Co-existence or displacement:

Do street trials of intelligent vehicles test society?

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Abstract

This paper examines recent street tests of autonomous vehicles (AV) in the UK and makes the case for an experimental approach in the sociology of intelligent technology. In recent years intelligent vehicle testing has moved from the laboratory to the street, raising the question of whether technology trials equally constitute tests of society. To adequately address this question, I argue, we need to move beyond analytic frameworks developed in 1990s Science and Technology Studies, which stipulated "a social deficit" of both intelligent technology and technology testing. This diagnosis no longer provides an effective starting point for sociological analysis, as real-world tests of intelligent technology explicitly seek to bring social phenomena within the remit of technology testing. I propose that we examine instead whether and how the introduction of intelligent vehicles into the street involves the qualification and re-qualification of relations and dynamics between social actors. I develop this proposal through a discussion of a field study of AV street trials in three cities in the UK - London, Milton Keynes and Coventry. These urban trials were accompanied by the claim that automotive testing on the open road will enable cars to operate in tune with the social environment, and I show how iterations of street testing undo this proposition and compel its reformulation. Current test designs are limited by their narrow conception of sociality in terms of interaction between cars and other road users. They exclude from consideration the relational capacities of vehicles and human road users alike – their ability to co-exist on the open road. I conclude by making the case for methodological innovation in social studies of intelligent technology: by combining social research and design methods, we can re-purpose real-world test environments in order to elucidate social issues and dynamics raised by intelligent vehicles in society by experimental means, and, possibly, test society.

Keywords: sociology of AI; real-world testing; social studies of testing; automobility; STS; autonomous vehicles.

O Public Road

You express me better than I can express myself

You shall be more to me than my poem.

Walt Whitman, the Open Road

1. Introduction

At least since early 2016, so-called autonomous vehicles, or driverless cars, have been tested on urban roads[1] across the UK, in London, Milton Keynes, Bristol, and Coventry.[2] The most well-known of these tests are funded by the UK government, by way of its Centre for Connected and Autonomous Vehicles (CCAV), and among their principal aims is to demonstrate the capacity of intelligent vehicle technologies to operate successfully amidst social complexity, on the open road. As the Department for Transport explained the approach in its 2015 code of practice for such testing:

> Manufacturers have a responsibility to ensure that highly and fully automated vehicle technologies undergo thorough testing and development before being brought to market. Much of this development can be done in test laboratories or on dedicated test tracks and proving grounds. *However to help ensure that these technologies are capable of safely handing the many varied situations that they may encounter throughout their service life,* it is expected that controlled “real world” testing will

[1] This includes pedestrian paths and cycling lanes, city streets, and ring roads, in many cases these streets and roads are closed off for the duration of the test. In other cases, CCTV is relied upon to monitor the test environment.

[2] Different terms are used to describe the prototype vehicles in question: popular media tend to refer to ‘driverless cars’, while government has opted for ‘connected and autonomous vehicles,’ and the field of engineering tends to refer to intelligent vehicles, as in the Intelligent Vehicles group at the University of Warwick. In this article I opt for the latter term, as it usefully highlights the issue I am concerned with here: the ability of these vehicles to orientate their actions towards others, and to invoke a sociological understanding of intelligence (for an example of such interactions, see Belcher 2017)

also be necessary. Testing of automated vehicle technologies on public roads or in other places should be facilitated while ensuring that this testing is carried out with the minimum practicable risk.' (Great Britain. Department for Transport 2015, my italics)[3]

As the lead engineer for one the UK trial projects, Dr. Simon Tong of the Greenwich Automated Transport Environment, or GATEway, project put it more briefly to the *Financial Times* newspaper in the summer of 2017: the aim of the trials is to get "driverless vehicles *to learn how to get along* with city transport." (Wright 2017, italics mine). Use of such language is revealing, in that it highlights the ambition of these technical projects to attribute social capacities to machines, like "learning to get along," to 'socialise' intelligent machines, at the very least, the inclination to invoke such ambitions as part of the public legitimation of these projects. What is more, the encounter between automated vehicles and other road users is not just assumed to be one-way. UK driverless car trials are also poised as an occasion *for road users* to become familiar with these relatively new technologies. As Ian Forbes, Head of UKs Centre for Connected and Autonomous Vehicles (CCAV) stated: 'what is important is that [tests] are taking place in the real world. A crucial part of the development of this technology is allowing people to experience it.' (Parliament. House of Lords 2017)

How should we understand and assess these diverse justifications for testing of intelligent vehicle technology on public roads, in terms of the technical requirements for performance testing of intelligent machines (which must be able to handle "many varied situations during their service life") and the purportedly public commitment of creating "engaging experiences" for people? Previous studies have noted how on-the-road testing of

[3] The same report stresses that '[p]articular consideration should be given to the concerns of more vulnerable road users including disabled people, those with visual or hearing impairments, pedestrians, cyclists, motorcyclists, children and horse riders.' (Great Britain. Department for Transport 2015)

autonomous vehicles a) requires new forms of governance in support of 'social learning' in addition to 'machine learning' (Stilgoe 2018); b) gives rise to new types of actor-relations such as that between driverless vehicles and third-party road users (Tennant et al. 2016); and c) enlists publics in innovation processes in potentially new, situational ways (Marres, 2019). In this paper, I would like to focus on a more general, or even fundamental, question, namely, **whether and how do street trials of intelligent vehicles bring social phenomena within the remit of automotive innovation?** Scholars in the philosophy and sociology of technology have recently proposed that real-world testing of technology "beyond the laboratory" can be characterised as a form of social experimentation (Van der Poel et al, 2017) and as "tests on and in society" (Engels et al, 2019): these studies view "the introduction of new technology into society.. as a learning process in which the consequences of it emerge only gradually." (Van der Poel et al, 2017, p. 1) and as involving "the enrolment of (more or less) well-defined populations as subjects of scientific inquiry and technological testing" (Engels et al, 2019, p. 10). In this paper, I evaluate the proposition that real-world technology trials test society through an empirical analysis of street tests of intelligent vehicles in the UK. I make the case for a re-constructive approach: I propose that the trials in question do not in their current design qualify as societal tests, but have the potential to do so, which, if it is to be realized, requires a modification of test protocols.

