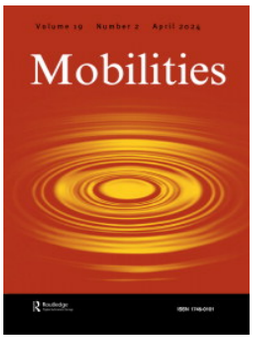

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Public anticipations of self-driving vehicles in the UK and US

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ABSTRACT

Developers of self-driving vehicles (SDVs) work with a particular idea of a possible and desirable future. Members of the public may not share the assumptions on which this is based. In this paper we analyse free-text responses from surveys of UK ($n = 4{,}860$) and US ($n = 1{,}890$) publics, which ask respondents what springs to mind when they think of SDVs, and why they should or should not be developed. Responses (averaging a total 27 words per participant) tend to foreground safety hopes and, more regularly, concerns. Many respondents present alternative representations of relationships between the technology, other road users and the future. Rather than accepting a dominant approach to public engagement, which seeks to educate members of the public away from these views, we instead propose that these views should be seen as a source of social intelligence, with potential constructive contributions to building better transport systems. Anticipatory governance, if it is to be inclusive, should seek to understand and integrate public views rather than reject them as irrational or mutable.

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1. Introduction: the idea of the self-driving vehicle

In this paper we take a lead from Macnaghten, Davies, and Kearnes (2019). When it comes to new technologies, they stress the need to 'understand how tacit assumptions of nature and social progress, often embedded in dominant scientific and policy discourse, may be radically at odds with wider public sentiment' (Macnaghten, Davies, and Kearnes 2019, 513). We explore public visions of self-driving vehicles (SDVs) and discuss how these views could and should shape the future constitution of the technology.

Scientific and policy discourse around SDVs has historically been bold. As long ago as 1968, AI pioneer John McCarthy set out what he considered to be the pathway for the development of SDVs (1968/1996). He anticipated that the most difficult challenge would be the technical programming of the vehicles' computers, and that matters such as computing volume and power, cost and telecommunications, would all be solved in one or two decades. His vision is part of a longer tradition mapping out the physical and social transformation of the world by a dominant automotive technology. Initially the auto companies predicted a physical and social world

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configured to optimise the possibilities of the automobile (Bel Geddes 1940/2017), but later they imagined futures informed by a science fiction aesthetic. This proposed varying modes of automated driving which could further optimise utilisation of the expanding road network and could make time spent travelling by car more useful or enjoyable (Norton 2021; Wetmore 2020).

Half a century later, SDV companies have been testing vehicles on public roads and offering SDV robotaxi services in designated geographic areas from Singapore to San Francisco. Trials of self-driving shuttle buses, delivery vehicles and distribution centres are also taking place. Their vision foregrounds promises of improved safety from the reduction of human error (Krafcik 2017). Safety claims frame SDVs as a moral imperative (see Sparrow and Howard 2017), and promoters have claimed that criticism of SDV deployment is putting lives at risk (e.g. McGoogan 2016). The benefits of safety, convenience, system efficiency, accessibility, and reduced pollution imagined by McCarthy are becoming marketing promises. Promotion of SDV technology often exhibits an uncritically modernist confidence in technological innovation: a certainty that machines can outperform humans, especially if the task is defined as repetitive, and a commitment to a liberal capitalist framework shaped by businesses bringing new products to market in place of the old. This technologically determinist framing suggests an inevitable future, closing off the possibility of alternatives (Sovacool et al. 2020; Wyatt 2008).

To achieve radical technological transformations, developers need government actors to endorse their vision to establish broader rhetorical momentum and to pave the way for necessary regulatory change (Brodsky 2016). SDV developers have the support of governments in the US (U.S. Department of Transportation 2018), in the UK (HM Government 2017), and across the globe (KPMG 2020). But there are dissenting voices: for example, some argue that the agency conferred by driving oneself is essential to notions of individual autonomy (Crawford 2020), others that SDVs' promises to do away with all the ills of modern car dependency ring hollow if the likely outcome is just more cars and more journeys (Norton 2021).

Science and technology studies scholars have offered frameworks to analyse how societies, and the technologists operating within them, build visions of the future (see Sovacool and Hess 2017 for an overview). One framework, sociotechnical imaginaries, stresses the role of nation states in developing visions of the future to mobilise the necessary institutional and financial resources (Jasanoff and Kim 2009). 'Regimes of promising' that techno-scientific developments will deliver 'desirable societal impacts' (Robinson et al. 2021, 1,3) are one way that technological means can become ends, with little democratic scrutiny.

Scholars have demonstrated how stakeholders are building an SDV socio-technical imaginary (Stilgoe and Mladenović 2022). In the UK (HM Government 2017) and elsewhere (Haugland and Skjølsvold 2020; Mladenović et al. 2020) policymakers have joined innovators in promoting SDVs as capable of addressing long-standing transport goals. The delivery of the technology then becomes the goal of policy (Van Lente 1995), focusing on the means rather than opening up alternative routes (Stirling 2008) to realising policy objectives, such as reduced vehicle use or increased road safety.

The various public trials of SDVs around the world can be seen as performances of this vision as well as tests of both technology and of public attitudes (see Engels, Wentland, and Pfotenhauer 2019 on testbeds for other technologies; McDowell-Naylor 2019; Stilgoe and O'Donovan, 2023). Some have pointed out that these tests tend to be unclear on what would be considered a failed outcome (Haugland and Skjølsvold 2020). Many public engagement exercises adopt an instrumental framing that makes the politics of SDVs one-sided, limiting the role of the public to that of a user to be persuaded into acceptance, or an experimental subject in public trials. This has prompted calls for more inclusive, democratic forms of governance that invite more open thinking about mobility futures (Graf and Sonnberger 2019; Hopkins and Schwanen 2018; Stilgoe and Cohen 2021).

Contested representations of SDVs offer an opportunity to anticipate an emerging technology that would connect the politics of everyday mobilities to the politics of artificial intelligence.

