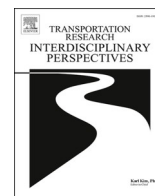


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Bearing the weight: A qualitative study on expert views on integrating ethics in autonomous vehicles

Stephen R. Milford^{a,b,*}, Bernice Simone Elger^a, David Shaw^{a,c}

^a Institute for Biomedical Ethics, Basel University, Switzerland

^b Department of Theology, North-West University, South Africa

^c Maastricht University, Netherlands

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ABSTRACT

AVs are increasingly becoming present on public roads, the ethics of which have captured the public's attention. This study represents the first ever investigation into the opinion of AV development experts on the ethics of programming AVs in collision scenarios. The study makes use of a qualitative research model. A sample of 24 Swiss experts were interviewed using semi-structured interviews. The majority of experts were directly involved in the development of AVs and represented both research, private, and public sectors as well as national regulatory bodies. Three core themes emerged from the data. 1) Experts were keenly aware of the ethical challenges involved in AVs on public roads, including in collision situations. 2) Experts felt a moral responsibility for how AVs are programmed and developed. However, experts' moral framework was not well developed with many experts stating that their own personal moral framework should not be used to program motion planning. 3) Experts saw a need for an ethical framework to guide the development of AVs. The paper concludes that it is clear experts are keenly aware of the ethics involved in AVs on public roads, and in particular collision scenarios. They feel a sense of responsibility for how AVs are programmed but do not feel ethically well-equipped themselves. Experts would, therefore, appreciate an ethical framework that would assist the development of these algorithms. This framework may be driven by either industry or government but should be clear and simple. We recommend countries like Switzerland develop such a framework.

1. Introduction

Autonomous Vehicles (AVs) have the potential to be a transformative technology that promises numerous benefits (Bertoncello and Wee, 2015; Etienne, 2021; Floridi et al., 2018). These include a radical reduction of road deaths (Airbib and Seba, 2017; Fagnant and Kockelman, 2015; Gao et al., 2016), increased traffic flow (Etienne, 2021; Stead et al., 2017; Szele and Kisgyörgy, 2018), and increased mobility for vulnerable people (Resnik and Andrews, 2023). In order to realise these benefits, the public must trust, accept, and adopt AVs on a mass scale (Nastjuk et al., 2020; Othman, 2022; Rowthorn, 2019; Zhou et al., 2023). Evidence suggests, however, that the public remains sceptical, with as much as 63% of the US public expressing unease with AVs on public roads (Faverio, 2022; Gross, 2022; Rainie et al., 2022; Smith and Anderson, 2017). If we are to deploy AVs extensively, more work is necessary to alleviate the public's concerns.

A key factor for the public's acceptance is the ethical questions that

arise from AVs (Gill, 2021; Liljamo et al., 2018). Questions of fairness, equality, ecology, and safety are all at the core of public concern, not to mention how AVs are to behave in collision scenarios (Andrade, 2021; Etienne, 2021; Gill, 2021; Rowthorn, 2019; Wang et al., 2023). These, and other ethical questions, are of paramount importance to the public. They must be addressed, not only through theoretical discussions in academic circles, but practically in the way we regulate, design, and program AV decision-making algorithms (DMAs). DMAs are responsible for all aspects of a self-driving car's behaviour. From planning and deciding its motion trajectory in a collision scenario, to choosing who to offer a preferential service to in a shared-transportation context. We cannot simply fail to program a vehicle's responses when dilemma scenarios present themselves. AVs need specific instructions on what to do in such situations (Evans et al., 2020; Umbrello and Yampolskiy, 2022; Wang et al., 2023). To ensure that DMAs are programmed in-line with publicly acceptable ethical principles requires empirical research.

While some empirical work has been undertaken, much of this work

* Corresponding author.

E-mail addresses: Stephen.Milford@Unibas.ch (S.R. Milford), B.Elger@unibas.ch (B. Simone Elger), David.Shaw@UniBas.ch (D. Shaw).

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has been quantitative and focused on a specific section of the public's intuitions (Awad et al., 2018; Zhu et al., 2022). On the other hand, some qualitative research has been conducted into numerous issues from the public's perspective. This includes the public's opinion of AVs in general (Hilgartner and Granig, 2020; Lazányi, 2023; Linehan et al., 2019; Rahman et al., 2021; Schneble and Shaw, 2021), of shared mobility (Merfeld et al., 2019; Pakusch et al., 2020; Stefanelli et al., 2022), on public trust in AVs (Wiegand et al., 2019; Zhou et al., 2023), explainability (Shen et al., 2022; Wiegand et al., 2020), or on AV's impact on vulnerable road users (Tabone et al., 2021). Other work has been conducted on professional users of AVs, such as professional driver's perceptions on safety (Dubljević et al., 2023), security and privacy (Liu, 2017), and carsharing (Harnischmacher et al., 2021; Merfeld et al., 2019).