To date, UK trials have mostly been engineering-led, and this raises the question of whether and how the test design, methodology and implementation are capable of operationalising the aforementioned publicly stated commitments to bring social phenomena - such as situational complexity and the co-existence of diverse users in the mundane environment of the street - within the frame of intelligent technology research and development. Indeed, from a sociological point of view, this would be a highly unexpected, and a truly remarkable feat, as sociological and anthropological studies of artificial intelligence (AI) have long argued that the technologies in question suffer from a "social deficit," that they are incapable of situated engagement, and attunement to social complexity (Suchman, 1986; Button and Dourish, 1996).

The question of whether and how street trials of autonomous vehicles are capable of operationalising the stated ambition to test and develop the social capacities of machines, then, has wider relevance for two areas of contemporary sociological enquiry: the sociology of artificial intelligence, and social studies of testing. Regarding the first, it has recently been argued that the current proliferation of automated agents and intelligent machines across society, in the form of fully scripted social media accounts, home assistants and "deep learning" applications in social domains from medicine and policing, has transformed the conditions for sociological engagement with machine intelligence (Castelle, forthcoming; see also Hildebrandt, 2019). In the 1980s and 1990s, sociologists used to criticise prevalent scientific approaches to the design of artificial intelligence for their limited and/or reductive treatment of social and societal aspects of cognition, behaviour, interaction and life in general (Woolgar 1985; Joerges, 1989; Suchman, 1986). However, in view of the de facto proliferation of AI applications across society, it has been proposed that the time has come for sociologists to move beyond critiquing the "social deficits" of the scientific representations of AI *and to analyse communication among heterogeneous actors in actually existing, partly automated environments from a sociological perspective* (Esposito 2016; Bialski et al, 2019). This paper takes up this invitation, but with a notable modification: instead of studying communication with machines as if it is happening 'in the wild', as 'naturally occurring,' I will approach artificial situations – like intelligent vehicle technology testing - in social environments, as a key object and resource for the sociology of AI: not only do real-world tests serve as a device for the introduction of intelligent machines to society (Van der Poel et al, 2017); they also present sociology with an empirical occasion, where it becomes possible to study the introduction of AI to society as an unfolding event, and to specify its consequences, incuding possible transformations of the capacities of social actors, the relations between them, and wider social dynamics.

Turning to social studies of technology testing, it should be noted that a similar assumption about the disregard for social aspects of technology in engineering has been operative in these studies, which have been undertaken in Science & Technology Studies and related fields since the 1980s. In the article ‘One, Two, Three Testing ...Toward a sociology of testing,’ Trevor Pinch made the telling point that ‘test data are usually thought of as providing access to a purely technical realm’ (1993: 25). The above characterisations of street tests of intelligent vehicles, however, could be taken to suggest that this limitation to the technical in technology testing is being surmounted in contemporary trials of intelligent technologies, as test representatives repeatedly express their commitment to bring social phenomena like interaction with pedestrians and the experience of people within the frame of the test. Taking seriously this possibility – which is different from confirming the suggestion -, I want to propose, means that a sociology of testing must move beyond the binary question of **whether or not** the remit of technology testing can include social phenomena, to engage with the far more open-ended, processual question of **how** social aspects are rendered visible, qualified, surfaced and/or obfuscated at the occasion of the test.

With this broader aim in mind, this paper begins by asking whether the commitments to test and develop the social capacities of intelligent machines was operationalised during the implementation of the CCAV funded street trials of autonomous vehicles. Based on an analysis of public documents and participant observation conducted in trial sites in London, Coventry and Milton Keynes, between February 2016 and November 2018, I will conclude that, alas, social phenomena still elude the autonomous vehicle tests in question. However, at the same time, the implementation of autonomous vehicles tests in the UK streets does surface social consequences of intelligent technology. By studying the testing of intelligent machines in social environments as generative events, sociology can make a key contribution to interdisciplinary efforts to elucidate these consequences. I propose that to do this well, we need to engage in methodological innovation, and to illustriate this I end by reporting on a recent interdisciplinary experiment that I undertook with colleagues in the "driver-in-the-loop" simulator at the University of Warwick in 2016. Taking up the design research method of prototyping, this experiment re-purposed street tests of intelligent vehicles to serve the ends of sociological enquiry, demonstrating how the introduction of autonomous machines into the street elicited distinctively social dynamics, such as stigmatization.

2. The case for real-world testing of automotive technology: 'learning from unexpected situations'

The stated commitment to bring social aspects of the functioning of intelligent vehicles within the remit of technology testing, during the CCAV funded trials in the UK between early 2016 and late 2018, was not limited to public statements. It was not just about publicity. Each of the publicly funded trials of autonomous and connected vehicles in Greenwich, Milton Keynes and Coventry had an explicit focus on assessing the interaction between vehicles, environment and road users, and indeed, with the wider social environment. Thus, the stated purpose of the Autodrive trials in Milton Keynes and Coventry, which a press release termed 'the UK's largest trial to date of connected and autonomous vehicle technology on public roads,' was to:

> 'explor[e] the benefits of having cars that can "talk" to each other and their surroundings – with connected traffic lights, emergency vehicle warnings and emergency braking alerts. The vehicles rely on sensors to detect traffic, pedestrians and signals but have a human on board to react to emergencies. The trials are testing a

number of features and most importantly seeking to investigate how self-driving vehicles interact with other road users' (Tute 2017).