Understandings of mobilities in general and the system of automobility in particular (Urry 2004) can bring speculative discussions of artificial intelligence down to earth, situating vehicles in a web of relationships to infrastructures, cultures and economic arrangements on which they depend.

In considering emerging mobility technologies, it is notable that each imagined future sees some things as mobile and others as fixed. The Silicon Valley imaginary of the SDV sees artificial intelligence as infinitely mutable, able to understand and adapt to all the world's complexity, while infrastructure is irredeemable. Digitally unscaleable, infrastructures are left out of the technological optimists' rhetoric, at least in the short run. If the technology follows this vision, its potential to alleviate mobility injustice (Sheller 2018) looks highly constrained. Thankfully, this is not the only possible constitution of the technology, nor is it inevitable (Cohen et al. 2020).

We reiterate John Urry's observation that 'The future is neither fully determined, nor empty and open … a key element of power is thus power to determine – to produce – the future, out of the many ways it is imagined, organized, materialized and distributed' (Urry 2016, 15,19). Rather than just aiming for a critical engagement with the 'social implications of autonomous vehicles' (Bissell et al. 2018, 116), the aim of our research is instead to explore the emerging social constitution of SDV technology as viewed by the public, considering it in the context of possibilities for its constructive reformulation (Cohen et al. 2020; Pink 2022).

2. Public attitudes towards SDVs

If the public are to have a role in the governance of SDV technology, we need to understand their views on the subject. Public surveys find attitudes reflecting both innovators' arguments for SDV technology but also wider concerns (Gkartzonikas and Gkritza 2019 provide an extensive list of perceived benefits and barriers/concerns in the survey literature). Benefits asked about in surveys are those promised by McCarthy: safety, convenience, system efficiency, accessibility, reduced pollution. Prominent concerns reported in the literature include safety and reliability of the technology, loss of personal control of the vehicle, cyber security and affordability.

In Western societies surveys suggest a mix of enthusiasm, hostility and ambivalence towards the idea of SDVs. Comparatively speaking, while broad questions about SDVs and the future commonly elicit more positive responses (e.g. in surveys by König and Neumayr 2017; Liljamo, Liimatainen, and Pöllänen 2018), 'present tense' questions implying the possibility of using an SDV *now* tend to receive more negative responses (European Commission 2015, 2017), with some variation across social groups (Lee and Hess 2022). In spite of some claims that attitudes are becoming more positive (Harb et al. 2021), the Eurobarometer surveys reveal a steady picture from 2015 to as recently as 2020 (European Commission 2015, 2020), extending into similarly worded questions fielded by the authors in 2021 (Tennant et al. 2022), even as the technology has advanced rapidly. Across this period, over half of respondents say they would not be comfortable when asked about using the technology in the present, and not more than a third say they are comfortable.

Academic studies of public attitudes towards SDVs often begin with assertions that the technology is inevitable (e.g. Bezai et al. 2021; Daziano, Sarrias, and Leard 2017) and/or a restatement of the case for the technology's development (e.g. Zhang et al. 2021). As literature reviews make clear, and as with the public engagement exercises described above, the objective is typically to identify factors predicting public 'acceptance' (Becker and Axhausen 2017; Gkartzonikas and Gkritza 2019; Raj, Kumar, and Bansal 2020). Reluctance to accept is perceived as a barrier to adoption (e.g. Bezai et al. 2021) rather than as a legitimate expression of hopes for alternative futures (Bauer 2015). A literature focussing on engineering acceptance through public education suggests there is little interest in engaging with this recalcitrant public as a potentially

constructive contributor in the way that some are calling for (e.g Hopkins and Schwanen 2018 and others, above).

McCarthy (1968/1996) took an equally blithe approach to the challenge of public acceptance as he did to the engineering challenges:

> A general resistance to technological innovation on the part of the literary culture will have to be overcome, but it seems to me that after the test phase the advantages will be clear enough so that this will not be difficult (p5).

Such frank commitment to technological determinism, coupled with a strong presumption that reluctant users will eventually accept the technology (Rogers 1983), can be disarming. It reduces the issue to one of a cost-benefit calculus, and negates the possibility that better socio-technical futures might be achieved in collaboration with, rather than in spite of, the public (Stilgoe and Cohen 2021). Even in terms of risk assessment alone, Paul Slovic (1987, 285) noted:

> There is wisdom as well as error in public attitudes and perceptions. Lay people sometimes lack certain information about hazards. However, their basic conceptualization of risk is much richer and reflects legitimate concerns that are typically omitted from expert risk assessments.

Later constructivist research on public engagement with science and technology has revealed the myriad other political concerns underpinning views that are often expressed in terms of risk and safety, some of which will not be resolvable with more research, more information or more exposure to a technology (Wynne 2002). Kearnes and Wynne (2007) conclude that public ambivalence about new technologies, far from being a problem to be solved through science communication, should instead be regarded as informative of people's nuanced views of the 'double-edged' nature of the technology, and 'producing a set of engaged relations with both technology and the structures of power governing it' (Kearnes and Wynne 2007, 139-141).

We have argued previously (Tennant, Stares, and Howard 2019) that social representations theory (Moscovici 2007) provides an illuminating framework for understanding public perceptions of SDVs. Several features of the theory are useful here. One is the idea that representations are formed in dynamic processes of communication, and as such they may be shared or contested in various degrees. This accommodates the concept of socio-technical imaginaries. Another is that the formation of social representations involves processes of anchoring elements of a new phenomenon to existing reference points – here for example, perhaps pre-existing representations of personal autonomy, transport, and new technology generally. This provides us with a means of approaching public anticipations of a new technology, in contrast to the argument that there is no point in asking people about their attitudes until the technology has been fully specified by developers. Another benefit of the theory is that it seeks to understand representations as *systems* of 'values, ideas and practices' (Moscovici 1973, xiii). This means that risk perceptions can be understood as ways of understanding the world that are not solely based on probabilistic analysis (Douglas and Wildavsky 1982; Gaskell et al. 2004). Mary Douglas showed that risk perceptions are embedded in perceptions of right and wrong. Whereas for many promoters of SDVs human drivers represent the greatest risk to road safety and there is a moral imperative to remove them from the process, others may see new and different risks from SDVs, and some of these may represent 'dread' and 'involuntary' risks (Slovic 1987). Lastly, social representations theory includes the concept of 'cognitive polyphasia'. This is the idea that individuals and collectives may simultaneously entertain different ideas or even rationalities about a topic, linked to different elements of their social identities. This key facet of the theory invites us to explore the variety in research participants' responses, and view ambivalence as informative.