Yet no qualitative or quantitative research, to our knowledge, has been conducted that explores the opinion of experts who are regulating, designing, developing, and deploying AVs on public roads. This is a serious gap in the research as it is these experts themselves who are both directly and indirectly responsible for how AVs will actually behave. The ethical framework of these experts is vital to understanding how AVs might, or should, be advanced. The present study goes some way to filling this gap. By qualitatively investigating the underlying ethical framework of AV regulators; programmers; developers; and deployers, this study analyses the ethical opinion of those closest to the problem and offers important insight into the ethics of AVs on public roads.

2. Methodology

2.1. Sample and data collection

As part of the Proactive Ethical Approach to Responsible Automation (PEpp) project – within the NCCR Automation, a Swiss National Science Foundation funded research centre – experts based in Switzerland were interviewed about the ethics of AVs on public roads. An experimental ethics approach to qualitative research was chosen as it enables participants to be more active, and participatory. Using this method, participants are encouraged to go beyond simply stating their beliefs. Rather, they were asked to explore and justify their opinions (Campbell and Kumar, 2012; Kahane, 2013; Knobe et al., 2010).

Following reflection on pilot interviews with three experts, the interview guide was adjusted and purposive, as well as snowball, recruitment was undertaken (Blackstone, 2012; Marshall, 1996). Inclusion criteria included that experts were working in Switzerland and involved in a field closely related to AV development; traffic planning; robotics; automation and control. Interviews were undertaken until saturation was reached, upon which a further 2 interviews were conducted to confirm saturation (Saunders et al., 2018).

24 experts in total were interviewed between March 2022 and February 2023. 8 experts were general programmers in automation and control theory. 7 of these experts had experience in transportation systems. For example, in traffic control, urban planning, or integrating public and private traffic systems. The last expert of this group had experience in robotics and automatic control with close connections to a research group working in transportation management systems. 9 experts had experience in either programming DMA for AVs, or experience in developing some aspect of AVs. 2 experts had experience in autonomous systems in general, including robotics. 1 had published in the field of AVs and crash scenarios with experience in human design interface. The remaining experts were professors of research centres focused on AVs, involved in trials of AVs on public roads, senior leaders in private companies developing AVs or senior leaders in regulatory bodies for AVs in Switzerland. Interviews were conducted in English and lasted approximately one hour guided by a semi-structured interview questionnaire. The interview questionnaire focused on the ethics of AVs on public roads, with a particular focus on participant's opinions of ethics in general and how they could be applied to DMAs for AVs.

2.2. Data analysis

Interviews were transcribed verbatim with all personally identifiable data being removed or anonymised (e.g. name, place of work, role etc.). Transcriptions were imported into MAXQDA – a standard program used for qualitative data analysis – and subjected to applied thematic analysis, the aim of which is to analyse and highlight thematic elements so as to describe and interpret a data set in detail (Braun and Clarke, 2006; Guest et al., 2012; Mayring, 2014). The first step involved the researchers familiarising themselves with the data set by actively reading the transcriptions and writing down initial ideas for coding and themes. Step 2 involved open coding to inductively generate descriptive codes from the data. A researcher initially coded three interviews which was followed by an in-depth meeting with the PI and research team to evaluate the quality of coding. Following this, the researcher proceeded to code the rest of transcripts with regular supervision from the PI. The result was an extensive code tree. Once the code tree was agreed by the research team, Step 3 involved the researcher searching for themes by sorting descriptive codes into key themes. In step 4 the research team met to review the themes created by the researcher, to critically review the themes created, and to capture new codes and themes. Step 5 involved interpreting the themes and organizing the data extracts into coherent accounts that would support core narratives present in the data.

3. Results

Interviews with Swiss experts revealed a number of themes related to the ethics of AVs on public roads. In particular our analysis identified three broad themes: 1) that experts were conscious of numerous ethical concerns with AVs in general, 2) that they broadly felt some level of moral responsibility and 3) that an external ethical guideline, or framework, would be advantageous. In each of these main themes a number of sub-themes were identified as follows.

3.1. Numerous ethical concerns

The interview guide presented open questions designed to avoid leading participants. Following a brief introduction, section two of the guide presented two open questions exploring the ethics of AVs on public roads. Participant 23 at first struggled to see any significant ethical concerns with AVs on public roads, stating:

...I don't think there's a bigger issue... where's the ethical issue with an iPhone? It's some technology that you may use for good or bad ... if you don't find it helpful, then drive your own car... (p#23)

Nevertheless, almost immediately this participant conceded that if AVs were the only vehicles on the road, then there may be a monopoly on mobility. In like fashion, and without prompting, in answer to question two of section two, 'Where do you see the main ethical/moral dilemmas arising?' participant 23 raised environmental concerns including the increase in CO₂ – presumably as a result of the production of AVs: 'I think... the risk of the AVs killing us with their CO₂ are substantially larger than the risks they will be killing us as vehicles.'