This focus on testing the interactional capacities of intelligent vehicles on roads, in turn, is often justified on methodological grounds. The capacity of machines to operate in a social environment is central to the understanding of 'intelligence' in intelligent vehicle research and development, where autonomous operation requires vehicles to negotiate unexpected encounters and, as quoted above, "many varied situations". The testing of these vehicles on the street rather than in the laboratory, or in dedicated automotive test sites, tends to justified in reference to precisely these requirements of intelligence. Large-scale street trialling is said to be *the only way* in which the interactional capacities of these machines can be fully assessed and developed. As the *Financial Times* put it succinctly, 'Testing in real world conditions is essential for driverless cars to learn from unexpected situations that would be difficult to simulate, such as how humans react to a driverless vehicle' (Campbell and Yang 2018). One of the defining features of intelligent vehicle technology is its alleged capacity to respond more or less spontaneously to dynamic occurrences in the road environment - we might paraphrase: to operate in a test-ing social environment. In a promotional video released by Jaguar Land Rover on the occasion of the already mentioned Coventry street trials of self-driving vehicles, a Jaguar Land Rover (JLR) engineer explained:

> 'The car is navigating in the urban environment, interacting with other traffic. This will always be the ultimate test for this type of vehicle. We have always had control over the environment and the urban environment is far more unpredictable. There are many more dynamic elements for the car to sense and react to. But we have been using all of this data to refine our systems and make sure that they do deal with them

in the correct way. We found a massive challenge in predicting how pedestrians are going to react.'

The focus on interactional capacities of intelligent vehicles has a technological justification: environmentally situated interaction and communication is the next frontier in automotive innovation insofar as this is the next big thing that data-intensive, 'learning' computational technology renders cars capable of.[4] Testing intelligent machines in the street is the methodological corollary of this technological claim.

However, the socialisation of machines through testing does not just serve the technological optimization of their intelligence, it is equally presented as enabling the re-positioning of cars, and the automotive system, more generally, in its relation to society. At the closing event of the Autodrive project in October 2018 in Milton Keynes, where project results were presented by the Autodrive Director, the JLR project lead and others, many if not most speakers made reference to the societal benefits that intelligent vehicles would bring: increasing road safety, reducing congestion, mobility as a service, regeneration of regional economies.[5] In an earlier, informal but in some ways more spectacular announcement on Twitter, engineers of Jaguar Land Rover, a partner of the Autodrive consortium, noted that the wider objective in intelligent vehicle development is to make cars 'relevant to all demographics' (Figure I). These stated benefits, to be sure, present the type of justification one would expect from a publicly funded engineering projects, but some of them disrupt more customary framings of social actors in the automotive sector. As Lochlann Jain (2004)

[4] This way of justifying the release of intelligent vehicles onto urban streets invokes a popular narrative about the roll-out of autonomous cars on public roads which was publicised widely in the wake of the Silicon Valley autonomous vehicle releases in the shape of Google's Self-Driving Car and Tesla's Autopilot, the claim namely that only by clocking up very large numbers of 'test miles' – which for tech-based automotive companies like Tesla are reported to be in the billions (see Lambert 2018) Will the computational systems implemented in these vehicles for environmental sensing, decision-making and navigation be able to 'learn' how to operate in the unpredictable environments of the 'open road' (see Stilgoe, 2018). To my knowledge, this argument about scale was not made by representatives of the CCAV trials .

[5] UK Autodrive International CAV Conference, Transport Catapult, Milton Keynes, 11 October 2018.

reminded us, at the start of the previous century the societal introduction of automotive technologies was accompanied by the establishment of individualistic, driver-centric frameworks for accountability, with traffic regulations, insurance policies and safety procedures biased towards drivers, at the expense of pedestrians in particular. By contrast, recent publicity around intelligent vehicles prominently feature socially defined agents - like busy mums and disabled persons - among the principal beneficiaries of the transition to self-driving cars.

Public presentations of the CCAV trials, and public outreach undertaken as part of the trials often place social scenario's and narratives in the foreground. The intended effect of situating abstract automotive technologies in real-world social contexts, seems to be to make them feel real, but also to dramatize the transformation of automotive infrastructure by invoking a transformed car culture. Thus, the Greenwich Gateway trials, which ran on the Greenwich peninsula in South London between 2016 and 2018, were accompanied by an exhibition in the London Transport Museum developed in collaboration with the Royal College of Art, in which visitors were invited to join in the imagination of 'driverless futures,' producing visual mappings that feature wishful scenarios such as 'I would no longer need to be the driver when my mates go to the pub', 'safer streets, even for pet animals,' or, 'more time to socialise, do fun or useful things on journeys.'[6]

To be sure, in the documentation of the GATEway trial there certainly are traces of an individualistic, objectified, non-social framing of on-the-road activity. This project has tested a variety of intelligent mobility technologies including Oxbotica driverless pods equipped with computer vision, pedestrian detection technology and autonomous steering capacity:

[6] Driverless Futures, Designology Pop-Up Studio, Transport Museum, London, April 2017.

> 'The Greenwich experiment is exploring a fundamental question about how autonomous vehicles will fit into city streets. Oxbotica, the Oxford company that developed the vehicle's software, is trying to improve the pods' ability to track people, cyclists and other non-vehicular objects. Performance on city streets will depend on how well they can *navigate around non-mechanised obstacles*.' (Wright 2017, italics mine)

However, investigation of the human-machine encounter in the Greenwich streets was *not* limited to the machine's steering abilities. A central component of the project was the 'observation and surveys of pedestrian interactions' (Fernández-Medina et al. 2018; McDowell-Naylor, 2018) and sentiment mappings of local attitudes and of the trial itself, labelled 'Rate my drive' and 'Rate my ride' (Commonplace 2018), which collected, analysed and visualised "real-world" comments on the arrival of driverless cars mentioning the already operative driverless DLR and the difficulty of negotiating fog and rain in London. The trial protocols were explicitly designed to facilitate encounters with the public, as the end of project report explains:

> 'One of the main objectives of the GATEway public trials was to provide open service - like operations where members of the public would be free to "walk up" to the pod stops and use the service. This ensured that the project was engaging different groups of users instead of being limited to only including groups with a particular interest in the technology.'[7]

[7] 'The three main participant groups were as follows: Participants who signed up in advance to receive information about GATEway and to participate in shuttle trials; "Walk up" participants who were in the area and were interested in trying the shuttle as part of their journey; Participants from the local area who saw publicity about the shuttles and wished to experience them.' (Fernández-Medina et al. 2018) Incidentally, efforts by myself and a collaborator to sign up for participation in the trial were unsucessful, we never received a reply.