Public engagement exercises and surveys necessarily impose framings of technologies in order to elicit responses (Corner and Pidgeon 2015). In our study we use a complementary approach by seeking instinctive responses to open-ended survey questions, to explore and understand the representations of SDV technology held by the public, in the hope that this can

open up new possibilities for anticipatory governance (Guston 2014), in terms of both its means and ends.

3. Methodology

3.1. Survey data collection

We conducted a survey in the UK from September to November 2021 and in the US from February to March 2022 as part of the *Driverless Futures?* project[1]. A detailed account of the methodology, and copies of the survey instruments, can be found online in the project reports (Tennant et al. 2022a;2022b). The questionnaire was administered via the market research company Qualtrics, to samples of panel respondents from their approved third-party providers. We applied nested age and gender quotas (plus income and region quotas in the US), but such survey panels are restricted to those who voluntarily participate in return for retail credits, and as such are not strict probability samples of their wider populations. After data cleaning we retained 4,860 UK and 1,890 US respondents. The reports discuss the sampling strategy in detail, data cleaning techniques and weightings used to address some sample imbalances.

3.2. Survey design

Survey design built upon issues raised in a set of over 50 expert interviews (Tennant and Stilgoe 2021), a series of public dialogues involving some of the authors (Traverse 2019), and the existing survey literature. Following some demographic screening items and questions concerning travel behaviour and views of the road today, the survey posed a range of questions on the topic of SDVs and AI more broadly. Two questions sought free-text responses and the answers to these form the principal data reported here.

Supplementary Materials Appendix 1 provides the full text of the questions prompting the free-text responses. The first of these asked, 'What first comes to mind when you hear the term 'self-driving vehicles'?' (Q4.1), while the second followed up the closed-ended question 'Do you think this technology should be developed?' by asking 'Why or why not?' (Q4.8). In both cases the instructions asked for a minimum of 7 characters and a maximum of 250.

The question sequence and phrasing encouraged respondents to think of SDVs on the road, but did not specify their purpose (e.g. passengers or freight), their exact level of automation (although the wording was consistent with Level 4, i.e. fully self-driving in defined conditions, or Level 5, fully self-driving without restrictions) or their business model (public transit, shuttles, robotaxi, private car, etc). The intention was to allow respondents to express their initial thoughts with as little priming from the text as possible.

3.3. Free-text question analysis: organisation of the corpus

Two of the authors coded the free-text answers. We had conducted a previous coding exercise for our project reports, but developed a fully revised coding frame for this paper and recoded the corpus. In the original exercise we coded the two free-text answers separately. Although the question framing meant some themes featured more prominently in one set of answers (i.e. comparing Q4.1 to Q4.8), many respondents reinforced their answers to Q4.1 in Q4.8 and the same key arguments appeared in both, enabling us to use the same coding frame for both questions. Since Q4.1 addresses 'present tense' attitudes and Q4.8 addresses attitudes to the future, we chose for this paper to code responses to both questions together, as a single piece of text capturing each respondent's representations of SDVs. Further, in the original coding exercise the thematic content of the UK and US texts was very similar: we have therefore analysed both

together as a single corpus. However, we report frequencies for the UK and US material separately for comparative purposes.

After creating the corpus, both coders started by coding small numbers of responses independently and then comparing notes to continue the process of refining the coding frame. This was finalised by both subsequently coding a small number of the same responses and comparing results. This process of repeated coding and revising the coding frame comprised elements of inductive and deductive coding. Initial explorations for the original project reports were inductive. The coding frame for this paper built on the themes identified in the earlier exercise together with the themes raised in our literature review: risk and safety, technological visions, concerns over control, the 'usefulness' of the technology, together with codes designed to capture more tonal aspects of the responses such as emotions or indications of conditionality to respondents' views. To the extent that we provide a quantitative analysis of the prevalence of themes, our approach is similar to a standard content analysis; to the extent that we have clustered our codes within broader themes our approach is akin to thematic analysis.

As detailed in Supplementary Materials Appendix 1 we carried out reliability checks at several stages in the process, measured against the Cohen's Kappa and Gwet's AC1 benchmarks, repeating the approach adopted in previous studies (Tennant, Howard, and Stares 2021).

In addition to identified key themes, we retained codes assigned in our initial reports that summarise whether respondents express positive, negative or neutral/ambivalent views of the technology, providing an overview comparison with people's answers to some of the fixed-response questions.

3.4. Use of quantitative survey data

In this paper, we make limited use of the quantitative survey data derived from the rest of the survey, where it provides relevant context. Full details of the quantitative elements of our methodology are available in our project reports (Tennant et al. 2022a;2022b).

4. Results

4.1. Overall valence of attitudes to SDVs

Tables 1 and 2 summarise overall valence of expressed attitudes, comparing the free text and selected fixed-response survey questions. 'Neutral' covers mid-scale responses in the fixed-

Table 1. Overall valence of expressed attitudes to SDVs in the UK, for free text and selected fixed-response questions.

UK respondents *N = 4,860*	Negative %	Neutral %	Positive %	Don't know %
What first comes to mind? (coded free-text)	55	30	15	
Should this technology be developed?	39	9	52	
Reasons why/why not (coded free-text)	43	21	36	
Comfort with using the roads alongside	55	15	26	5
Comfort with riding in	58	13	24	5

Table 2. Overall valence of expressed attitudes to SDVs in the US, for free text and selected fixed-response questions.