Apart from participant 23, most other participants pointed to numerous ethical concerns. These may be sub-divided into 3 broad areas:

3.1.1. The ethics involved in collisions

The issue of collision scenarios – often associated with trolley problem like dilemmas – was mentioned by many participants (15 experts in total) with 9 mentioning it as a major challenge and 6 participants expressing a view that although collision situations may take place, they would be very rare and, therefore, should not be taken seriously:

... you know puzzling scenarios where ... this sort of cartoon: The car can go straight and you know hit... a baby and go left and hit... another person.... I don't have an answer, and I do see... all the ethical concerns there. (p#10)

So I think there are many,... things like the trolley problems that gather a lot of attentions by the media... But I think this [has] little relevance in practice. (p#15)

3.1.2. The question of responsibility

A few participants (6) mentioned responsibility, accountability, or liability as a core ethical concern, particularly as this relates to collision scenarios:

I would say the main challenge that I believe the public may identify is the accountability. So whether the company should be responsible or the driver, or the policy makers. (p#11)

So for example if a car caused the accident, an autonomous car caused an accident, who can I blame? (p#14)

Participant 3 questioned their own responsibility or liability by expressing concern with what would happen to them personally if a collision took place: 'how much I am responsible... What will happen to me if something like that [collision] happens?' Participant 5 linked the question of responsibility to criminal/civil responsibility and the difference between the USA and European approaches:

But if I go in a car and I kill somebody, I can be criminally responsible here [Europe, as opposed to the USA]... But somehow if instead I am doing the programming and the car kills something, somebody... nobody is criminally responsible, and so this, for me, is one of the holes that I don't see how to reconcile.

3.1.3. A diversity of views on the ethical concerns

In addition to the core concerns of collision scenarios and responsibility, a number of other ethical concerns were expressed throughout the interviews. Participants 14, 15 and 22 spoke about the challenges of training data. This was both from a bias and privacy perspective:

... one thing that many people do not understand is that Tesla is filming everything everywhere continuously. You inside and everything outside. If I put a dashcam, to do that, if the police stop me, I will have problems, big problems.... [but] nobody says a single word [about AVs]. Plus, all the filming is not staying in European or Swiss soil, they go to United States. (p#22)

While participants 7, 8, 16, and 21 raised concerns that not everyone would have equal access to AVs, or that AVs may be expensive to use:

Actually, how do we make sure that everybody has the same level of mobility in our country. Because that's actually...[how] you can partake in society if you have access to mobility. But if you cannot afford it, it doesn't matter if there are autonomous cars or not. (p#7)

4 participants argued that AVs would increase traffic challenges and congestion on public roads:

...when we have autonomous cars, it will lower the generalized cost of travelling, so you can actually do much more while you're travelling. You can focus on other stuff, and this is what actually will impact a lot of how our society is currently structured and working. So people will commute much further away, so we will have much more implications, actually, on society. (p#7)

3.2. Experts' moral responsibility in programming AVs

As reported above in 1.2, the question of responsibility was raised by a number of experts. Researchers followed up on this topic by asking

whom experts felt had a moral responsibility for programming AVs. Three sub-themes were identified.

3.2.1. Experts bear some moral responsibility

When experts were asked about who bears moral (not legal, criminal, or financial) responsibility for programming AVs in collisions situations they expressed a number of potential candidates. Nine experts mentioned that manufacturers/producers of AVs are morally responsible:

... actually that's why we have companies, because... when I work for somebody, I will give them my [labour] and they will sell that, so they are actually also responsible for... all the mistakes that I do, because there will be other people checking my work... (p#7)

Participants 9 and 22 were clear on the extent of the moral culpability of a company: 'To me that's absolutely the responsibility of the company... they are morally responsible for ensuring that their cars are 100% reliable, not 99.9' (p#9). 'Morally who is responsible? ...the manufacturer, because [they] made the bad programming ...[for] autonomous vehicles it is the manufacturer who is supposed to implement and program it.' (p#22)

Similar to participant 7 quoted above, four participants noted that programmers cannot be held personally responsible: 'I don't think we should... blame the engineer or who developed this algorithm, but the... people on the management level who... approve this product and decide that we should put these AVs on road' (p#17). Participant 22 claimed:

Who had the moral responsibility when Oppenheimer was making the atomic bomb? How [far]down [do] we go... there were people who started putting bits and bytes together, or gluing, metal, and electronics. Who was responsible for that? ...I mean, if we started going down to the... 23 years-old programmer who finished school and his [is] programming a part of it, to put the moral responsibility on him, I think we go too far... So no, the responsibility has to stay [with] higher people...