As socially defined scenarios, agents and locations are so prominently invoked in CCAV trial designs and public presentations, should we infer that society is successfully brought within the frame of intelligent technology testing in these instances? The regimes of justification activated by the CCAV trials suggest that street testing is deployed to locate automotive technology in a social environment not just spatially but ontologically: the tests' focus on the capacity of intelligent vehicles to 'co-exist' with others on the road implies a departure from the individualistic ontologies classically associated with driving (Denis and Urry 2009), towards a more 'socially aware' approach to automotive innovation. The 'interactional framing' of the UK street tests of intelligent vehicles should then be understood not just in relation to a next stage of technological – data-intensive, AI-led – development, but in relation to wider efforts to redefine the relation between automotive systems and society, culturally and economically speaking. However, as I will go on to show, while this promise is consistently invoked in the public presentation of street tests of intelligent technology, it is not followed through - operationalized - in the methodology and trial design of street tests of intelligent vehicles.

[INSERT 'Figure I' HERE]

Figure I: @Insidernwest, breaking #business news, 20 September 2016

3. From the lab to the street: testing beyond the laboratory, beyond the 'social deficit' of intelligent technology?

Taking one step back, it should be noted that the commitment to testing intelligent vehicle technology in the social environment, on public roads, can be understood as moving us beyond historical tendencies in technology testing in the automotive sector. Until recently, laboratory-based testing was considered the established paradigm in the automotive sector. In *From the Road to the Lab to Math* (2010), the organisation studies scholar Paul Leonardi, who has conducted extensive fieldwork in car companies, shows how, over the course of the 20th century, prominent forms of performance assessment such as crash testing – with its iconic plastic dummies getting shaken and crushed inside a car on a indoor test track - and other forms of automotive testing, like societal impact modelling, have been increasingly confined to dedicated test sites and lab-based computer simulations. In his account, the defining development in automotive testing has been the move away from testing on 'the open road' in the early 20th Century, to controlled experimentation in the closed spaces of the lab and then to modelling-driven 'simulation' at the start of the 21st. Today's automotive testing in everyday environments like the street arguably take us beyond this narrative.

Street tests of intelligent vehicles can be taken to exemplify a wider paradigm shift in technology testing, and the management of relations between innovation and society, through testing. A variety of scholars have commented on the rise of "real-world" experimentation, whereby technologies are increasingly tested in sites "beyond the laboratory" (Van der Poel et al, 2017; see also Gross and Hoffmann-Riem, 2005). Contrasting such experimentation to controlled laboratory experiments, Van der Poel and colleagues note that real-world testing entails affirmation of the fact that "only after its implementation will we gradually learn about the impacts of a technology on society, the normative and moral issues raised by such processes, and the best way to embed it in society." They give the example of Autopilot, Tesla's driver-assist feature which has been advertised as enabling autonomous or driverless driving, and was rolled-out in Tesla cars at an early stage of its development, and presents it as an examplar of experimentation in society: "because Tesla explicitly recognizes the technology as experimental, but also because the experience of using it may lead to further improvements in the system [..] along the way." (Van der Poel et al, 2017, p. 5-6) In a similar vein, Jackson et al. (2014) have discussed the 'beta-testing model' for the introduction of technology to society (see also Stark and Neff 2004).

In line with the logic of data-intensive machine learning invoked above, real-world testing of intelligent vehicles is here understood as implementing an approach to technology testing that derives from software development, which Jackson et al. label "beta-testing." They argue that, in the tech industry, it has become customary to release experimental products and services to users at an early stage in their development, as companies release relatively un-tested, un-stable devices into everyday environments, relying on user trials and field tests to identify not only technical problems with the applications in question, but also ethical, social, and legal issues with their functioning in society (on this point, see also Neff and Stark, 2004; Marres 2018). Finally, Laurent and Tironi (2015) have suggested that street trials of smart vehicles, in Saint Denis near Paris, implement a new, emerging paradigm in automotive innovation which they call 'experimental innovation.' They contrast this model with an older, industrial approach to the introduction of automotive technology to society in France: whereas the former involved the construction of 'complete socio-technical systems in-house,' car companies today increasingly enter into partnerships with a diverse set of agencies in government, business and society in order not just to implement a new form of transport, but to configure 'a whole ecosystem' of mobility, in which social actors become involved as stakeholders, and in which the very role of these agencies in the transport system is put at stake (Laurent and Tironi 2015: 211). In street trials of intelligent vehicles in Greenwich, Milton Keynes, Coventry, can we observe a similar approach to the one identified by Van der Poel, Jackson et al. and Laurent and Tironi? Could we even observe *an expansion or radicalisation of the experimental approach to the introduction of technology to society in these cases, as these tests do not just locate testing in the social environment, and* *enrol social actors as stakeholders and/or test subjects, but define the very object of technological innovation in social terms*?

It is necessary to pose this question, partly because it helps to bring into view current limitations of the sociology of intelligent technolgy as formulated in the 1980s. Real-world testing of intelligent technology can be taken to amount to a partial falsification of assumptions formulated in the sociology of AI in that period, insofar as sociologists of technology claimed then that artificial intelligence research, 'lacks a social theory' (Woolgar 1985). This claim continues to reveberate today: in a recent article on the sociology of robots, Elena Esposito (2017) posits that 'the sociological perspective is not involved in designing algorithms, which are programmed without adequate consideration of social and communicative aspects' (see also Sloane and Moss, 2019) Meister (2014) states that to date sociology has had limited influence on the field of social robotics, and notes artificial intelligence's reliance on narrow interactional framings of sociality (see also Alač et al. 2011). These critiques build earlier work in the sociology and anthropology of technology, which examined the blind spot for social aspects in technical fields, positing a 'social deficit' of computational systems (Suchman 1987; Joerges 1989).[8] These authors claimed that AI and robotics disregard or ignore the situated, contextual and generative character of human-machine interaction (Suchman 2007; see also Suchman and Weber 2013). Button and Dourish (1996) neatly sum up this critique in observing that many problems with computational systems derive 'not so much from their technological limitations, but more from their insensitivity to the organisation of work and communication in real work environments.' The question is: are these criticisms still valid and/or effective ways of engaging sociologically with intelligent machines in a context defined by real-world testing?