US respondents *N = 1,890*	Negative %	Neutral %	Positive %	Don't know %
What first comes to mind? (coded free-text)	49	34	17	
Should this technology be developed?	35	7	58	
Reasons why/why not (coded free-text)	39	23	38	
Comfort with using the roads alongside	46	20	29	5
Comfort with riding in	53	15	28	4

response questions (maybe or neither/nor), 'Not sure' answers to 'Should this technology be developed?' and neutral or ambivalent responses in the open-ended questions.

Results for the questions asking people how comfortable they would be riding in or using roads alongside SDVs are similar to previous surveys with similarly framed questions (European Commission 2020; Tennant, Stares, and Howard 2019). Results for the more general, future-orientated 'Should it be developed?' question tend to be more positive comparatively speaking, in common with previous literature (above, Section 2). This may partly explain the higher prevalence of 'positive' answers to the follow-up open-ended question 'Why or why not?', compared to the initial open-ended 'What first comes to mind?'.

4.2. Themes coded in free-text questions

The corpus totals 184,000 words from 6,750 respondents. Answers range from a single word, like 'Dangerous', to extended argument sometimes cut off by the 250 character limit. The final coding frame is detailed in Supplementary Materials Appendix 2. It comprises 52 codes in total, grouped into broader themes. These include various facets of risk perceptions including safety and reliability; emotional reactions and evaluations; explicit comparisons of humans versus machines both generally and for the task of driving; anticipated visions of how SDVs and technology more broadly might shape the future; expressions of conditionality or comments on timing of SDV development, such as 'not ready yet'; systemic (i.e. transport system) versus user perspectives; implementation issues such as liability and regulation; comments on the usefulness of SDVs in terms of different potential benefits; thoughts on positive or negative environmental impact; ambivalence or uncertainty; and a set of specific topics including comments on job losses, freight and logistics, references to Tesla and science fiction.

Some codes are straightforward: did the respondent mention a sci-fi film? Others are more interpretative. For example, in the 'Conditionality and timing' codes, some explicitly state an unconditional 'never', (e.g. US1,401 '*I would never want to ride in this type of vehicle because I would feel unsafe riding in it*'), while we coded others as 'implicitly' never, for example when both free-text answers suggest strong hostility or one answer expresses flat rejection (UK3,880 '*Danger! Cars going wrong and crashing*' with '*Money could be better spent on cancer research for example*', or US1,296 '*I'd rather ride a horse*' and '*I don't trust it*')[2].

We report the percentages of respondents coded for a particular theme as a measure of prevalence. However, as is common practice with qualitative text analysis (Bauer 2000), our interest is not only in those themes that dominate the corpus. We also pay attention to some of the more complex ideas found in longer answers even though those themes may have lower prevalence percentages. We reference quantitative data where relevant to support some claims made about the salience of views across the whole sample, and we illustrate the codes with examples from each country.

4.3. Overview of themes

Table 3 shows the most prevalent themes from our coding: the top 15 UK codes and the top 13 US codes. In the following sections we describe them in more detail. In some places we augment this with mention of other related topic codes, all of which can be found in Supplementary Materials Appendix 2. To facilitate our interpretation we have used a slightly different grouping of codes in one or two places. The three 'topic' codes (safety, humans vs. machines, and systemic views) were used to capture reference to a broad topic while the more detailed codes below them capture the valence of the view expressed on the topic. As can be seen, almost all themes have similar prevalence in both the US and UK material. This suggests responses often reflect an imaginary projected by promoters of SDVs that goes beyond a single national context. Others, as will be seen in both the UK and US material, reflect competing visions of the technology.

Table 3. Most prevalent themes in coded free text responses, with frequency rank, percentage of responses coded with each theme, and corresponding article paragraph containing commentary.

Rank			UK %	US %	
UK	US	Code *N*	*4,860*	*1,890*	Paragraph
		Risk Perceptions			4.4
1	1	Reference to topic of safety (topic code)	70%	68%	4.4.1
2	2	Strong safety concerns: (feels like) probable implication of SDVs as dangerous, never safe	26%	26%	4.4.1
6	7	Safety concerns expressed but (feels like) might be temporary	19%	13%	4.4.1
7	6	Presumption of SDVs safer than human drivers	16%	18%	4.4.1
9	12	Emotions: negative (dread, aversion)	12%	11%	
5	5	Reference to reliability, error, hack, malfunction etc.	20%	21%	4.4.2
14	19	Reference to trust	8%	7%	4.4.2
		Humans versus machines			4.5
3	3	Human vs machine driving: comparison explicit or implied (topic code)	25%	25%	4.5
10	11	Humans better than machines. Need for a human in control; assumption machine cannot cope with variation on road	11%	11%	4.5
18	20	Machines better than humans, because of human error	6%	7%	4.5
		Visions of the future			4.6
13	13	Negative evaluation of technology shaping future	8%	8%	4.6.1
23	18	Positive evaluation of technology shaping future	5%	7%	4.6.2
		The transport system, implementation and usefulness			4.7
12	10	Applying system-level rather than/as well as user-level considerations (topic code)	10%	11%	4.7
11	8	Useful: convenience (generally useful for society)	11%	13%	4.7
		Conditionality and ambivalence			4.8
15	15	'Bivalence', e.g. pros and cons referenced	8%	8%	4.8
8	9	Explicit needs more testing, research, other conditions to be fulfilled	14%	12%	4.8
4	4	Implicit never - conviction of not acceptable/dangerous appears entrenched	20%	22%	4.8

4.4. Risk perceptions

We referenced above Mary Douglas' argument that social evaluations of risk frequently express beliefs in what is right and wrong (Douglas and Wildavsky 1982). Promoters' first argument on what is right about SDVs is based on safety, evidencing accident rate statistics. Safety is also the most prominent theme in our corpus. Respondents more often express worries over new dangers than hopes for safety improvements, and these worries are frequently framed normatively in terms of the propriety of machines carrying out human tasks.