However, participant 22 did continue to note:

Nevertheless... if you put the program [to] a young [programmer] to start programming, and he makes shortcuts that will compromise the security of the whole system, then we'll have a problem.

Participant 22 went on to note the pressure of being fired or silenced that a young programmer might face and that this may be a reason they do not have the power to speak out when they notice something is wrong.

Five experts said that they personally did not carry any responsibility for how AVs were programmed or deployed. A few of those participants were not directly involved in programming motion planning algorithms and this may be the reason they denied any responsibility. Participant 2, who is involved in programming traffic automation in general, claimed that because they were involved in the auditing of data, and not the production of programs, they did not bear responsibility: 'actually, we are not on that side, like we are trying to audit things, so how do they work.' While Participant 17 (a transport strategist developing data for AVs), stated that while they might feel bad if something went wrong, they would not actually hold moral responsibility:

...personally I will feel bad about this if... I programmed that vehicle. But if... I was someone else, not the engineer, but some random people in the society, I wouldn't blame that engineer.

Notwithstanding that some participants were reluctant to claim that either programmers or themselves had any moral responsibility, a large number of participants noted that engineers or programmers did indeed carry some responsibility, with many of the experts (12) agreeing that they (as programmers, or designers themselves) would carry some responsibility:

...if I'm one of the developer(s) who designed this and it caused the problems, then I will surely blame myself; why I didn't consider this situation before... (p#14)

I think morally and ethically, I think people should do their best to make sure that the vehicles are as safe as reasonable... No different than people that design anti-lock brakes... Just because they're autonomous how does that differ from any other source of automation? (p#19)

...even you [they themselves have] the duty to speak up, even if you're not allowed to do what's best, you know what's safe, then you're not excused because ...somebody else [did it], but you should speak up and say it. (p#5)

Participant 25, when speaking about their own personal moral responsibility for AVs, linked this responsibility to their own personal moral values:

Yes, absolutely. Because also you [themselves] were raised with some moral values... the people I know from my company... from the CEO,... [to] higher management level, to my lower mid-level, we have moral values.

3.2.2. The personal moral framework of Swiss experts

When asked about their own personal moral framework, participants expressed a range of views. Only Participant 12 noted that they had actively considered the underlying grounds of their moral framework by referring to their formal education and their reflective, structured approach to ethics. Other experts noted a general sense of what is right or wrong. Participants 16 and 23 spoke about a sense of responsibility for their actions, participants 10 and 8 noted that the opinions of others affected how they might act, with participant 8 commenting on the 'struggle' (in terms of a hassle) of making a wrong decision. Three participants made mention of the 'good of society' (p#7 and p#14) or what is 'helpful to others' (p#16). Participant 9 mentioned 'common sense' (without expounding on what that they mean by this) which they aligned with an internal 'moral intuition.' Participant 19 noted that 'for the most part people know what the right thing is' and that it is 'human nature' to simply know this.

When asked where this moral 'intuition' came from, a large number (11 participants) noted their upbringing, often linking it to their religion or their parents:

I don't know how it came about... possibly related to my upbringing. What my parents would tell me what is right or wrong. (p#9)

Even Participant 12, who noted education and philosophy underlying their ethical approach noted in addition to this that their upbringing, religion, and parents were formative:

We can take from education. We can take from your parents. You can take it from a religion... Who taught me that? My parents. Are they unique? I don't think so. (p#12)

3.2.3. The insufficiency of expert's personal ethical frameworks

The question about participants' personal moral framework was followed up with a question about whether the personal moral framework expounded on by participants would be suitable as a guide in programming AVs in collision situations. While 2 participants (11 and 19) noted that it would be – stating 'probably yes' and 'Yeah, why not' respectively – 4 participants were unsure while 8 stated it would not be suitable:

I do not think they [personal moral framework] would be because I am just one person and especially these trolley-like dilemmas, they are really tricky. (p#9)

No, I believe for example that definitely there is some bias that I would have. (p#16)

...it would be sufficient but probably not ideal. In my case, let me say [I am] way too ambitious, performance driven, aggressive, risk taking, whatever you want to call it. So maybe I don't take the most conservative approach [laughs]. (p#18)

Consequently, some noted the need for other's opinion as being crucial to making ethical decisions in crash scenarios:

I cannot say my own moral guidance is sufficient for designing cars, I mean for the techniques to develop the autonomous cars... it's like I [need to] listen to different perspectives. (p#14)

I do consider that having some rigorous foundation in ethics would be very precious... I think in those cases I would be happy to have some expert opinion (p#10)

One AV programmer (Participant 9) argued that they would refuse to program the car in an ethical dilemma without clear guidelines:

So if it's not clear... what is the right thing to do, which is typically the case in these trolley-like scenarios, then... I as a programmer would... not want to take any moral credit for what to do... personally I would refuse to do that.

Consequently, there was general agreement that an ethical framework for programming AVs in collision situations was required.