[8] These arguments must be distinguished from philosophical critiques of AI such as John Searle's (1980) 'Chinese Room' thought experiment, which argues that computers lack subjective features such as intentionality.

One of the problems with the 1980s social deficit thesis, in my view, is that it prevents us from analysing how social phenomena emerge and/or are articulated experimentally – as proto-type – in real-world technology testing in society, in ways that may or may not be recognized by the designers of these tests, but which could help to surface societal aspects and issues that otherwise tend to remain un- or under-analysed. Briefly put, positing the social deficit often means that the sociological potential of technology tests remains out of view. Here it is relevant to note that sociologists have applied the notion of a 'social deficit' not just to intelligent technology, but also to technology testing, even if they did not explicitly use this label. In 'Testing - One, Two, Three... Testing!,' Trevor Pinch (1993) sets himself the task to disprove the notion that testing 'providing access to a purely technical realm.' (25) In relation to computer systems, he notes that 'tests [of computer systems] can be construed to be as much about testing the user as they are about testing the machine. [..] any technology that requires the user to act in new sorts of ways (such as when a new technology is first introduced) will involve some in vivo testing.' (36) However, Pinch goes on to note that user testing tends to be highly constrained in the process of technology development, as the smooth functioning of technology is widely understood to depend on predictable and disciplined user behaviour. In Pinch's account, sociologists may be sensitive to the social dimensions of technology testing, prevailing approaches to the development of computational technology are not:

> 'the machine has embedded within it assumptions about us whereby our future interaction with it can be projected. This "embedded projection" gives the appearance of a kind of volition-it seems that the machines are training us to use them properly. [..] The possibility of negotiating with and persuading the machine [..] are extremely

> curtailed.[..] For technological systems with interchangeable parts, it is highly desirable to have the potentially capricious user black boxed' (37-8).

This focus in early 1990s social studies of testing is still traceable in well-known STS concepts like the socio-technical script, which lead us to understand the role of users in technology testing first and foremost in terms of compliance and resistance (Woolgar 1993), the enrolment or not of "humans" (Callon, 1986). This approach may be less suitable when empirical sociology is confronted with artificial situations in which specific forms of social action – interact with the machine! – are being framed and promoted, and actors are qualified in terms of social attributes ("busy mum," "disabled person").

In what follows I will argue that it is, however, not enough for sociology to observe and describe how social phenomena feature in intelligent technology testing. We equally need to attend to how such phenomena are bracketed and/or disavowed in the test. Most importantly, to realize the potential of real-world testing for social enquiry, sociology must move beyond treating tests as object as enquiry, as has been the norm in social studies of testing, and engage methodologically with real-world testing. If such tests are to qualify as sociological tests, we will need to modify test protocols so as to attune them to sociological phenomena. On this point, it is relevant to remember that, even in the 1990s, not everyone in the social studies of testing subscribed to the idea that AI "lacks a social theory". In that same period, Harry Collins (1990) proposed that intelligent technology tests can be approached as tests of sociological propositions. His study of artificial systems (1990) argued that 'the artificial intelligence experiment, is not just a problem of engineering and psychology, but an empirical test of deep theses in the philosophy of the social sciences.' (p. 8) Collins proposed that AI tests could be treated as experimental operationalisations of fundamental questions such as: is there a distinction between social action and behaviour? Does methodological individualism obtain? Can knowledge be acquired without participation in a social community? Latour's (1996) slogan, that technology is sociology 'by other means' (210) expresses a similar confidence in the equivalence of engineering-based and sociological approaches. Whereas Pinch, then, diagnosed a kind of 'social deficit' in relation to prevalent protocols in technology testing, namely their indifference to a recalcitrant, testing user, Collins and Latour suggested that engineering paradigms were already attuned to societal phenomena, in and of themselves, *without any modification of the test protocol required to achieve this.*

Today's real-world testing of intelligent technologies in social environments requires a different approach. Even as the "social deficit" of intelligent technology can no longer be assumed, neither is it possible, today, to express confidence in a spontaneously given, instead of hard won, equivalence between engineering and sociology. As real-world tests explicitly bring social phenomena ('interaction', 'experience', 'public engagement') within the frame of engineering-based research designers, it becomes obvious that engineering is different - methodologically speaking - from sociology. As I would like to show, there is also a range of sociologically relevant phenomena which are patently *not* included within engineering-led real-world tests, or at least not in the UK street trials of intelligent vehicles under discussion here. When considering the implementation of intelligent vehicles tests in the UK streets, real-world testing can for the most part *not* be said to bring society within the experimental remit. We can nevertheless establish a significant difference with previous sociological accounts of the 'social deficit' of intelligent technology and technology testing: in the trials under scrutiny, the social deficit primarily presents *a methodological problem.*