4.4.1. Safety

The theme of safety was mentioned in some way by 70% of UK and 68% of US respondents. We identified three main sub-categories:

1. Those who have concerns that seem entrenched: e.g. US458 '*I don't trust them to be safe*', or that SDVs definitely should not be developed (Q4.7) because '*It is not safe*'. 26% of both UK and US respondents expressed such views.
2. Those who have concerns but seem to believe that these could be resolved: e.g. UK33 whose first answer includes '*potentially unsafe*' but goes on to argue SDVs should be developed because '*It could be useful if used correctly and didn't malfunction*'. 19% UK and 13% US respondents relayed such thoughts.
3. Those who anticipate that machines would be safer than human drivers: e.g US1,289 '*I think of much safer vehicles, vehicles that are able to stop quicker because they are automatic and robotic and whatnot. I also think of road trips being safer because sleepy drivers wouldn't be the ones driving*'. 16% UK and 18% US respondents shared this perspective.

Many respondents with strong safety concerns express an idea of wanting never to use them or for them never to be deployed: over 80% (in both UK and US) of those with strong concerns are coded as saying either explicitly or implicitly 'never', such as US1,260 whose two answers are '*I do not want or will ever use this worthless crap*' and '*If I wanna die from not driving I will use this garbage*'. For some (12% UK and 11% US respondents), strong safety concerns are expressed in terms of dread risk: e.g. UK909 '*Scary I don't like the idea at all*'.

4.4.2. Reliability and trust

The theme of reliability includes going 'wrong', being hacked, malfunctioning, glitching etc: this covers 20% of UK and 21% of US respondents. Some echo SDV proponents' argument that machines are necessarily more reliable than humans who are liable to get distracted or fall asleep, so machines should take over the driving as soon as feasible (see Section 1). Some respondents share this judgement. For example, US1,010 says '*Probably would be better than human idiot drivers on the road now*' and '*It's time to take the human error from the equation of accidents from drunk or driving under the influence of drugs*'. Some are less explicit about poor human driving but refer to the idea that SDVs might result in fewer collisions due to reliability.

For others, technology is inherently unreliable. UK1,205 says '*Computers sometimes crash so will auto cars*'. US374's first thought is '*it's a computer. My computer at work messes up every day. Self-driving would cause even more accidents, injuries and deaths just from glitches alone*', going on to say '*Technology glitches out too often. Not reliable*'. Others express more generalised worries: e.g. UK514 '*Too much could go wrong and there would be lots of crashes*'. Hacking is a specific reliability concern: a word-search of 'hack' specifically shows it is mentioned by 2% of both the UK and US respondents whether framed simply, e.g. UK368 '*Computers can be hacked or glitch and is not safe*' or as a more developed security worry, e.g. UK223 ' *I would also be very worried about the technology being hacked by terrorists, kidnappers, etc. and being used against ordinary people*'. Hacking concerns are fundamentally connected to the broad theme of control. For example, US488's comment evokes Slovic's (1987) notion that people distrust a system beyond their control: '*I fear that they could be too easily hacked into and controlled by someone other than the person in the vehicle*'.

One facet of reliability, which is fairly prominent in the literature, is trust (Raats, Fors, and Pink 2020). Unprompted, only 8% of UK and 7% of US respondents reference trust directly, usually a lack of trust in SDVs, for example UK86: '*Terror. I have minimum trust in this technology*', or US913 '*I'm not sure I trust technology that completely with my life*'. But UK13 stated '*I trust self-driving is best*'.

4.5. Humans versus machines?

In several instances, where respondents invoke themes falling under other codes, such as control, safety or risk, they frame it in terms of a 'humans versus machines' comparison. 25% of responses in the UK and US are given this code.

11% of respondents in the UK and US express the idea that machines should not be drivers. For example, for UK257 it is instinctive and linked to the theme of safety: '*I just don't feel that this is safe enough, and wouldn't be happy being driven somewhere by a computer as opposed a human driver*'. For US501 it is a question of individual agency and control: 'I *never want to give up the control of driving my own vehicle to a computer*', while UK3,347 pitches this theme at the collective level: '*Taking things out of our control, always risky in my opinion*'. Some respondents assert an absolute rejection of the technology's capabilities, such as UK412 '*Robots can't drive*', while others elaborate on reasons why, e.g. US498 '*Can't depend on AI to perform driving duties in the same manner as a human being would*'. The issue some point to is the complexity of the road environment, e.g. UK3,168 who also invokes the theme of trust: '*I honestly despair at the*

thought of vehicles driving themselves …. there are infinite situations on the roads which humans can easily adapt to, which I trust more', and US956 who links this to issues of safety and control: '*Too dangerous, too many unknowns that need a person to control the car*'. Often there is a sense that only humans can anticipate the variety of behaviours of other humans, e.g. UK671 '*In my experience of life, I could never condone a vehicle without a driver. Vehicle with drivers are hazardous enough, but to trust one with children running out into the road, old people crossing, other cars jumping red lights, I wouldn't go out!*' For these respondents the road is a social space for human, rather than human-robot, interaction.

A smaller proportion of respondents pitch the human vs. machines contest in the context of reliability but favour the machine: 6% of UK and 7% of US respondents take this stance. For example, UK353: '*I would rather AI controlled vehicles were on the roads rather than the many idiot human drivers*'. Just as some express emotional hostility to SDVs some can be emotionally positive, e.g. US661 '*Heaven! It would be great to take the human reflexes and bad habits out of the equation*', or even US1,526's confident assertion that '*Robots make less mistakes than humans*'. But such broad confidence is rare among respondents making the human machine comparison.

4.6. Visions of the future

We have commented earlier that slightly different responses tend to be elicited from survey questions framed in the here-and-now than in a longer-term perspective. Our questions yielded some answers from the user's or consumer's point of view, but also some framed at the broader societal level, including representations of socio-technical imaginaries, which often seem to be anchored to particular socio-political outlooks. We have coded these responses as visions of the future, and next compare those that are negative or positive in tone.