3.3. An ethical framework

Experts were asked about the suitability of an ethical framework or guidance to help programmers, developers and manufactures as they program AVs to react in collision situations. This led to 3 distinct themes:

3.3.1. The need for an ethical framework

A large number of experts (17) noted the need for an ethical framework:

I think that there should be some guideline on how the car is designed. (p#3)

I would actually say there should be even a kind of norm or... an authority, an ethical authority that kind of forms standards how these ethical standards should be implemented... (p#7)

I mean we have procedures and guidelines even for how much a car can pollute. So definitely there's going to be guidance and rules and procedures to make sure that the way they drive is ethical. (p#8)

Participant 12 took this concept even further:

How are you dealing with ethical dilemma to govern a country?... How are you, how are you dealing with ethical dilemma to operate your job? I think these ethical dilemmas have always existed in the history of humanity, in any decision-making process... There were structures. There were laws. There were a committee... we have always addressed that and we have to follow the same. Nothing is new.

13 participants noted that it would be helpful for programmers to have a guideline:

I think they [programmers] don't want necessarily to be... responsible... as a scientist I design an algorithm, then I discover my algorithm is responsible for killing people, I would not feel good... I think they will be happy to comply with this [an ethical guideline].

Participants 2 and 3 cautioned that programmers would be happy as long as the guidelines were not 'restrictive' or offered too many 'boundaries', respectively. 2 participants questioned whether it would be well accepted by programmers or developers. Participant #16 noted that not everyone thinks ethically:

So for me there's two kind[s] of people. In my opinion everyone should think this way [ethically], but not necessarily everybody does. (p#16)

Participant 25 argued that an ethical framework would be necessary for public acceptance:

Because first of all, the public is necessary to accept that service offer right? Without them understanding, is there actually a moral compass in this machine, they would most probably – after some horrible accidents would happen – would say: Okay, no, we don't use this kind of offer or service...

3.3.2. *Those involved in developing an ethical framework*

When asked about who should be involved in developing an ethical framework, a large number of participants (14) mentioned a wide range of stakeholders together:

So there must be people from the industry, they know better about the technology, and the people from the government, they have a ... a global perspective... what is good for the society. And from the academia, they ... know more about this ethics, and also some people from the general public, because after all they are the majority of the society. (p#17)

I think it should be a combination of folks. It shouldn't just be technocrats... it's a sociable [sic] decision, it's not just a technical decision, it's not just a legal decision, it's not just an ethical decision. I think it's all of them put together. (p#19)

Participants 21 and 23 noted that ordinary citizens should be involved in developing a framework, while several participants (6) mentioned industry experts such as developers and programmers, or legal /governmental personal (6 participants). Several Participants (8) mentioned ethicists or philosophers:

...you might need to be someone that has knowledge of ethics, of spirituality, of religion, of theology... the same way that we've tried come up with vertical rules to govern our country, we don't ask engineers to write ethical rules. We actually ask people with some sound reason. (p#12)

3.3.3. *The implementation of an ethical guideline*

There were some concerns expressed about the manner in which such an ethical guideline might be implemented. For example Participant 23 was not sure if it should be industry led, self-regulation, or a government law:

Clearly if you put it into a legal framework it becomes a tool to attack the competition. If you make it self-regulatory, you have the issue that self-regulators tend to be weak. So I'm not sure what, from a societal point of view, would achieve the goal most effectively. Because... we want to have the systems as fast as possible, and overburdening the requirements stops progress.

There was some unprompted support for an industry led standard. For example, participant 24 stated:

...it can be an industry standard. So today, a lot of things on safety systems are just norms, ISO norms, ISO standards...if you don't follow [them] you go to jail.

While participant 22 expressed concerns about making use of government legislation, favouring the use of directives (regulations) which can be implemented more rapidly:

Whatever we decide now 5/10 years will be totally obsolete, we have learned so many things, we have to revise it. And if we have to vote a new law that has to pass through Parliaments and Cantonal it will not be changed. It will be too late by the time it has been changed. So it's better with directives.

However, participant 10 noted that unless it was a law, some programmers might not apply the guidelines:

you know ideally you have ethical guidelines and everyone... acts accordingly. In practice this probably will not be the most effective thing... I think the way... I would do it is there should be some sort of law... that encapsulate[s] those principles and so that you know then companies they act accordingly.

In like fashion there were a number of participants that were either in support of a government regulation (6 participants) or a combination of government rules and industry standards (6):

It has to be written in a paper. It cannot be something random or like social norm. It can be a product of both the industry and the government, and also researcher[s]... we need to include... as many opinions as possible. (p#17):

I mean if we are designing something, then we will have sometimes frameworks or guidelines. Sometimes they will come from the government that says these are the standards. Sometimes they will come from industry. Sometimes it will just be the normal way of doing things. (p#14)

Participant 23, as mentioned above, was cautious of slowing progress in this field and, therefore, cautioned against over-burdensome regulations:

I think one of the issues with written guidelines is that they tend to be long and aim for special cases... I think any guidelines should be kept simple and direct. So that it can develop force, because the moment you have exceptions and this case and that case in there, it... makes the task much harder ... [it] should be clear sparse guidelines guiding the work and what form it should take.

