the relationship between formal rules and laws along with informal rules and norms. Fourthly, this discussion on rules is used to explore an empirical case study of cycling in a car-dominated transport environment. This leads to the final section that asks how different interpretations of the informally regulated relationships between people using streets might lead to very different impacts for the spread of AV technologies on cycling and indeed other non-motorised road users.

2. Streets as Spaces of Sharing (and cooperation)

What is a street? This is not as immediately obvious as it might sound. A street is a space constructed of concrete or tarmac, perhaps cobblestones, or paving, gravel even. It is a carriageway certainly, but also a pavement and a cycle lane if you are lucky. There might be signs, road markings and street furniture, like railings, barriers, bollards, traffic signals, speed humps, pedestrian refuges and zebra crossings. Any street is also a collection of laws and regulations defining where different things and people should be, and how they should behave. Amidst all this, there are also people on foot, scooters, bicycles, mopeds as well as those in cars, vans, buses and heavy-goods vehicles going about their business. The precise mix, of course, depends on the street being described. More conceptually, a

[1] Despite the potentially profound implications of autonomous vehicles, so far, there has been surprising little attention on this in the *Journal of Transport Geography,* say for one article (Milakis, et al., 2018) and two book reviews (Parkin, 2018a; Lyons, 2018).

street could be thought of as being an amalgam of materials, regulations, people and normative patterns of negotiation[2].

Materials involve those physical objects that make up the street and afford certain kinds of movement, this includes the stuff commonly referred to as 'infrastructure' along with all sorts of objects people are putting to use in their everyday lives. These objects are to varying degrees planned, designed and engineered into place. It is worth noting the materials bound up with infrastructure are often 'obdurate' in the sense that once they are in place they are often difficult or costly to remove or rearrange (Hommels, 2005). But how infrastructures get 'taken up, used and integrated' into the everyday practices of users also matters (Latham and Wood, 2015:303). That is, they become infrastructure through the situated patterns of use being performed (Star, 1999; Pinch, 2010; Furlong, 2011).

Regulations are those formal rules and laws that exist to organise and structure how a street, and the different spaces that make it up, are used. Rules and laws are backed – with varying degrees of efficacy – by institutional actors charged with their enforcement and oversight. Regulations contain both material and immaterial elements. They form a regulatory grammar that is immaterial in the sense that rules and regulations become embedded in how people make sense of a situation and material in as much as regulation involves all sorts of objects that provide direct guidance over appropriate conduct (Adams, 1995; Tyler, 1990; Banister, 2018).

People use streets in all sorts of ways. Streets are sites of transport and much else besides. Travelling involves far more than moving from A to B for any defined purpose. Whilst travelling, people are also parenting, working, conversing, listening, reading, networking and so on. If streets are sites of movement they are also places of stasis. Put another way streets are inhabited. This inhabitation is certainly corporeal – it involves physical human bodies in specific places. It is also, however, hybrid. As it involves people in relationships with – and in the case of motorised vehicles often within – all

[2] Our starting point here is an institutionally thick, wealthy and already car-dominated transport environments. Clearly, different streets in different kinds of places, including in the so-called Global South, will confront somewhat different problems and configurations of materials, regulations, people and normative patterns of use.

sorts of objects and technologies. This hybridity plays into the particular ways people use and inhabit streets along with how they make sense of and interact with others (Katz, 1999; Gehl, 2010; Sadik-Khan and Solomonow, 2016; Bissell, 2018a).

Normative patterns of negotiation are the common understandings for how a street should be used that inform and structure interactions amongst people. In part these are formed through formal regulations. Most formal rules and laws, however, involve significant degrees of interpretation around what is reasonable. This interpretative play is situational. How a law or rule is made sense of often depends on the specific configuration of people, materials and regulation that come together in a specific situation. In other cases, formal laws and rules are disregarded almost entirely and, in their place, people rely on emergent informal rules and norms to regulate behaviour. In this sense, people's working assumptions are 'formed from a [particular] "Here" in the world', which means others with the same perspectives will likely reach similar interpretations and act in similar ways (Schütz, 1953:30). It is important to stress that whilst there are many practical ways sharing a street could happen, these formal and informal rules ensure not all uses are commonly sensed as equally valid or appropriate (Gregory, 1985; Jain, 2004; Norton, 2008; Vanderbilt, 2008; Christmas and Helman, 2012).

To summarise then, a street or road is an amalgam of materials, regulations, people and normative patterns of negotiation. Together these shape how people share spaces within streets. At a basic level this could be framed as a problem of optimising coordination familiar to traffic engineers. However, once the agency of the people and objects making up the street are taken seriously, what is at stake is not just how to coordinate but also how to reasonably cooperate. Formal and informal regulations provide a grammatical structure for how cooperation should happen, a structure that invokes a particular moral order. This regulatory grammar gives rise to competing claims about who is permitted access, who holds priority, as well as where certain people belong in relation to other inhabitants of the street. In some cases, certain uses are actively marginalised as others are prioritised (Adams, 1995; Norton, 2008; Jain, 2004; Banister, 2018). Put another way, there is an institutional dimension to the way certain uses and forms of cooperation become a more legitimate way to go about sharing a street. They seem normatively acceptable based on a particular sense of the material objects and regulations in that situation.

3. Autonomous Vehicles on the Street

Recent years have seen tremendous developments in AV technology. Existing automobile manufacturers and a whole range of tech-firms – including many of the biggest actors in Silicon Valley such as Alphabet, Uber, and Intel – have committed billions of dollars to the development of fully autonomous vehicles and the technologies underpinning them[3]. Whilst there is much disagreement about when AVs are likely to be introduced in any volume, and whether they will be primarily for ride-hailing or private ownership, there is a consensus amongst industry and many regulators that they will happen (Le Vine and Polak, 2014; Cavoli, et al., 2017; Cohen, et al., 2018)[4]. Making a fully autonomous vehicle consists of three fundamental tasks (Liu, et al., 2018; Herrmann, et al., 2018; see Stilgoe, 2017; 2018a). *Perception* involves building a detailed picture of the material objects and people around the vehicle using LiDAR, radar and high-resolution cameras. *Predictions* about what might happen next are based on pre-programmed rules and machine-learning that infers the rules from exposure to huge datasets covering a vast number of examples. And *Driving policy*, is where data from these perceptions and predictions shape what is deemed the safe and appropriate path ahead. For Sebastian Thrun, a pioneer of AVs formerly at Stanford and Google, executing driving policy 'makes up just 10% of the problem, as perception and predication are the hard parts' to solve (The Economist, 2018a).