4.6.1. Negative visions

We found negative technological visions in 8% of both UK and US responses. One way in which these are presented is as protest against broad technological determinism: for example, UK3,131 '*Tech can go too far sometimes and some things should just not happen*'; US1,195 '*Scary and giving tech too much power*'; UK806 '*Just because it's possible doesn't mean we should*'. Some respondents link this to the profound theme of human versus machine and anticipate adverse consequences for humanity, such as UK752 '*Humans are becoming reliant on technology. We will be useless in a couple of generations*'; US663 '*I think it's a terrible idea … makes drivers lazy and dependent on technology instead of paying attention and being alert an on guard*.' We also see negative visions expressed in terms of control, e.g. UK588 '*I will not be in control of my own destiny. Just another nail in the coffin of humanity by dehumanising normal activity in pursuit of pointless technological change*' and US1,286 '*Devolution of human kind*'. UK588's idea that the technology is pointless, or unnecessary, is shared by 7% of UK and 4% of US respondents.

Negative visions for some are emotive and redolent of dread risk, such as UK3,155 '*The beginning of the robot-led apocalypse. People hacking cars to kill people*' and '*The thought is terrifying. There is so much that could go wrong. When will [w]e stop and go back to nature?!*'. And for some, negative visions of the future seem to be anchored to apathy regarding the political and economic systems in which it is understood that they will be embedded. For example, UK2,184 '*Dangerous. Unworthy. Pushed by greedy individuals whose true priorities are to make excessive profits without care for others and likelihood of fatalities and accidents*'; UK939 '*They're a solution to a non-existent problem. Although gullible people wanting to appear tech-savvy are always an excellent source of profits for the sector concerned, so we'll be stuck with 'em til the novelty wears off*'; and US920 '*Government control of where you are driving and giving up our freedom and our privacy. Relying too much on systems that could crash*.'

4.6.2. Positive visions

We found positive technological visions in 5% of UK and 7% of US responses. Most are a combination of enthusiasm, a sense of forward progress, and mention of one or two concrete benefits. Some are emotive celebrations of the idea of SDVs: they should be developed (UK4,183) '*Because it would be cool*', or (US1,397) '*Because it's encouraging, comfortable and wonderful*'. Some frame their enthusiasm as an issue of progress, e.g. UK3,063 says that we should develop SDVs '*As it can only be a positive. We got to the moon now we head for Mars. We are designed to evolve*.' US667's perspective has a shade of contented acquiesence: '*It's the wave of the future*' alongside '*It's already being developed, so why not continue?*' For others, positive visions of the future are linked to principled general trust in science, e.g. US602: '*Modernity and science, actually I trust it*' and '*We have to trust science and evolution moving away from human errors*'. Some respondents anticipate the safety and system-level convenience benefits emphasised by developers, e.g. UK300, '*It's the future and will ultimately result in greater efficiency, less congestion, cleaner air and safer roads*'. For some the individual-level emancipation potential is key, e.g. UK938 '*I think they are a great idea! Looking forward to it being the norm and not needing to own a car for many older people. Just book a self driving car to take you where you need to go*'.

4.7. The transport system and implementation of SDVs within it

Under this overarching heading we describe several more fine-grained codes. We mention the two most frequent, listed in Table 3, plus a selection of particular interest from the detailed codebook given in Supplementary Materials Appendix 2.

10% of UK and 11% of US respondents made a comment that we considered to be pitched as a system-level rather than consumer-level consideration. Positive evaluations often restate arguments made by developers for SDVs such as UK300: '*greater efficiency, less congestion*', however, often framing the system as that of an aggregate of sovereign consumers, e.g. US466: '*More useful commute time, fewer accidents, more efficient driving, more available forms of individualized transportation*'. By contrast, respondents such as UK2,036 resist this vision: '*That [SDVs] shouldn't be a priority. What should be a priority is reducing car dependency*'. However, references to public transport are limited, to 2.2% in the UK and 1.4% in the US. 6% in the UK and 7% in the US mention the potential for non-drivers, the elderly and disabled to have better access to road transport. Notably, non-drivers and the elderly are only slightly more likely to mention this than others, suggesting a generalised awareness or concern over the mobility injustices that inaccessibility creates in present transport systems.

We categorised mentions of freight and logistics separately as a specific segment of the transport system (noted by 2% of UK and 1% of US respondents). Some refer to benefits in logistics and delivery services, or suggest that SDVs could address heavy goods vehicle driver shortages (a frequent UK and US media topic in winter 2021/22). In some cases respondents make system-level connections with job losses (mentioned by 4% of UK and 3% of US respondents). US744 considers competing needs at two levels of analysis: '*SDVs are likely to become the best way to transport goods on the open road. However, my friend is a long-haul trucker whose job has made it possible to support her daughter and herself and the impact on truckers would be disastrous*'. UK3,168's comments link job loss concerns to the human-machine theme: '*Not only do I think that it's highly dangerous but automation generally is replacing humans, which is gradually making us redundant in society when it comes to jobs*.'

Developers and regulators are together wrestling with how best to establish a liability regime in the absence of a driver. 3% of respondents in both the UK and US mention responsibility and liability issues, e.g. US1,241 '*What occurs when there is an accident? Who is responsible, too many legal issues*'. As well as technical complexities involved, some express concern in principle about shifting responsibilities, e.g. UK192 '*The lessening of personal responsibility and skills. What levels*

of safety do driverless cars have? I am uneasy about most moves to create a robotic/less accountable world'. Some stress the desire for humans, not machines, to be held responsible for actions with social consequences, e.g. US1,310 '*As long as it is safer and the manufacturers are held responsible for any accidents*'. Some focus on worries about mixing human driven vehicles with SDVs, which tend to be downplayed by developers: 5% of UK and 4% of US respondents suggest the incompatibility of humans and machines, the need for segregated systems or fear of sharing the road with SDVs, e.g. UK1,080 '*The technology can never be 100% safe so the legal aspect of this is a minefield. When there is a crash, who is responsible? The only possibility is if ALL cars are autonomous and all interconnected*' and US1,016 '*It is an all or nothing situation. All cars need to be driven by humans or all be driven by technology*'.