4. Testing technology but not society: 'Learning to get along' as an individual, not a relational, challenge

While accounts of UK street trials of intelligent vehicles published in news, online and governmental media deploy social frames to characterise the trials, a different picture emerges from our fieldwork. Together with colleagues, I attended trials and visited test sites in Greenwich (London), Milton Keynes, Coventry and the Horiba Mira Test site in Nuneaton between 2016 and 2018, and in many cases, we found that opportunities for interaction between intelligent vehicles and other road users were significantly curtailed. To start with, in all cases the trials design and implementation included significant provisions for the containment and management of the machine's encounter with 'social complexity', to the point that the trial situation could not be said to qualify as an operationalisation of that notion from a sociological perspective. These efforts at containment take various forms, but they include the use of media embargos to prevent the public being notified of tests until after the tests in question were concluded, as was the case during the Coventry trials in November 2017 and the Milton Keynes trials in October 2016 and October 2018. This does not mean the trials aren't noticed or recorded by the public: in November 2017, the Coventry Telegraph published a video of Autodrive and JLR vehicles on the streets of Coventry city centre, showing a fenced-off bit of road, with test vehicles entering and leaving a car park to enter a stretch of road turned into the test track. A user commented: 'It needed people every 10 seconds to stop anyone crossing the roads lol. So they can't cope with someone stepping out.'[9] Furthermore, social media offer myriads of reports of intelligent vehicle sightings on urban streets, as in Milton Keynes where a Twitter user noted in the autumn of 2016 that they 'had to drive out of the way of one of Milton Keynes' autonomous cars on the sidewalk yesterday. By the time my phone booted it was gone.'

[9] Another user commented: "shouldn't the public no what goes on, news to me" Coventry Telegraph, Facebook live page, 15 November 2017 https://www.facebook.com/coventrytelegraph/videos/1638060592917755/?q=Coventry%20Telegraph%20driverless

While the ostensible aim of the tests is then to demonstrate the capacity of technology to co-exist with other road users, the settings in which they take place tell a more complex story. In all of the trials we observed, the test involved material, organisational and regulatory operations upon the street environment, which rendered it more passive, less open, and more

[INSERT 'Figure II' HERE]

Figure II: Driverless pods test route, Milton Keynes [photograph by the author], October 2018

compliant with the machine's needs. In Milton Keynes, cyclists are not permitted on the pedestrian pathways on which driverless pods were tested (Figure II). Probed on this point during a public panel discussion, a city counselor clarified the legal background to this state of affairs: technically 'you can't run a pod on a pedestrian pathway because it was passenger carrying so we know we need to change the regulation to change pedestrian paths into roads.'[10] In several cases, pedestrians themselves were prohibited from using pedestrian pathways where intelligent vehicles were being trialed. On encountering a driverless pod in Milton Keynes in October 2018, I was politely but firmly asked to get out of the way. When I enquired whether pedestrian detection wasn't part of the vehicle's technical features, a street marshal wearing the customary Hi-Viz jacket pointed out to me that the ride in question was part of a public demo, and the test vehicle had notable guests inside.[11] Preparations of the vehicles path, finally, do not just take the form of temporary provisions like marshals and temporary fencing along the test route, but also involve material intervention in the street

[10] UK Autodrive International CAV Conference, Transport Catapult, Milton Keynes, 11 October 2018.
[11] One of the functions of the marshalls in CCAV trials is to ensure members of the public had a positive experience of AVs, according to McDowell-Naylor, who studied the GATEway trial in Greenwhich,. He quotes one of the trial organisers: "we don't want any dramas because that means that something has probably gone wrong." (McDowell-Naylor, 2018, p. 174). This type of curation of "experience" by means of public trials, I am arguing here, is not compat-able with a conception of tests as forsm of "social experimentation."

environment. Along the Thames Path on the Greenwich Peninsula, where the Gateway trial took place, a high blue fence, which looks like it is there to stay, separates the shuttle path from the neighboring conference centre. As the trial organisers noted during a public presentation, we ‘added a distinct path for the shuttle, a "shuttle route” so that pedestrians have an expectation that a shuttle is operating, with a logo on the floor of a pod, and we have improved surfacing for the pods.’[12] An extensive CCTV system allows for the monitoring of this pathway. Apparently, when there were too many people the shuttle wouldn't run.

While public accounts of intelligent vehicle trials emphasise the commitment to investigate and enable the co-existence of machines and road users in the street, observation of the tests’ implementation bring into focus a number of limitations that call this ambition into question, when approached from a societal perspective. To be sure, many of these limitations make sense from a technical point of view - the machine after all is *still learning* to get along with city transport, they severly limit the ability of social actors to even engage with the trial. Importantly, the limitations in question are not only technical, but also methodological: while the capacity to ‘share the road with others’ is the stated objective of the trials, the trial protocols specify this objective as an individual not a relational challenge. This was apparent during a demonstration of Autodrive driverless technology at Horiba Mira, the UK automotive test site. Here, stakeholders were invited into test vehicles to experience various features of connected and autonomous vehicle technology, including this Emergency Vehicle Warning (EVW) demo. As I put it in my fieldnotes at the time:

> ‘The driver – German? – tells us about the “blind spot system” – a system for automated vehicle detection – but he says: “no bikes, no horses, and no pedestrians.” However, it *can* detect roundabouts and stop lines. I ask about information

[12] GATEway presentation, Driverless Technology Conference DTC16, Milton Keynes, 22 November 2016

> asymmetry, talk about how making space for a vehicle involves coordination work, which is hard when we don't know who has and hasn't received the 'smart" signal [from the passing emergence vehicle]. He says nothing for a few seconds. Then: yes, we assume this will be mandatory for all cars. Another passenger takes a more constructive approach: he asks whether the people in the emergency vehicle need to do anything to get this signal out. They say, yes, they will have a switch in their fire truck – which they can switch on the same time as their siren. A fire truck comes by.'

In an exchange like this, the constitutive role of situated interaction and the need for the mutual coordination of action among multiple actors is clearly missed. Indeed, the test design seems to render its participants insensitive to the following relational question raised in and by on-the-road interaction: how, in an encounter between diverse entities and agents - in society, in public - can we find a language or register of communication that diverse actors are able to share? The experimental design for establishing communication between machines and human entities in a social environment, then, *misses the central challenge of co-existence, a challenge that is constitutive of social life*: how to negotiate difference, how to relate across chasms that separate cultures, genders, classes, experiences? Street trials of intelligent vehicle may be presented, in media outlets like the Financial Times, as directly concerned with social phenomena like interaction and engagement, the implemented trial designs have technology, not social life, as their object. That is also to say, an analysis of the methodology and implementation of street trials of autonomous vehicles from a sociological perspective suggests that what we need is a re-constructive approach to intelligent technology testing in society: if society is to be brought within the frame of street trials of intelligent technology, prevalent test protocols will need to be modified.