Solutions to these technical challenges are emerging due to parallel advances in sensor technology and computing power that processes in real-time a picture of the world around the vehicle; although there is still a significant amount of debate and variability in terms of the precise technological form that AVs will take (Stilgoe, 2018a; Hopkins and Schwanen, 2018a; Kent, 2018; Stone, et al., 2018). Nonetheless, one central feature of AVs is that they are in part pre-programmed by engineers to follow known rules. As Liu et al., (2018:109) explain, designing AVs are simplified by 'traffic rules always being fixed' and mandating a 'limited number of [possible] traffic behaviours'. Yet streets are not

[3] There are 5 levels of automation, as defined by the Society for Automotive Engineers (SAE) International. These range from Stage 1 driver assistance technologies, like adaptive cruise control, where failure sees the driver resume full control, to Stage 5 where fully automated driving is performed everywhere and in all environmental conditions (SAE International, 2014).

[4] Although it is worth noting that within the social science literature that is a good deal more scepticism about the inevitability of autonomous vehicles. This is partly as a result of recognising the social and institutional complexity involved in introducing AV technologies, and also a questioning if the technological capacities of existing AV systems (Bissell, 2018b; Bissell, et al., 2018; Hopkins and Schwanen, 2018a; 2018b).

always performed in strict accordance to formal traffic laws, and the rules themselves often leave space for situated interpretation. For this reason, machine-learning has become central to the development of AVs. Engineers allow the AV – generally in connection with cloud-based networks – to infer the relevant rules from observational data about how streets are currently being used and shared. This means an AV trains and retrains itself on how to fit into existing patterns of use that enable it to safely deal with unexpected situations.

At the moment there are limitations on the degree of complexity AVs can deal with. For example, DriveMe – a project involving Volvo in Sweden – purposely 'avoids complex traffic situations with pedestrians and bicyclists' as their interactions with AVs are deemed to sit far beyond the safe operating space of current AV technology by Swedish authorities (Eriksson, 2017:49). These AVs are honing their skills and experience on dual carriageways that are an unusually predictable and orderly kind of street used only by motorised vehicles. Similarly, Waymo, Alphabet's self-driving car subsidiary, has, since late 2017, been trialling fully autonomous ride-hailing minivans in a suburb of Phoenix, AZ. Again, this uses similarly car-centric streets to control for the complexity AVs will meet in more obviously multi-modal environments[5]. This raises interesting questions about how AV technology will deal with this increasing complexity. More specifically, it raises questions about how AVs adapt to and work with informal rules defining existing patterns of use on the street. To take an obvious example, how should AVs deal with existing norms around the rules of speeding? On many roads, in many parts of the world, driving slightly over the speed limit is normal driving practice[6]. Should AVs never exceed the speed limit as that would transgress the legal rules? Or, should they go at the traffic speeds currently observed on a street to ensure seamless compatibility with human drivers conforming to the prevalent convention to speed? Implicit in such decisions are moral evaluations about what – and who – should be prioritised (Awad et al., 2018; Chater et al., 2018; Fishman, 2018; Luetge, 2017).

[5] In this case, pedestrians and cyclists are not banned from the road space. But the modal share of these users means that this is *de facto* a car-orientated space, which means how AVs interact with pedestrians and cyclists is marginal (see YouTube Video by Waymo, 2018)

[6] The UK Department of Transport reports nearly three-quarters of those driving exceed the speed limit in 20mph zones and over-half do so in 30mph zones (see SPE0112, DfT, 2018).

Questions such as these point to the far-reaching ways AVs could transform cities, including how motorised vehicles share streets with those walking and cycling (Marsden, 2018; Skeete, 2018; Stone, et al., 2018). Social scientists have highlighted how these transformations might have perverse and socially divisive impacts, and that they present a tremendous challenge to existing planning and governance structures within cities (Marres, 2018; Bissell, et al., 2018; Crawford and Calo, 2016; Porter, 2018). And yet, AVs are positioned by tech-firms, automobile companies, ride-hailing operators and many politicians as a means of unproblematically combating a wide range of urban and social problems through improved efficiency, productivity and safety (McCarthy, et al., 2015; Fagnant and Kockelman, 2015; Anderson, et al., 2016; Kalra and Groves, 2017). *Efficiency*, as travelling closer together could increase 'lane capacity (vehicles per lane per hour) by up to 500%', whilst ride-hailing AVs would require significantly less vehicles on the street and also reduce the demand for parking (Hermann, et al., 2018:295). *Productivity*, as full automation frees people from the task of driving as well as improving transport accessibility for those who cannot currently drive (Zakharenko, 2016; Fagnant and Kockelman, 2015). *Safety*, with human error cited as a cause of over 90% of all crashes, AVs are expected to have less crashes meaning less people killed or seriously injured on the road (Smiley and Brookhuis, 1987; Urmston, 2015). Some, like Mary Barra, CEO of General Motors, have gone as far to suggest that AVs provide all the advantages of automobiles without the negative drawbacks as there will be 'zero crashes, zero emissions and zero congestion' (The Economist, 2018b). Absent from these boosterist accounts is much sense of the ethical choices and dilemmas AVs might generate. Moreover, there is a degree of incommensurability between the various benefits that AVs might bring. Much of this incommensurability relates to the competing systems of rules that govern how streets operate (Bonnefon, et al., 2016; Cavoli, et al., 2017; Awad, et al., 2018; Cohen, et al., 2018).

Take improved road safety. This is a big selling point of AVs. If human error really is the main cause of road fatalities and injuries then replacing human judgement with that of intelligent machines seems an obvious improvement. This, however, is difficult to reconcile with visions of speedy and efficient movement of AV traffic; at least without tight regulation of non-motorised modalities (Parkin, et al., 2016; Cohen, et al., 2018). To illustrate this point, John Adams (2015) uses the example of a ball being thrown into the road by a child. The technical solution is obvious: sensors identify the ball and child (perception); algorithms predict what might happen next (prediction); and then apply the brakes to stop the vehicle (driving policy). As Adams (2015) muses, though welcomed, 'such a programmed

response' leads to the unintended consequence of 'inventing an exciting new game for children: throw the ball and watch the car stop'. Likewise, those walking or cycling could be 'liberated to stride confidently into the road' in full knowledge AVs will stop for them in the interests of road safety (Adams, 2015; Parkin, et al., 2016). Perhaps. But equally, AVs might learn – or indeed be taught – the rules for current patterns of sharing where non-motorised modalities avoid motorised traffic. In this case, roads might well be somewhat safer as well as being more efficient. Yet the existing hierarchy where motorised traffic has priority over all other forms of mobility remains in place, as does the responsibility of those walking and cycling to make sure they remain out of harm's way.