4.8. Conditionality and ambivalence

As with safety, we found variations in levels of conviction and conditionality across views on many other themes. Some respondents expressed their views with partisan certainty, whether positive or negative. We coded 20% of UK and 22% of US respondents as having an 'entrenched' negative view of SDVs. We categorised 14% in the UK and 12% in the US as saying there were conditions to be fulfilled before the technology was ready, e.g. more testing or research, or restriction of SDV use to particular operational design domains, e.g. UK2,054 '*Only for closed environments*'. Earlier examples given for other codes above illustrate conviction or conditionality, so we do not elaborate further on these relatively clear categories.

The code of ambivalence requires more unpacking. We categorised 8% of respondents in the UK and US as 'bivalent': i.e. they provide statements both for and against SDVs. We applied a separate code for uncertainty, to 4% of UK and 3% of US respondents. Bivalent views are consistent with the concept of cognitive polyphasia: that different considerations and evaluations may be salient according to the context in which a person is thinking about an issue. Some views that we coded as ambivalent are for those who answer 'yes [SDV technology should be developed]' to Q4.7 while providing overwhelmingly negative free-text answers, e.g. US177 '*It sounds really scary and very unpredictable*'. Some juxtapose competing evaluations e.g. US12 '*Personally I would be too scared to use it but it would really help out when you have to drive all alone but need to do other things*'. Some respondents analytically separate advantages and disadvantages, such as UK368 '*I can see both pros and cons to developing self-driving technology. Human error would be eliminated & people that can't drive/disabled people would be able to get around easier, but it's bound to put many out of work & technical errors would occur.*' Only rarely does ambivalence turn to resignation: UK936 '*It's bound to happen anyway so there's not much point opposing it*'.

Tables 1 and 2 show that the spread of answers of positive, neutral or ambivalent and negative tone of the free-text answers is quite similar to those for other general measures of attitudes towards SDVs, at the aggregate level. At the individual level the overall valence of free-text answers is statistically associated with measures of general technological optimism and attitudes towards SDVs (Tennant et al. 2022a;2022b). The free-text questions elicit a higher rate of neutral or ambivalent answers than the fixed-response questions, suggesting to us the value of this approach for gaining new insights into public views. But we would not pretend that our data have the richness of a focus group discussion. Notably, the rate of positive answers is higher for the 'why or why not [should it (not) be developed?]' question than for the initial 'what first comes to mind?'. It may be that the fixed-response question between them, 'should this technology be developed?' primes respondents to some extent to 'take sides' in the follow-up open-ended question. Public dialogue allowing more space for deliberation might find more nuanced views and more complex ambivalence than our methodology has revealed.

5. Discussion and conclusion

We opened our introduction with Macnaghten and colleagues' assertion that the public's assumptions about nature and progress might be different from dominant scientific and policy discourses; following Slovic, we suggested that we might treat such assumptions as wisdom rather than ignorance. The development of new technologies is typically accompanied by a construction and a problematisation of the public and their concerns (Graf and Sonnberger 2019). Faced with public scepticism or ambivalence, the instinct of innovators is often to seek to correct or mitigate such concerns. Innovators often work with a mental model of public opinion that divides people as potential users into early and late(r) adopters (Rogers 1983), with the presumption (shared by McCarthy) that the speed of adoption might be slowed by public ignorance. The solution is seen as education and awareness, and this is actively pursued by some SDV promoters (see https://pavecampaign.org/ and Niedermeyer 2019) as well as advocated by some academic researchers on public attitudes (e.g. Sanbonmatsu et al. 2018). We have argued elsewhere that this model of public acceptance is multiply flawed (Stilgoe and Cohen 2021; Tennant, Stares, and Howard 2019) as have others (Irwin 2014; Sturgis and Allum 2004).

Our research contributes to the project of anticipatory governance which, following Guston (2014, 219), we take to mean 'a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible'. In this paper, we have focussed on one key tenet of anticipatory governance, that of public engagement. Rejecting the reduction of public concerns to a question of technology acceptance, we use minimal prompts to elicit survey respondents' views as much as possible within their own framings. Our work builds on a social scientific approach that, by seeking non-expert views, sometimes fleshes out and sometimes challenges the narrow technical idea of an SDV that presumes a simple substitution between human driver and automated driving system. For example, ethnographic research can show how people are using emerging technologies and how individual travellers anticipate they might integrate new technological options into their own future behaviour (Pink, Fors, and Glöss 2018). At the level of potential user, people can anchor their responses to their existing routines. At the level of system-wide issues, principled or normative concerns, or sociotechnical imaginary, they often anchor their responses to relevant experiences, such as frustrations with computerised or automated systems, general enthusiasm for technology, or feelings of inefficacy in the political system. For those interested in systems of mobility, this presents a challenge. Public responses from either personal or big picture frames might not translate obviously to sociotechnical systems. The gap between public opinions and governance implications therefore requires substantial interpretation.

Public surveys can provide a source of social intelligence that can inform trustworthy governance. In our survey we categorise about 19% of UK and 13% of US respondents as expressing concerns they perceive are temporary or resolvable. From a technologically determinist viewpoint, such potential converts would be later adopters. However, a larger proportion (26% across both US and UK) have concerns that seem less tractable, for example, seeing SDVs as inevitably and insolubly dangerous or incompatible with current mobility systems or with principled ideas about the roles of humans and machines.