5. Testing on the social road: the explication of mutual constraints

To sum this up in a straightforward manner, the test protocols implemented in the observed street trials display a technological bias. They are organised to put intelligent technology prototypes to the test, to challenge *their* capacities to interact with other road users – so that these capacities can be qualified, strengthened and developed further. But this experimental approach is not extended to social actors present in the situation, or at least not intentionally so. Pedestrians, cyclists, other road users and passengers are not put to the test in this same way, their capacities to relate - to learn to get along with others - is not subject to deliberate experimental qualification (although their attitudes towards the trials and intelligent vehicles are documented and reported upon. However, the (re-)qualification of social actors implicated in the trials - their capacities and relations - *does* occur, as an *effect* or *consequence* of the trials' implementation (even if it is not its intended object). In the case of the Greenwich test, a variety of experimental effects did and do arise: for example, some actors have explicitly taken issue with its stated commitment to machines 'learning to get along' with others, objecting that the trial's design in fact prevents this hypothesis from being put to the test. As E&T Magazine reported this summer, '[c]yclists were horrified when a dedicated riverside bike lane was commandeered for use by an autonomous shuttle bus in the Greenwich Peninsula district of London earlier this year as part of another government-backed trial.' (Loeb 2017) Not co-existence of machine and human, but displacement of other road users by machines is here explicated as an empirical consequence of street tests of driverless cars. An organisation called the Pedestrian Liberation Front has been considering lodging a formal complaint against an Ocado trial with driverless delivery vans in Woolwich: it alleged that pedestrians are discriminated against by the trials as they take over streets previously marked as 'pedestrian-friendly.' (Loeb 2017) Such interventions surface possible re-qualifications of the capacities of social actors – in casu pedestrians – as a consequence of the introduction of intelligent vehicles into the street. When approached from the standpoint of their effects, it then appears that street testing of intelligent vehicles *can* do double work – they can facilitate technological as well as social experimentation. While we can clearly detect sociological limitations of engineering-led designs of real-world technology tests, they may give rise to social experimentation all the same.

Rather than continuing to insist on the shortcomings - the social deficits - of the current designs of intelligent vehicle street trials - their less-than-relational, less-than-experimental envisioning of the encounter between social actors and intelligent machines in UK streets - I would like to emphasise that street trials have *the potential* to surface and frame social aspects of intelligent vehicle technology. Crucial in this respect is a particular disjuncture between the trials design and the effects of their implementation: While the tests I observed mostly rely on an *interactional* definition of the encounter between machines and other road users, *street testing in practice pushes the commitment to co-existence beyond this narrow* '*interactional frame.*' The question of the possible co-existence of diverse road users – cars, cyclists, pedestrians – is not just a question of the physical encounter of individuated actors in the street. It includes the question of how their existence in the street is environmentally enabled – cycling, for example, is associated with geographic proximity (living in the city), while automobility implies societal inter-dependence (Latimer and Munro 2006). [13] From this perspective, the challenge of co-existence inevitably exceeds the question of interaction in the street, but includes the wider challenge of how to negotiate difference – 'what currently separates' different road users in terms of their commitments and dependencies, capacities, their life forms, and so on, and what threatens to constitute their diverse life forms as mutually exclusive, and to render their co-existence impossible: How

[13] Indeed, this latter circumstance is usefully highlighted in the intelligent vehicle discourses that foreground of *care and caring subjects* - busy mums, the visually impaired, the elderly.

can cyclists, pedestrians, drivers and the driven co-exist peacefully on the UKs open roads?[14] While it is not currently addressed within CCAV trial designs, the question of an agent's capacities for 'co-existence' may equally be posed of pedestrians and cyclists, and cycling advocates: are *they* prepared to share the street with others? And: are *they* able to recognise the societal constraints and interdependencies expressed in the car system? If we are to 'learn to get along,' the encounter among mutually contested forms of mobility must be explored, and indeed, tested.

The above criticims of UK street trials with intelligent vehicles as excluding sociological phenomena like mutual coordination in situ and the negotiation of difference among diverse actors from the trial design, can then be re-formulated as a methodological challenge: is it possible to design a street trial that enables the exploration of these relational challenges raised – and highlighted - by the appearance of intelligent vehicles in the UK streets? Can street trials of intelligent vehicle technologies serve as experimental occasions for the explication of the varied mutual constraints that today limit, and indeed, render impossible, co-existence among diverse entities on the open road? Together with my colleagues [four names removed for review] we undertook an interdisciplinary experiment in 2016 that took up these broad questions. The pilot project brought together sociologists, design researchers and vehicle engineers at the University of Warwick to examine possibilities of conducting social research in the "driver-in-the-loop' simulator, a new simulator that was:

[14] I build here on earlier work on so-called "issue-publics," which I defined in terms of diverse actors being jointly and antagonistically implicated in a matter of concern, "[such as] environmental NGOs and leading international banks [involved in fossil fuels], [who] are bound together by mutual exclusivities between their attachments to the matter at hand" (Marres, 2005, p. 129)

> "designed specifically to test real-world robustness and usability of smart, connected and autonomous vehicle technology. [..] Using 30 miles of photorealistic, real world driving routes presented via a 360-degree high definition visuals, accompanied by 3D surround sound and real vehicle motion, they will deliver an immersive experience for driver-in-the-loop technology evaluations."[15]