The key point is that while AVs are likely to generate profound shifts in the relationship between materials, regulations, people and normative patterns of sharing on streets, the direction of such changes depend in large part on what AV systems infer as the rules to be followed. On this basis, the particular ways AVs share streets might either: reduce or increase traffic congestion; entrench or recalibrate whose safety is prioritised; make transport more or less accessible; as well as facilitating denser cities or suburban sprawl (Milakis, et al., 2018; Stilgoe, 2017; 2018b; JafariNaimi, 2018; Kent 2018; Marsden, 2018). The precise outcome is likely to depend to a significant degree on how the rules of the road, and the learning of these formal and informal rules, are framed for AVs. This of course, is in part an institutional problem; a problem of regulating behaviour in ways that fosters cooperation and coordination in certain directions and not others. This is to highlight the concerns raised by many social scientific commentators about managing and governing innovations in AV technology (Hopkins and Schwanen, 2018a; Marres, 2018; Bissell, 2018b; Porter, 2018). But it also involves some quite challenging questions about the kinds of formal and informal rules that structure the particular ways in which people in traffic cooperate. To this end, and before turning to a concrete empirical case, the next section briefly outlines how to think more carefully about the ways formal and informal rules operate.

4. Formal Rules and Laws, Informal Rules and Norms

Rules are central to how people go about their everyday lives. The Oxford English Dictionary (2018) defines a rule as an 'explicit or understood regulation that governs conduct within a particular area of activity'. And this holds up well for most everyday purposes. Yet enormous variations are found in

the ways people make sense of the form, function and reach of rules (Taylor, 1995; Ellickson, 1991; Tyler, 2011). There are formal rules written down and recognised as binding by external authorities that have the power of enforcement through various sanctions. There is no guarantee people will heed these formal rules and laws, or even make sense of their situated reasonableness in the same way (Stark, 2009; Haidt, 2012). In fact, there are many times when people rely on informal rules to regulate behaviour. These social norms – even though they might not be directly articulated – arise from a commonly held sense of what normalised behaviour entails (Finkel, 2000; Kahan, 2002). These informal rules can supplement, or even diverge and supplant the kinds of behaviour prescribed by formal rules (Ellickson, 1991; Tyler, 1990). Making sense of any rule, whether formal or informal, comes with a fuzziness and ambiguity around what is morally and practically understood as right or wrong. That is to say it always involves a degree of interpretation. So, the rules guiding how people navigate streets are bound up with commonsensical understandings that 'reflect, maintain and direct' what is fair, just and appropriate in both a practical and moral sense (Boeckmann and Tyler, 1997: 377).

The crucial point is that rules can mean different things to different people. Any rule may be subject – depending on circumstance – to multiple, potentially contested, interpretations; and each may have its own validity, even as other actors challenge it. A central dimension of this, as the philosopher Charles Taylor (1995:170) argues, is that in everyday interaction, rules 'reside' and are 'animated' through the very practices which give rise to the need for a rule. People draw upon a commonsensical set of 'propositions' and 'premises' from which it might make perfect sense to follow a particular rule in a given situation, whilst discounting or ignoring others (Taylor, 1995; see Wittgenstein, 1953; Holtzmann and Leich, 2005). The form and function of any rule is itself subject to moral judgements that emerge through practices justified on the commonsensical basis they conform to 'our intuitive feeling for what is right or wrong' (Taylor, 1995:227; Anderson 1993). In other words, a rule one group of people find obvious may not make sense in the same way, or at all, to another group. It follows – to come back to how streets are shared – that formal rules and laws along with informal rules and norms impact to varying extents how people make sense of how and where different modalities become a legitimate part of the traffic landscape of a given street. Analytically, then, in making sense of how any rule-bound environment works, it is important to examine the overlaps and differences in what those people within that space deem reasonable and appropriate (Boltanski and Thévenot, 2006;

Tilly, 2006; Stark, 2009). This is less about making a judgement in terms of whether people are following the rules and more a question of what are the rules to be followed as well as what are the accompanying sense of moral order informing these rules[7].

5. Rules, Cycling and Traffic: a case study of doing a Right-Turn

To examine how thinking carefully about the way formal and informal rules shape how different transport modalities interact on streets, this paper turns to a case study of cycling in Carlisle. Carlisle is a small city in Northwest England. Like most places across England, very few people currently cycle; cycling accounts for 2% of modal share, whilst over two-thirds of all trips involve driving (ONS, 2016; Aldred, 2012; 2016). It is also a city with limited and poor-quality cycle infrastructure. This makes it a good case for examining the kinds of norms and patterns of use shaping how people share the street in a car-dominated transport environment – the sort of environments that have the most potential for expanding the modal share of cycling. At the same time, they are environments that may also be most profoundly affected by the introduction of AVs.

Before getting into the detail of the case study, a quick word on method. The material for the case study involved three stages of data gathering. Firstly, to understand how people on bicycles go about cycling in Carlisle, video-recorded ride-alongs were undertaken with 21 adults (F=8; M=13). Following on from similar work (Spinney, 2015; Simpson, 2017; Latham and Woods 2015), the videos were analysed to gain a sense of the practicalities of cycling in Carlisle. Secondly, ride-along participants were subsequently interviewed and asked to explain the appropriateness of what they were doing, with particular attention being paid to actions that appeared to be at variance to *The Highway Code* or local bylaws[8]. Thirdly, a video was produced that drew together eleven examples of ambiguous cycling practices repeatedly seen across the 21 original ride-along videos. This video formed the basis

[7] The discussion on rules presented here, is obviously brief and stylised. There is an enormous literature on rules within philosophy and the social sciences (see Holtzmann and Leich, 2005; Bicchieri, 2006).

[8] *The Highway Code* is seen as essential reading for 'all road users…and applies to pedestrians as much as drivers and riders' (DfT, 2015:4). Many of the rules in *The Highway Code* are legal rules that carry punishment as a criminal offence for non-compliance. In addition to these legal rules, *The Highway Code* also contains many other rules and guidelines that provide road users with guidance over how to use the street. Though not legal rules (laws) that someone can be prosecuted against, they can be used to establish liability in a court of law. In the UK, there are also bylaws that are made and enforced by local authorities requiring a certain course of action to be done. A bylaw is accompanied by some sanction or penalty for their non-observance that can be prosecuted through the legal system.

of interviews with a further 60 adult road users in Carlisle (F= 29; M=31). More specifically, 20 were predominantly drivers, 20 mostly walked, and 20 regularly cycled. These interviewees were asked to comment on the appropriateness of the cycling shown in the video, whether they themselves would do the same thing, and if not, what they felt was a more justifiable approach. Interviewees were also asked to comment on the justifications provided by the original ride-along participants. The aim of these video-based interviews was to understand the ways a wider public – or community – of road users made sense of how those cycling go about using the spaces of a street. The interviews also sought to understand the common sense rules that inform road user understandings of appropriate patterns of use (Sayer 2012; Tilly, 2006).