Finding safety to be the dominant topic in the corpus might invite the simple inference that this is largely a divergence of risk perceptions. But we note that, alongside those who worry that the technology might go wrong in the sense of technical 'glitches' or malfunctions, some respondents consider the technology 'wrong' in the moral sense highlighted by Douglas and Wildavsky (1982). Results from the main body of our questionnaire show large majorities considering the road to be a social space, where drivers should be considerate and use common sense, rather than just following the formal rules of the road[3]. Majorities of our respondents anticipate that SDVs cannot do this[4].

Viewing the road as a social space encourages a widely held concern over human drivers and SDVs sharing the same road. While only c.5% of respondents addressed this directly in the free text answers, these worries were evident in other survey questions that prompted the issue[5]. The references to questions of responsibility also point to concerns over SDVs operating as agents in social space. Additional questions in our survey covered the use of robots and AI systems in other domains. While more are comfortable than uncomfortable with robots performing manual tasks, more respondents are uncomfortable than comfortable with robots or AI systems taking responsibilities like 'performing an operation on you' or 'deciding eligib[ility] for state benefits'[6]. The free text corpus finds many respondents arguing that machines should not be acting in human operational design domains, where their presence is considered wrong, breaching what Douglas (1991) would have called a taboo. Addressing such a taboo would prompt a broader societal discussion about the relationship between human beings and the technological systems that surround them, rather than modelling citizens narrowly as consumers to be persuaded to take up a product. As many have noted, road users would not be able to 'opt out' of engaging with SDVs used by others on public roads.

At first sight, the idea of an autonomous vehicle looks radically disruptive. On closer inspection the narrative of autonomy (Tennant and Stilgoe 2021) looks oddly conservative, promising to replace drivers but leaving the rest of the system untouched. There are hopes that the downsides of car transport, including traffic, frustration, wasted time driving, excessive space given over to parking, might all be resolved, without new issues emerging. The lop-sidedness of this speculation (what happens when all those zero-occupancy vehicles meet the single-occupancy ones that already comprise an average city's traffic problem?) reveals that too little is being done by those developing the technology to think through its possibilities for improving mobility justice (Sheller 2018) or even just avoiding the exacerbation of existing injustices. But while the people developing the technology look to balance some more utopian visions against a conservative presumption that centres on car dependence, the possible ramifications for invisible parts of the infrastructure are substantial. People's responses on questions of control and human-robot interaction speak not just to the question of who is holding a steering wheel, but who is in charge of future systems that are increasingly data-intensive.

In our main questionnaire, a majority of respondents agree with the statement that SDVs are coming 'whether we want them or not'[7]. This sense of alienation and threat to agency both on the road and in matters of policy and future technology may contribute to the strength of feeling. The narrative of vehicular autonomy that currently dominates suggests that the technology will directly substitute human drivers with automated systems. It has less to say about the circumstances to which the technology is most suited or the limits of current approaches (Tennant and Stilgoe 2021). Those respondents giving voice to negative technological visions should be heeded. In particular, the promise that self-driving cars will free individuals from the chore of driving rings hollow for many, who view it instead as a dehumanising process of denying individuals autonomy, control and agency. Whether expressed in terms of safety, ethics, jobs or a loss of control, their concerns should be taken as a message to innovators and policymakers that the story that is currently deployed to persuade investors or sceptics needs to be rethought.

What is not present in a corpus is often as important as what is. Our respondents rarely mention hopes for the restructuring of transportation to address present day mobility injustices. This presents a challenge for those of us calling for public involvement in the governance of future transportation systems. We would argue that the rarity of fundamental restructuring in our respondents' visions reflects their absence from those offered by promoters, whose conservative imaginary of the future too frequently suggests a technologically enhanced version of the present. But deeper forms of public engagement are required to explore whether the alienation and desire for a more human-centred system that we report might lead to public insistence on more radical implementations of new transportation technology than currently imagined.

During the twentieth century automobility innovations and policies drove pedestrians from streets, encouraged planners to force roadways through busy neighbourhoods, and created negative outcomes that SDV promoters now promise to resolve (Norton 2008, 2021). Transport is an area of technology that is felt viscerally by the public. We should therefore not underestimate the significance of the concerns explored in this paper. To be anticipatory and inclusive, SDV governance needs to understand public views rather than reject them as irrational or mutable.

Disclosure statement

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Notes

1. Driverless Futures, https://driverless-futures.com/. ESRC grant ES/S001832/1. The survey was given ethical approval by the UCL STS ethics committee. Reference STSEth231. All respondents were informed about the process and purposes of research and gave their consent at the start of the survey.
2. Quoted responses are all in italics and attributed to a numbered respondent. We have amended some typographical errors in the responses, such as 'to' to 'too', or replacing 'a actual' with 'an actual'. We usually report individual answers to either Q4.1 or Q4.8: we sometimes report Q4.1 'with'/'and' Q4.8. For brevity we sometimes report partial answers if not misleading.
3. In the UK 91% (US 91%) agreed that *'Being considerate to other road users is as important as following the formal rules of the road'*, and 77% (US 79%) agreed that *'drivers sometimes have to use common sense instead of just following the Highway Code'*.
4. In the UK 60% agreed, 12% disagreed, (US 53%, 16%) that SDVs might *'be limited in how well they drive because they lack the common sense of human drivers'* . Some free-text answers express this, e.g. UK2, 968 *'They won't have the capabilities that a human would have… where is the common sense or the quick reactions in case of an emergency?'* or US680 *"Automation doesn't replace common sense and human abilities"*.
5. In the UK 30% disagreed with the statement '*Human-driven vehicles and SDVs should not share the same stretch of road*', with 38% undecided and 32% agreeing (US 36%, 34%, 29%). These questions were asked of sub-samples, UK N= 992, US $N = 485$.
6. In the UK 63% were uncomfortable, 25% comfortable, with 'Having a medical operation performed on you by a robot' (US 56%, 23%). 52% were uncomfortable, 25% comfortable with 'systems deciding whether applicants are eligible for state benefits' (US 54%, 26%).
7. In the UK 60% agreed, 13% disagreed (US 69%, 10%).

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