4. Discussion

The findings represent the first in-depth analysis of the opinions of industry experts on the ethics of AVs on public roads. The findings may be grouped into four significant themes that have implications for policy makers:

4.1. *An awareness of ethical concerns*

The experts interviewed as part of this research project spontaneously referred to a range of ethical concerns, with all experts giving at least one example of an ethical challenge for the implementation of AVs on public roads. Even the single participant who at first struggled to see any concern whatsoever, quickly self-reflected and conceded that if AVs were the only option, this may have ethical implications in terms of a possible monopoly on transportation.

As in the literature, the themes of responsibility, accountability and liability were widely present among the experts' responses (Krisztian Pinter et al., 2017; Scales, 2020). There were broad questions about who should bear responsibility, with one participant asking about their own personal liability were something to go wrong. The literature does mention the possibility of personal liability remaining as AVs are deployed, even criminal liability (Kauppinen, 2021; Klasinc, 2022; Kriebitz et al., 2022). The question of civil or criminal responsibility and the distinction between different countries was also raised by experts in this research. In addition, the question of dilemmas arising in crash scenarios was often referenced, as is the case in the literature. This question has been noted as being an important concern for the general public (Davnull, 2020; Gill, 2021; Hübner and White, 2018; Nyholm and Smids, 2016) – although this was at times disputed as a serious concern by the experts in this project due to its rarity. This dispute was also seen in the literature (Cunneen et al., 2020; Hansson et al., 2021).

A number of other ethical concerns were raised that mirror the literature. For example, the possibility that AVs might increase traffic and congestion – the opposite of their promised benefit (Stead et al., 2017; Szele and Kisgyörgy, 2018), or that AVs might have an impact on

vulnerable road users or those who are disabled (Resnik and Andrews, 2023; Tabone et al., 2021). Environmental concerns, which are present in the literature (Rafael et al., 2022, 2020; Zong, 2019), were also raised by the experts interviewed. Although in the literature AVs are seen as possibility having a positive effect on the environment, one participant was of the impression that the issue of CO₂ emissions from AVs themselves (presumably in the manufacturing of EVs) was a more serious ethical problem than AVs killing people directly.

Of particular note was the question of data usage in order to develop AVs (Schneble and Shaw, 2021; Shaw et al., 2020). Participants raised the question of data bias as well as privacy concerns, but also the question of training AVs using data from certain geographical regions with the question of possibly exporting or importing data across different countries or regions being an issue. This is significant because there is some empirical evidence to demonstrate that culture has an impact on the ethical choices the public would make in a crash scenario (Ahlenius and Tännsjö, 2012; Awad et al., 2018; Evans et al., 2020; Lazányi, 2023).

4.2. Experts feel some moral responsibility

There was some disagreement about who is responsible for the ethics of AVs on public roads in general, but in particular for programming AV DMAs for crash scenarios. The literature is devoid of how experts feel about this and whether they themselves bear moral responsibility. The findings of this project suggest mixed feelings, with a large number of experts conceding to feeling some moral responsibility.

As present in some of the literature, a number of the experts interviewed in this project placed ultimate responsibility on manufacturers or producers of AVs (Hevelke and Nida-Rümelin, 2015; Marchant and Lindor, 2012). Indeed, there is evidence that the industry as a whole is aware of this responsibility (Martinho et al., 2021). In some cases, experts felt that developers and manufacturers should take sole responsibility. In other cases participants felt that programmers cannot be held responsible because it is the programmer's line-manager or company that oversees the production. Consequently, some participants said that they themselves did not carry any responsibility for the development and implementation of AVs on public roads. It is possible that this could be because these participants did not have direct experience with programming AV DMAs.

Nevertheless, a number of participants (12) did note that individual programmers could be held morally accountable, and that they themselves bore some of the moral responsibility for AVs on public roads. The questions of feelings and blame did arise, with some participants saying they would feel bad, or even blame themselves, if something went wrong. Two participants noted the need for individual programmers to 'speak out' if they felt something was unethical. Although this was not widely referenced in the interviews and could not stand as a theme on its own, it does add weight to the idea that experts may feel a responsibility to act as whistleblowers if they feel something is morally not right with the way AVs are developed. Others argued that it was their moral responsibility to do their job to the best of their ability so as to ensure that their programmes were as safe as possible and that this was no different to the engineers designing other technologies such as anti-lock brakes or airbags in non-autonomous cars. This is a novel finding that suggests experts involved in developing AVs feel a keen sense of moral responsibility.