One compelling example of how those cycling in Carlisle deal with road infrastructures set up around motorised traffic, is making right-hand turns (see figure 1). For those in motorised vehicles in England, this involves: checking mirrors; signalling right; moving towards the centre of the carriageway; before making the turn when safe to do so[9]. For those cycling, Rule 74 of *The Highway Code* provides similar guidance to those driving (DfT, 2015). Yet, the code also offers a second alternative, 'it may be safer to wait on the left for a safe gap' in the traffic or 'dismount and push your cycle across the road' (DfT, 2015:25). This acknowledges the potentially fraught and dangerous nature of making a right-turn when cycling compared to driving. This is a product of the 'common sense physics' (Jain 2004: 74) of the carriageway. There are three aspects to this. One, a driver doing a right-turn is generally – or at least capable of – travelling at the same speed as other traffic. Two, if forced to wait in the centre of the carriageway to make their turn, drivers have the physical protection of their vehicle. And, third, the material bulk of their vehicle makes it easier for others to see and respond to their actions. Devoid of these capacities and protections, those cycling may be uniquely vulnerable to injury or death when turning into a junction on the right.

[9] The relevant Highway Code rules are Rule 179 and Rule 180. 'Well before you turn right you should: use your mirrors to make sure you know the position and movement of traffic behind you; give a right-turn signal; take up a position just left of the middle of the road or in the space marked for traffic turning right, leave room for other vehicles to pass on the left, if possible. Wait until there is a safe gap between you and any oncoming vehicle. Watch out for cyclists, motorcyclists, pedestrians and other road users. Check your mirrors and blind spot again to make sure you are not being overtaken, then make the turn. Do not cut the corner. Take great care when turning into a main road; you will need to watch for traffic in both directions and wait for a safe gap. Remember: Mirrors – Signal – Manoeuvre' (DfT, 2015:62).

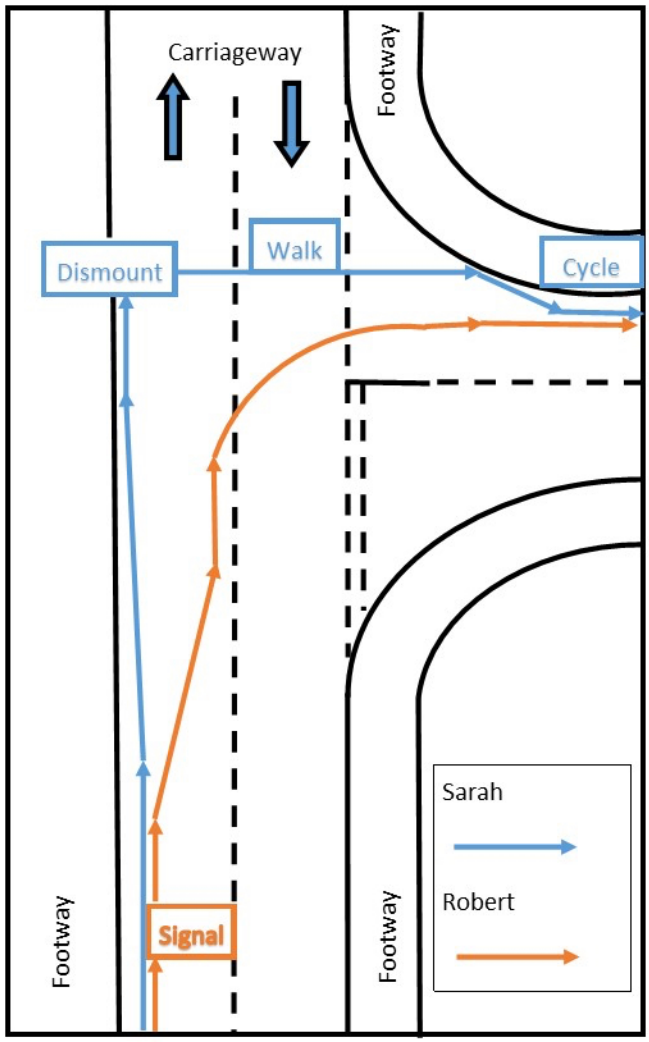

Figure 1 - Schematic diagram showing the different approaches taken by Sarah and Robert to completing a right-turn.

In Carlisle, cyclists use both ways of turning right. For example, Sarah, an office worker in her early-forties, at junctions on particularly busy and fast-moving carriageways will follow the second part of Rule 74; moving to the edge of the road, dismounting, and wheeling her bike across the road before remounting and continuing (see Figure 1). She would not necessarily do this in slow moving traffic. Here she would most likely follow the approach taken by Robert, a retired teacher in his early-seventies. He follows the instructions of the first part of Rule 74, essentially behaving like motorised traffic; moving towards the centre with his right arm outstretched, slowing the traffic behind him until he completes his right-turn. Whilst *The Highway Code* might allow for both possibilities, those using

the city's streets for cycling have a more ambiguous and situated sense of the practical and moral appropriateness of each. Interviewing Sarah and Robert, both could give carefully reasoned accounts of why and when these approaches might be appropriate. These more-or-less mapped onto the reasoning implicit to *The Highway Code*. However, others when shown videos of the turns made by Sarah and Robert interpreted their actions rather differently.

Certainly all interviewees agreed that those cycling could use streets. That is to say, they were unambiguous in recognising the legitimate presence of those cycling on the carriageway and the street infrastructure more generally. Though interviewees agreed that this is a space to share with people cycling, they articulated different points of view on the terms and conditions upon which this sharing should happen. These reflect a range of different senses of how to keep people and traffic moving safely on streets. And these responses reflect a particular sense of whose movement and safety has priority.