We asked: can this test environment, which was designed for engineering-led research on intelligent vehicles, including the development of "next generation communication protocols [..] and approaches to validate sensing technologies like Radar, LiDAR camera and ultra-sonic,"[16] be adapted to investigate social aspects of autonomous vehicles? Elsehwere I report on the test methodology in more detail (Marres et al, 2017), but for the purposes of this article it's important to note it consisted of two stages. In a first step, we conducted a public debate mapping, in which we used digital methods to identify issues raised on the social media platform Twitter in relation to autonomous vehicles and driverless cars in the West Midlands. The aim of this exercise was not to arrive at a representative overview of public debates on our topic, but rather, to build up a list of issues raised by driverless cars in this region. We used a query-based Twitter data-set, including tweets containing the terms driverless, CAV and intelligent vehicle.[17] For the purposes of this particular debate mapping exercise, we analysed only the tweets of which the account description listed relevant locations (Coventry, Birmingham, Warwick, Warwickshire). In order to identify the issues raised on Twitter in relation to the Coventry/Warwick trials, we then manually coded our Twitter data using a loose interpretative framework, which we visualised using different

[15] https://warwick.ac.uk/newsandevents/news/world146s_most_adaptable/
[16] https://warwick.ac.uk/newsandevents/news/world146s_most_adaptable/
[17] We collected our Twitter data with the aid of T-CAT - the Toolset for the Capture and Analysis of Twitter data (Borra and Rieder, 2012), between 10 June and 9 September 2016. The data set of region-specific tweets was small, containing 662 tweets. We identified a total of 138 issue terms

criteria (such as uniqueness and frequency in Figure III [revised]). This initial issue visualisation suggests, we found, that UK street trials of driverless cars enable the explication of wider societal constraint, as they mobilised terms such as ‘mobile living room for shopping’, ‘job creation’, ‘Brexit bus driverless” and ‘car for the rich.’ We invited students to visit public places to seek responses to this and similar visualisations, on the Warwick campus, and in Coventry city centre, in an effort to deploy our issue maps as ‘devices of elicitation’, assuming that displaying concerns offers a way of inviting everyday actors - in the street - to make sense of issue formations, and to elaborate on them. Results were mixed, however, in that public responses focused as much on the representation (why Twitter? How did you get to this picture?) as on the issues surfaced by our research.

In a next step, we conducted a participatory exercise in the driver-in-the-loop simulator, inviting social researchers, designers, engineers, and policy makers, to explore autonomous vehicle issues in this environment. Presenting the simulator as an environment for the exploration of “issue-scapes,” we invited participants to annotate the simulator, using issue terms featuring on our Twitter maps. Participants received instructions as to how to produce an issue scape, namely by using sticky notes to attach issues to objects present in the simulator – like the car itself, or the stretch of Coventry road projected on the 360-screen surrounding them. There were also cardboard figures available for annotation, representing human actors and cardboard boxes representing non-humans (machines; technologies; institutions; etc.). While participants were clearly fascinated by the simulator - the technology - itself, they also made significant efforts to locate some of the issues raised on Twitter inside the driverless simulator environment, in doing so elaborating and generating further issue articulations. Thus, ‘the elderly’ were introduced in the setting in the form of an ‘old lady’ cardboard figure, which was settled into the back seat of the car, with a note on the window noting ‘a dashboard that says 'old lady on board': stigma’. Someone attached a 'basket for collecting road kill' to the front of the car, arguably signaling the lack of provisions for animal presence in the simulator environment. In the relative darkness of the simulator, one of the vehicle engineers observed that Coventry as a transport environment has one crucial feature that he believes his profession needs assistance in negotiating: ‘city-ness’ (Marres et al, 2017).

[INSERT '‘Figure III’ HERE]

Figure III: Issues raised in relation to driverless cars in the West Midlands on Twitter (2016, N. Calvillo)

Conclusion

The location of intelligent automotive technology testing ‘in' society remains an unfinished project, from the standpoint of the sociology of technology testing. The STS proposition that engineering can be regarded as “sociology by other means” (Latour, 1996) cannot, at present, be extended to real-world testing of intelligent vehicles in the UK streets: the transformation of intelligent technology tests into sociological tests, if this is feasible at all, will require significant modifications of test protocols, at the very least. However, neither does it suffice today to diagnose a “social deficit” of intelligent technology testing, and leave it at that. The exclusion of social phenomena from technology tests does not only presents a substantive limitation of these tests. It can equally be approached as an experimental, methodological challenge : how *could* street trials of intelligent technology serve the elucidation of societal issues? In the driver-in-the loop simulator, we tried out ways of introducing society into the test environments – can ‘issue maps’ do this job? – as well as ways of dramatizing societal concerns in this setting – can we use cardboard figures to explicate dynamics of stigmatization? In taking this approach, we treat society not as as a "model community" to be demonstrated - and promoted - in a test environment, as is the prevalent, rather un-experimental approach in test bed design (Engels et al, 2019), but as composed of an open-ended set of actors, relations, issues, and dynamics that a test environment may render explorable, and perhaps indeed, test-able. In this sense, environments designed for the real-world testing of inteligent technology do have the potential to 'test society."

It may then be time to redefine what is put to the test in technology testing in society – not just the capacities of machines, but also their relations to social actors, and the relational capacities of all involved. And also, to redefine the job description of the sociology of testing, and what it adds to engineering in these cases. STS scholars have long argued that technological tests inevitably also put social actors and arrangements to the test, yet they too – not only engineers - have applied different criteria to both. Whereas technology testing was defined in terms of the *qualification and development* of machinic capacities, the test of human capacities was often described by sociologists of technology testing in much flatter terms – most notably in term of the enrolment, compliance and alignment of users and stakeholders. The challenge of how tests can qualify and activate relational capacities was consequently not really broached by social studies of technology in the 1980s. Intelligent technology testing in social environments today brings this challenge to the fore. Conceivably, the 'co-existence' of social actors and machines on the road could be achieved by compelling humans to comply with machinic requirements. But surely realization of the ambition to achieve intelligence, in the street environment, would require something different, something like relational attunement between diverse road users, and this will require the design of different tests than those currently being rolled out on UK streets.

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