While individual moral responsibility is not presently evidenced in the literature on AV developers, there is ample evidence that professionals in other fields, similar to AV programmers, take seriously their individual responsibility. For example, in engineering, ethics have been taught for many decades. Here there is an emphasis on the moral character of individual engineers themselves and its impact on what they design and build (Poel and Royackers, 2023; Pritchard, 2001; Whitbeck, 2011). In the field of computer programming generally, there is also an understanding that programmers must take some moral

responsibility for their programs, even if this is at times difficult to assign in complex systems because of the problem of many hands (Birsch, 2004; Goetze, 2022; Noorman, 2012). It should be noted that it has been shown that public officials are not exempt of moral responsibility because of the problem of many hands (Thompson, 1980). Therefore, it was not surprising that so many experts in our project noted their individual responsibility.

A significant new finding of our project relates to the personal moral framework of experts developing DMAs for AVs. At present no studies have been conducted exploring this aspect. When experts were asked about their own personal moral frameworks, only one noted a moral framework based on active reflection. Among the other experts, there was a sense that people in general had an 'intuition' and that their actions should be for the good of society, or to help others, and that this could be based on 'common sense.' For a number of experts (11) the question of personal responsibility was linked to their own personal sense of knowing what was right and wrong. They argued that they, and others, were raised with moral values and this was linked to their upbringing, religion or parents.

Yet, when asked if their personal moral intuition or framework is sufficient for programming AV DMAs in crash scenarios, four experts were unsure, and eight participants noted that it would not be sufficient. One noted that their moral framework was for themselves personally and not for their work, while others stated that their personal moral framework was biased and not ideal as a benchmark for the ethics of AVs. Two participants noted that it was important to listen to other perspectives on the issue and that they would encourage ethicists to give their opinions. Consequently, these findings suggest that ethical training is needed for experts involved in developing and deploying AVs on public roads. Not only are these experts aware of ethical challenges, but they can feel a keen sense of responsibility. They openly admit that their personal moral frameworks are not suitable to program DMAs in ethically challenging situations.

4.3. Experts would appreciate an ethical framework

There has been much research on the ethics involved in AVs on public roads in general, and in collision scenarios in particular (Hansson et al., 2021; Hevelke and Nida-Rümelin, 2015; Martinho et al., 2021; Nyholm and Smids, 2016; Robinson et al., 2022). Yet these studies have yet to consult experts as our study has done. A considerable number (17) of the experts interviewed for this project expressed the opinion that there was a need for an ethical guideline or framework to help them program AV DMAs. Participants argued that since there are guidelines for other areas, such as pollution or safety, there should also be guidelines for ethical driving. The experts in this study also noted that programmers do not necessarily want to be responsible for the ethics involved in AVs and would appreciate others to take that responsibility by providing guidance on how to program DMAs.

At present ethics for AVs have yet to be formalised into regulatory frameworks for DMAs. Some work has been done on safety guidelines in AVs, such as the EU's General Safety Regulation for Vehicles (2022) that begins to establish the legal framework for the certification of AVs for use on EU roads (European Commission, 2022). In 2017 the ethics commission of the German Ministry of Transport and Digital Infrastructure drafted the world's first official set of ethical guidelines for AV programming (BMDV, 2017; Futurism, 2017). Being only 17 clauses long, in 2022, this guideline formed the basis of an amendment to the German Road Traffic Act so as to include extensive reference to autonomous vehicles (BMDV, 2021; Kriebitz et al., 2022). However, since then, to the best of our knowledge, no new ethical frameworks, or codes of practice to govern AV DMAs have been formally accepted by regulatory bodies and certainly not in Switzerland where this research was conducted. Although it should be noted that the Swiss government has begun a public consultation on how to regulate AVs in Switzerland (ASTRA, n.d.). Among the participants of our study, there was general

agreement that a range of stakeholders should be involved in developing such guidelines, including experts from industry, those who understand the technology, the government and also the general public. Several experts mentioned ethicists or philosophers as being important with one noting that including these stakeholders was similar to how one developed an ethical system for governing a country.

While there was general agreement as to the necessity for a framework, there was some disagreement as to the manner in which this should be implemented. Should it be government or industry led? One participant noted that the pace of change in the AV industry is so rapid that whatever is implemented now might be obsolete in 5 or 10 years. They were, therefore, not convinced that legal frameworks driven by governments could keep pace with this change. Others were in support of the idea of an industry led standard, for example ISOs, which exist for numerous industries. Indeed, there are already some ISO standards that deal with the safety aspects of AVs, such as UL 4600, ISO 26262 and ISO 21448 (“Autonomous vehicle safety training and advisory,” 2023). However, currently no ISO standards exist that deal with the ethics of programming AV DMAs, and in particular for crash scenarios. A number of participants were in favour of some form of governmental regulation or a combination of government rules and industry standards. One participant noted that without a legal framework, companies may not implement ethical behaviour. A participant noted that both industry standards and government regulations have their drawbacks. A legal framework would be a tool to attack competition, while self-regulation was seen as weak. In either case, they felt overburdening requirements on AV producers would slow down progress and this would be undesirable. Therefore, they advocated for a simple and direct framework whether it was government or industry led.