For some, the formal rules and laws provide all the answers to how those cycling should behave. Here following the formal rules ensures those cycling fit with the patterns of use expected – and mostly followed – by motorised traffic. According to these people, just as Robert does a right-turn properly, Sarah's cycling was misguided given that her actions depart from how motorised vehicles negotiate this manoeuvre. These claims were articulated by a minority of both driving and cycling interviewees. Their reasoning centred on the idea that streets and traffic work because legal rules provide a consistent sense of how this space will be shared. The interesting point was that whilst condemning Sarah, and indeed in some cases being baffled by her actions, this group were not oblivious to the risks faced by those cycling[10]. Rather, the unreasonableness of what Sarah was doing compared to Robert, was articulated through words like 'unpredictable', 'unexpected', difficult to 'anticipate' and as a result, being more 'dangerous'[11]. Brian, for example, a heavy-goods vehicle driver who has not cycled in decades, was clear those cycling just need to have the 'confidence' and 'awareness' to 'follow road

[10] For example, one respondent said: 'Why is she not positioning herself in the middle of the road that is what you are supposed to be doing. You are then thinking that you are going to dismount and walk across the junction there... why? That for me is all about getting yourself into the right position coming along there, and it is all about positioning yourself in the right place then there is not a problem'. Another respondent said: 'Why the hell did you get off your bike coming along there, why did you not move into the middle of the road'.

[11] All quotes are from the video-based interviews and names of interviewees are pseudonyms.

user regulations' regardless of the traffic. His view was that the 'law of the land' allows cars to do certain things when turning right and those cycling should do exactly the same if 'they want to be a road user' and not get injured or worse. Brian and many others like him, assumed being in the 'right place' as permitted by formal rules was the surest way for anyone cycling to safely do a right-turn. And so, even though those cycling are legally permitted to do a right-turn differently, the form and function of the formal rules and laws were being defined through the ways those driving are expected to use the street. For these interviewees formal rules not only keep different road users safe, they do so whilst – and through – keeping traffic moving as smoothly and efficiently as possible.

In contrast, other interviewees, in fact the majority, were amenable to the kinds of right-turns performed by Sarah, whilst also being open to Robert's approach. Why both seemed appropriate was not, however, due to them being permitted by formal rules. It was more about cycling being understood as dangerous and how to responsibly work around such risk[12]. Several responses were along the lines that 'getting out the way is obviously safer' than being 'exposed to fast-moving traffic'. Others claimed they would 'do the same' as both Sarah and Robert since they were 'correctly responding to the traffic situation'. These responses reflect three common concerns. First, the speed and volume of traffic. Second, whether those driving can be 'trusted' to 'anticipate' and 'respond' to someone cycling. And third, a general worry about the vulnerability of those cycling. Take Pauline, an office worker who drives every day. She recognised that in principle Robert's right-turn was 'right and proper'. But qualified this saying that in certain traffic situations that 'just seems crazy, if the cyclist really cares about their own road safety'. Were Sarah to do the same as Robert on busy and fast-moving carriageways, Pauline, like most people, was absolutely convinced it 'just does not feel right, as cycling into – never mind waiting – in the middle of road would be really dangerous'. Such risks were understood to be less when turning into the same junction whilst driving, for reasons of greater trust, protection and control over their relations to other drivers. Irrespective of the formal rules then, differences in the material, regulatory and normative relationships between those cycling and other road users, compared to someone driving, gave rise to a different sense of how to appropriately share this space. Such interpretative play reflects how those making these claims relied more on commonsensical notions of keeping safe being foremost the responsibility of those cycling. Many,

[12] A somewhat unsurprising finding since many studies of low-cycling countries have shown the propensity to cycle is largely inhibited by the heightened sense of risk around sharing carriageways with motorised traffic (Adams, 1995; Aldred, 2016).

like Pauline, had decided those cycling should keep out of harm's way in traffic situations where following the formal rules and laws would leave them in danger of injury or death, given the fast movement of motorised vehicles has obvious priority over other modalities.

What is clear from the interviews is that the formal and informal rules regulating the simple manoeuvre of cycling into a junction on the right are being subject to multiple reasonings about what morally counts as reasonable and appropriate. Understandings that in turn meant the patterns of sharing some found obvious, did not necessarily follow through to make perfect sense to others. The differences in these lines of reasoning were in part a product of how the interviewees themselves typically use Carlisle's streets. Drivers interpreted the cycling presented in the interview video through their own situated sense of driving on these streets. Evaluating this same cycling, those interviewees who regularly cycled drew upon their own practical experience. Meanwhile, interviewees who walked leaned towards safety, emphasising how pedestrians, and other vulnerable road users, need to carefully choreograph their interactions with motorised traffic. But it was also clear from talking to these different road users that how they relate to cycling and make sense of how those on bikes interact with other road users is subject to moral considerations found in common with other people who typically use other modalities. The point was not that some hold views on this rule-bound space that are morally or practically deficient when compared to others, rather they are situated interpretations that each make sense according to a particular sense of worth and the moral order around how to cooperate. The fact that these judgements overlap and differ from those of others, reflects a varying sense of 'what counts or should count' as the right, fair and acceptable ways for materials, regulations, people and normative patterns of negotiation to form the traffic landscape of a street (Thévenot, 2002:8; Stark, 2009). All of which matters since these moral judgements have far-reaching consequences on the kind of infrastructural settlement people understand as defining where different modalities belong and how they ought to act to appropriately share streets (Latham and Woods, 2015; see Latour, 2005; Stark, 2009).

6. Conclusion

To talk about infrastructural settlements brings the discussion back to autonomous vehicles and their potential relations to other modalities and the existing patterns of use on contemporary streets. An

infrastructural settlement describes how the materials, regulations, people and normative patterns of negotiation around a particular set of practices come to take on a certain fixed quality (Latham and Woods, 2015; Hommels, 2010). Such infrastructures – which remember are both material and immaterial – can change and evolve over time. However, they tend to do so within the taken-for-granted parameters set by the prevailing settlement; parameters that are not value neutral when it comes to whose infrastructural demands get prioritised. So, for autonomous vehicles the question that needs to be asked is: what impact will AVs have on the kinds of infrastructural settlements seen in car-dominated transport environments like Carlisle?

The answer depends upon which interpretation of the formal and informal rules AVs end up following when sharing the street with other road users. As the case of right-turns in Carlisle has shown there are multiple possible interpretations of these rules. On the one hand, AVs might take cues from those people who believe everyone on the carriageway should behave like a motor vehicle. Here formal rules are seen to support the predictable patterns of use that keeps traffic moving efficiently and safely. This settlement would leave streets to be used by AVs in more or less the same way as motorised vehicles currently do. Populated by AVs, streets configured in this way may well be more efficient and – at least for those in motorised vehicles – safer and more productive. This is a settlement that leads AVs to interact and deal with those cycling and other non-motorised traffic in much the same way as existing motorised patterns of use. Such a retained – or maybe even enhanced – priority, would likely mean AVs further crowd out other ways of moving around cities. On the other hand, it is possible to imagine an alternative future where AVs are taught the sorts of rules that value and prioritise the safety of non-motorised traffic above the demands of traffic efficiency (Adams, 2015; Bonnefon, et al., 2016; Awad, et al., 2018). This interpretation of the rules could lead AVs to interact with non-motorised users of the street in profoundly different ways than currently observed. In the case of cycling into a junction on the right, this might involve a following AV slowing down to the speed of the cyclist and refraining from undertaking except when sufficient space is available to leave a substantial gap between it and the person cycling. These two different outcomes involve a particular set of practical and moral judgements about how people, undertaking different modalities, should cooperate and coordinate with each other on streets (Jain, 2004; Norton, 2008; Parkin, et al., 2016).

The artificial intelligence and machine learning technologies being used to develop AVs are impressive. They find answers to the questions put to them by unearthing patterns within large datasets and learning from them.But this is just one form of intelligence. Another form of intelligence is coming up with the right questions to ask. Questions like, whose movement and safety should be valued and prioritised over others? Who should be responsible for what in particular situations or interactions? How far – and when – should certain rules be bent or overlooked to allow things to run smoothly? These are questions that require the sorts of moral judgements and intersubjective deliberation that artificial intelligence and machine learning cannot currently make (Larnier, 2013; O'Neil 2016; Amad, et al., 2018; Luetge, 2017). And yet, these are the sorts of questions that have far reaching implications for the predominant kind of infrastructural settlement shaping streets in low-cycling transport environments. Indeed, one of the things that it might be necessary to think about when programming AVs, is to make them sensitive to the different infrastructural settlements defining different places in different contexts (Fagnant and Kockelman, 2015; Eriksson, 2017; Stilgoe, 2018b).

Proponents of AVs, including many governmental bodies, believe the spread of AVs to be more or less inevitable – even if the current technology is unproven and far from settled (Hopkins and Schwanen, 2018a; 2018b). Be that as it may, there are many possibilities trajectories AVs could take when becoming part of the traffic landscape of streets. As this paper has shown, how people are expected to cooperate and coordinate on streets is shaped by an amalgam of materials, regulations, people and normative patterns of negotiation. If cities and neighbourhoods want AVs that help facilitate the growth and spread of non-motorised mobilities like cycling and walking in car-dominated transport environments, then politicians, policy makers and communities will need to argue for them. There is a politics to autonomous vehicles (Marres, 2018; Bissell, et al., 2018). Local and national governments will need to develop innovative regulatory frameworks that define where different modalities belong in relation to others as well as whose movement and safety has greater priority (Cavoli, et al., 2017; Cohen, et al., 2018). But to create cities and streets for people in transport environments that are currently dominated by motorised traffic, also requires profound changes to the materials that currently make up streets and afford certain kinds of movement. Changes that involve a whole host of new or remodelled physical objects, such as cycle lanes, cycle traffic lights and traffic calming that reorganise how streets are used. To state this is not to be anti-AV. Rather it is to

highlight the usefulness of a certain scepticism about what AVs might offer and demand that they behave in the ways society wants them to.

References

Adams, J.G.U. (1995) *Risk*. London: UCL Press.

Adams, J.G.U. (2015) 'Self Driving Cars and the Child–Ball Problem: Why Autonomous Vehicles are not the Answer'. London Essays. Available at: http://essays.centreforlondon.org/issues/technology/self-driving-cars-and-the-child-ball-problem-why-autonomous-vehicles-are-not-the-answer/ [09.10.2018]

Aldred, R. (2012) 'Governing Transport From Welfare State to Hollow State: The Case of Cycling in the UK. *Transport Policy*. 23, pp. 95-102.

Aldred, R. (2016) 'Cycling Near Misses: Their Frequency, Impact, and Prevention'. *Transportation Research Part A: Policy and Practice*. 90, pp. 69-83.

Aldred, R. and Dales, J. (2017) 'Diversifying and Normalising Cycling in London, UK: An Exploratory study on the Influence of Infrastructure'. *Journal of Transport and Health*. 4, pp. 348-362.

Alessandrini, A., Campagna, A., Delle Site, P., Filippi, F. and Persia, L. (2015) 'Automated Vehicles and the Rethinking of Mobility and Cities'. *Transport Research Procedia*. 5, pp. 145-160.

Anderson, E. (1993) *Value in Ethics and Economics*. Cambridge, MA: Harvard University Press.

Anderson, J.M., Kalra, N., Stanley, K.D., Sorensen, P., Samaras, C. and Oluwatola, O.A. (2016) 'Autonomous Vehicle Technology. A Guide for Policymakers'. RAND Corporation. Available at: https://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-2/RAND_RR443-2.pdf [09.10.2018]

Awad, E., Desouza, S., Kim, R., Schulz, J., Henirhc, J., Shariff, A., Bonnefon, J-F. and Rahwan, I. (2018) *Nature*. 563, pp. 59-64.

Banister, D. (2018) *Inequality in Transport*. Marcham: Alexandrine Press.

Bicchieri, C. (2006) *The Grammar of Society: The Nature and Dynamics of Social Norms*. Cambridge: Cambridge University Press.

Bissell, D. (2018a) *Transit Life: How Commuting is Transforming our Cities*. Cambridge, MA: MIT Press.

Bissell D. (2018b) Automation interrupted: How autonomous vehicle accidents transform the material politics of automation. *Political Geography*. 65, pp. 57–66.

Bissell, D., Birtchnell, T., Elliott, A. and Hsu, E.L. (2018) 'Autonomous Automobilities: The Social Impacts of Driverless Vehicles'. *Current Sociology,* doi.org/10.1177/0011392118816743

Boeckmann, R.J. and Tyler, T.R. (1997) 'Commonsense Justice and Inclusion Within The Moral Community: When Do People Receive Procedural Protections From Others?'. *Psychology, Public Policy and Law*. 3(2-3), pp. 362-380.

Boltanski, L. and Thévenot, L. (2006) *On Justification: Economies of Worth.* (Translated from French by Porter, C.) Princeton: Princeton University Press.

Bonnefon, J.F., Shariff, A. and Rahwan, I. (2016) 'The Social Dilemma of Autonomous Vehicles'. *Science.* 352(6293), pp. 1573-1576.