Some, such as the European Commission’s Expert Group on the Ethics of Connected and Automated Vehicles, have argued that the already existing rules of the road act as descriptions of good driving and that these can be used for ‘choosing appropriate behaviours in exceptional driving cases and for answering the Trolley Car problem.’ However, unless there is a common understanding of the ethics involved in programming AVs for crash scenarios, different manufacturers will inevitably develop different driving behaviours for AVs with the inevitable uncertain safety consequences (Papadimitriou et al., 2022). Considering the impact of culture on human values – particularly as they pertain to AVs and crash scenarios (Awad et al., 2018; Evans et al., 2020; Lazányi, 2023) – it appears prudent that different countries or regions produce and adopt their own ethical guidelines for AV DMAs.

5. Limitations

Two limitations should be noted. First, in many cases English was not the first language of our participants. This meant that at times participants struggled to express themselves fully, while transcription and analysis required careful reading and listening. However, considering all participants were experts in professional spheres where advanced English is required on a regular basis, we feel that this limitation does not diminish the results of the project. With careful reading and some clarification, we are confident that the views of the participants were faithful to their intended meaning.

The second limitation has to do with the geographic applicability of our data. Our data focuses exclusively on the Swiss context and involves a limited number of Swiss experts. Switzerland is a small country whose investment in AVs is dwarfed by larger countries such as the USA and China. Therefore, it may be difficult to generalise the findings of our research to these larger domains. Notwithstanding this, it is important to note that Switzerland is a highly developed country and the first to introduce autonomous vehicles in public transport (PostAuto, n.d.). In addition, while many of our participants worked in Switzerland, the nature of their roles were such that they had extensive connections with other countries. Consequently, while our data is particularly relevant for the Swiss context, it is not entirely irrelevant for other regions.

6. Conclusions and implications for policy makers

Our project represents the first in-depth analysis of the ethical opinions of experts in the field of autonomous vehicles. This is significant, as it is these experts that most influence the manner in which AVs are programmed, developed, and deployed on public roads. The findings of our project are novel in that they demonstrate experts’ awareness of a range of ethical issues that can affect autonomous vehicles on public roads, and in particular the dilemmas that are unavoidable in crash scenarios. Of significance is that our findings support the conclusion that many of these experts take this seriously and do feel a keen sense of moral responsibility for the way AVs are programmed and deployed. Yet these experts do not have a well-developed ethical framework to rely on. For the most part, they rely on their upbringing, community, parents, and culture. Many of them noted that their moral framework is insufficient to program AV DMAs for crash scenarios. Consequently, there is an argument in favour of providing these experts with clear ethical guidance.

Our findings suggest that policy makers need to take the ethics of AVs seriously. Not only are the public concerned about this, but AV experts are as well. Policy makers need to be seen to take these concerns seriously as well. This includes data collection, storage, and cross-border transfer; fairness for vulnerable road users and those who are already marginalised; environmental concerns; as well as (seemingly rare) trolley-problem-like cases. A key concern is the criminal or civil culpability of AV designers and users alike.

Policy makers need to clarify who is morally responsible for AVs on public roads. In the literature and our findings, the question of moral responsibility remains opaque. Our results, however, highlight that many AV developers feel moral responsibility for the ethics of AVs on public roads. What is significant is that the moral framework of AV experts is often based on conceptions inherited via their upbringing or culture. That is to say, AV experts did not display a well-thought through moral framework. Consequently, their personal moral frameworks were poorly developed and may be open to experience serious conflict with other frameworks. With a lack of clarification as to who is morally responsible, and what moral framework should be used, comes the possibility of moral injury (Jinkerson, 2016; Shay, 2014; Williamson et al., 2021). Policy makers must heed this risk.

To address the concerns raised by the experts in this study, and alleviate the risk of moral injury, we recommend policy makers take 4 clear steps: 1) clarify who bears ultimate responsibility for the ethics of AVs on public roads, 2) outline a coherent moral framework upon which the ethics of AVs are to be based, 3) provide clear and concise ethical guidance (in the form of ethical standards, guidelines and regulation), and 4) provide, and insist on, ethical training to those developing AVs in the same way other industries do (such as civil engineering).

Statements and declarations

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CRediT authorship contribution statement

Stephen R. Milford: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Bernice Simone Elger:** Writing – review & editing, Supervision, Funding acquisition. **David Shaw:** Writing – review & editing, Supervision, Funding acquisition, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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