Cavoli, C. M., Phillips, B., Cohen, T., and Jones, P. (2017) 'Social and behavioural questions associated with Automated Vehicles. A Literature Review'. London, UK: Department for Transport.

Chater, N., Misyak, J., Watson, D., Griffiths, N. and Mouzakitis, A. (2018) 'Negotiating the Traffic: Can Cognitive Science Help Make Autonomous Vehicles a Reality?'. *Trends in Cognitive Sciences.* 22(2), pp. 93-95.

Christmas, S. and Helman, S. (2011) 'Road Sharing: Does it Matter What Roads Users think of Each Other?'. London: Royal Automobile Club (RAC) Foundation for Motoring Ltd.

Cohen, T., Stilgoe, J., and Cavoli, C. (2018) 'Reframing the governance of automotive automation: insights from UK stakeholder workshops'. *Journal of Responsible Innovation.* 5(3), pp.257-279.

Crawford, K. and Calo, R. (2016) 'There is a Blind Spot in AI Research'. *Nature.* 538(7625), pp. 311-313.

Department for Transport (2015) *The Official Highway Code.* (15th Edition) London: DSA.

Department for Transport (2018) 'Statistical Dataset: Vehicle Speed Compliance in Great Britain (SPE0112)'. London: Department for Transport. Available at: https://www.gov.uk/government/statistical-data-sets/spe01-vehicle-speeds [09.10.2018]

Ellickson, R.C. (1991) *Order without Law: How Neighbours Settle Disputes*. Cambridge, MA: Harvard University Press.

Eriksson, M. (2017) 'The Normativity of Automated Driving: A Case Study of Embedding Norms in Technology'. *Information & Communications Technology Law*. 26(1), pp.46-58.

Fagnant, D.J. and Kockelman, K. (2015) 'Preparing a nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations'. *Transportation Research Part A.* 77, pp. 167-181.

Finkel, N.J. (2000) 'But it's Not Fair: Commonsense Notions of Unfairness'. *Psychology, Public Policy and Law,* 6(4), pp.898-952.

Fishman, E. (2018) 'Autonomous Vehicles: Opportunities, Challenges and the Need for Government Action'. *Planning Theory & Practice.* 19(5), pp. 764-767.

Furlong, K. (2011) 'Small Technologies, Big Change: Rethinking Infrastructure through STS and Geography'. *Progress in Human Geography.* 35(4), PPP. 460-482.

Gehl, J. (2010) *Cities for People.* Washington, DC: Island Press.

Gregory, S.W. (1985) 'Auto Traffic in Egypt as a Verdant Grammar'. *Social Psychology Quarterly.* 48(4), pp. 337-348.

Haidt, J. (2012) *The Righteous Mind: Why Good People are divided by Politics and Religion.* London: Penguin.

Herrmann, A., Brenner, W. and Stadler, R. (2018) *Autonomous Driving: How the Driverless Revolution will Change the World.* Bingley: Emerald.

Holtzman, C. and Leich, C. (eds) (2005) *Wittgenstein: To Follow a Rule.* London: Routledge.

Hommels, A. (2005) 'Studying Obduracy in the City: Towards a Productive Fusion between Technology Studies and Urban Studies'. *Science, Technology and Human Values.* 30(3), pp. 323-351.

Hopkins, D. and Schwanen, T. (2018a) 'Experimentation with Vehicle Automation'. In. Jenkins, K.E.H. and Hopkins, D. (eds.) *Transitions in Energy Efficiency and Demand: The Emergence, Diffusion and Impact of Low-Carbon Innovation.* London: Routledge, pp. 72-93.

Hopkins, D. and Schwanen, T. (2018b)'Automated Mobility Transitions: Governing Processes in the UK'. *Sustainability.* 10(4), 956.

JafariNaimi, N. (2018) 'Our Bodies in the Trolley's Path, or Why Self-driving Cars Must *Not* Be Programmed to Kill'. *Science, Technology and Human Values.* 43(2), pp. 302-323.

Jain, S.S.L. (2004) '"Dangerous Instrumentality": The Bystander as Subject in Automobility'. *Cultural Anthropology*, 19(1), pp. 61–94.

Kahan, D.M. (2002) 'Signalling or Reciprocating - A Response to Eric Posner's Law and Social Norms'. University of Richmond Law Review, 36, pp.367-385.

Kalra, N. and Groves, D.G. (2017) 'RAND Model of Automated Vehicle Safety (MAVS)'. RAND Corporation. Available at: https://www.rand.org/pubs/research_reports/RR1902.html [09.10.2018]

Katz, J (1999) *How Emotions Work*. Chicago: The Chicago University Press.

Kent, J. (2018) 'Three Signs Autonomous Vehicles Will Not Lead to Less Car Ownership and Less Car Use in Car Dependent Cities – A Case Study of Sydney, Australia'. *Planning Theory & Practice*. 19(5), pp. 767-770.

Lanier, J. (2013) *Who Owns the Future*. London: Allen Lane.

Latham, A. and Wood, P.R.H. (2015) 'Inhabiting Infrastructure: Exploring the Interactional Spaces of Urban Cycling'. *Environment and Planning A*. 47(2), pp. 300-319.

Latour, B. (2005) *Reassembling the Social*. Oxford: Oxford University Press.

Le Vine, S. and Polak, J. (2014) 'Automated Cars: A smooth ride ahead?'. Independent Transport Commission Occasional Paper, Number 5.

Liu, S., Li, L., Tang, J., Wu, S. and Gaudiot, J-L. (2018) *Creating Autonomous Vehicle Systems*. London: Morgan and Claypool.

Luetge, C. (2017) 'The German Ethics Code for Automated and Connected Driving'. *Philosophy and Technology*. 30(4), pp. 547-558.

Lyons, G. (2018) 'Book Review: Governance of the smart mobility transition, Greg Marsden, Louise Reardon (Eds.), Emerald, Bingley'. *Journal of Transport Geography*. 72, pp. 277.

McCarthy, J., Bradburn, J., Williams, D., Pieckocki, R. and Hermans, K. (2015) 'Connected and Autonomous Vehicles. Introducing the Future of Mobility'. Atkins. Available at: http://www.atkinsglobal.co.uk/~/media/Files/A/Atkins-Corporate/uk-and-europe/uk-thought-leadership/reports/CAV_A4_080216.pdf [09.10.2018].

Marsden, G. (2018) 'Planning for Autonomous Vehicles? Questions of Purpose, Place and Pace'. *Planning Theory & Practice*. 19(5), pp. 771-773.

Marres, N. (2018) 'What if nothing happens? Street trials of Intelligent Cars as Experiments in Participation'. In. Maassen, S., Dickel, S. and Schneider, C.H. (eds.) *TechnoScience in Society, Sociology of Knowledge Yearbook*. Nijmegen: Springer.

Milakis, D., Kroesen, M. and van Wee, B. 'Implications of automated vehicles for accessibility and location choices: Evidence from an expert-based experiment'. *Journal of Transport Geography*. 68, pp. 142-148.

Norton, P.D. (2008) *Fighting Traffic: The Dawn of the Motor Age in the American City*. Cambridge, MA: MIT Press.

Office for National Statistics (2016) '2011 Census Aggregate Data'. UK Data Service.

O'Neill, C. (2016) *Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy*. London: Penguin Books.

Oxford English Dictionary (2018) Oxford: Oxford University Press.

Parkin, J., Clark, B., Clayton, W., Ricci, M. and Parkhurst, G. (2016) 'Understanding interactions between autonomous vehicles and other road users: A Literature Review'. University of the West of England, Bristol. Available at: http://eprints.uwe.ac.uk/29153/1/UWE%20autonomous%20vehicle%20interactions%20literature%20review%20June%202016.pdf [09.10.2018]

Parkin, J. (2018a) 'Book Review: Driverless: Intelligent Cars and the Road Ahead, Hod Lipson, Melba Kurman, The MIT Press, Cambridge MA'. *Journal of Transport Geography*. 66, pp. 379.

Parkin, J. (2018b) *Designing for Cycle Traffic: International Principles and Practice*. London: ICE.

Pinch, T. (2010) 'On Making Infrastructure Visible: Putting the Non-Humans to Rights'. *Cambridge Journal of Economics*. 34(1), pp. 77-89.

Porter, L. (2018) The Autonomous Vehicle Revolution: Implications for Planning. *Planning Theory & Practice*. 19(5), pp. 753-775.

Pucher J. and Buehler. R. (2008) 'Making cycling irresistible: Lessons from The Netherlands, Denmark and Germany'. *Transport Reviews: A Transnational Transdisciplinary Journal*. 28(4), pp. 495-528.

Sadik-Khan, J. and Solomonow, S. (2016) *Streetfight: Handbook for an Urban Revolution*. New York: Viking.

Sayer, A. (2011) *Why Things Matter to People: Social Science, Values and Ethical Life*. Cambridge: Cambridge University Press.

Schütz, A. (1953) 'Common-Sense and Scientific Interpretation of Human Action'. *Philosophy and Phenomenological Research*. 14(1), pp. 1-38.

Simpson, P. (2017) 'A Sense of the Cycling Environment: Felt Experiences of Infrastructure and Atmospheres'. *Environment and Planning A*. 49(2), pp. 426-447.

Skeete, J-P. (2018) 'Level 5 Autonomy: The new face of disruption in Road Transport'. *Technological Forecasting and Social Change*. 134, pp.22-34.

Smiley, A. and Brookhuis, K. A. (1987) 'Alcohol, drugs, and traffic safety'. In. Rothengatter, J. A. and de Bruin, R. A. (eds.) *Road Users and Traffic Safety*. Assen: Van Gorcum. pp. 83-105.

Star, S.L. (1999) 'The Ethnography of Infrastructure'. *American Behavioural Scientist*. 43(3), pp. 377-391.

Stark, D. (2009) *The Sense of Dissonance: Accounts of Worth in Economic Life*. Princeton, NJ: Princeton University Press.

Stone, J., Legacy, C. and Curtis, C. (2018) 'The Future Driverless City?'. *Planning Theory & Practice*. 19(5), pp. 756-761.

Spinney, J. (2015) 'Close Encounters? Mobile Methods, (post)phenomenology and affect'. *Cultural Geographies*. 22(20), pp.231-246.

Stark, D. (2009) *The Sense of Dissonance: Accounts of Worth in Economic Life*. Princeton, NJ: Princeton University Press.

Stilgoe, J. (2017) 'Seeing Like a Tesla: How Can We Anticipate Self-Driving Worlds?', *Glocalism: Journal of Culture, Politics and Innovation*. 3, doi:10.12893/gjcpi.2017.3.2

Stilgoe, J. (2018a) 'Putting Technology in its Place'. *Planning Theory & Practice*. 19(5), pp. 776-778.

Stilgoe, J. (2018b) 'Machine learning, social learning and the governance of self-driving cars'. *Social Studies of Science*. 48(1), pp. 35-56.

Taylor, C. (1995) *Philosophical Arguments*. Cambridge, MA: Harvard University Press.

Tilly, C. (2006) *Why?* Princeton, NJ: Princeton University Press.

The Economist (2018a) 'From here to Autonomy: Autonomous-Vehicle Technology is Advancing ever Faster'. Available at: https://www.economist.com/special-report/2018/03/01/autonomous-vehicle-technology-is-advancing-ever-faster [09.10.2018]

The Economist (2018b) 'A Different World: Self-driving cars will profoundly change the way people live. Foreseen and Unforeseen Consequences'. Available at:

https://www.economist.com/special-report/2018/03/01/self-driving-cars-will-profoundly-change-the-way-people-live [09.10.2018]

Thévenot, L. (2002) 'Which Road to Follow? The Moral Complexity of an 'Equipped Humanity'. In. Law, J. and Mol, A. (ed.) *Complexities: Social Studies of Knowledge Practices*. London: Duke University Press, pp. 53-87.

Tyler, T.R. (1990) *Why People Obey the Law: Procedural Justice, Legitimacy, and Compliance*. New Haven: Yale University Press.

Tyler, T.R. (2011) *Why people cooperate*. Princeton: Princeton University Press.

Urmson, C. (2015) 'Chris Urmson: How a Driverless Car sees the Road'. TED Talk. Available at: https://www.youtube.com/watch?v=tiwVMrTLUWg [09.10.2018]

Vanderbilt, T. (2008) *Traffic: Why we Drive the way we do (and What it says about us)*. London: Penguin Books.

Waymo (2018) 'Waymo 360° Experience: A Fully Self-Driving Journey'. YouTube. Available at: https://www.youtube.com/watch?v=B8R148hFxPw&t=0s&list=PLCkt0hth826GHYY8nqr8LjrjNkz_TL_e2&index=3 [09.10.2018]

Wittgenstein, L. (1953) *Philosophical Investigations*. London: Wiley.

Zakharenko, R. (2016) 'Self-Driving Cars will Change Cities'. *Regional Science and Urban Economics,* 61, pp. 26-37.