Perceived Safety and Comfort of Pedestrian Interactions with Self-driving Vehicles

Recommendations for responsible introduction of self-driving vehicles

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EXECUTIVE SUMMARY

Project background

To counter some of the negative environmental, social, and economic impacts of our long-existing reliance on motor vehicles, many urban areas in Canada and throughout the world are promoting active modes of travel such as walking and cycling. For example, the Regional Transportation Strategy for Metro Vancouver (Transport 2050) has set a goal of at least half of all passenger trips to be made using active modes and transit by 2050 (*1*). Transport 2050 also emphasizes the importance of active mode users' perceived safety and comfort to realize that mode share goal: "If people enjoy their transportation experience, they are more likely to travel. Walking, biking, rolling and using transit should be inviting and enjoyable experiences. A key part of this is feeling comfortable, safe, and secure when travelling" (*2*).

While promoting active modes of travel, public agencies are also planning for the introduction of self-driving vehicles (SDVs) into existing transportation systems, as SDVs have the potential to improve the safety, efficiency, and accessibility of our transportation systems. But SDVs should be introduced and integrated responsibly; SDV technology should be trustworthy and SDVs should support active modes of travel rather than degrade their experience.

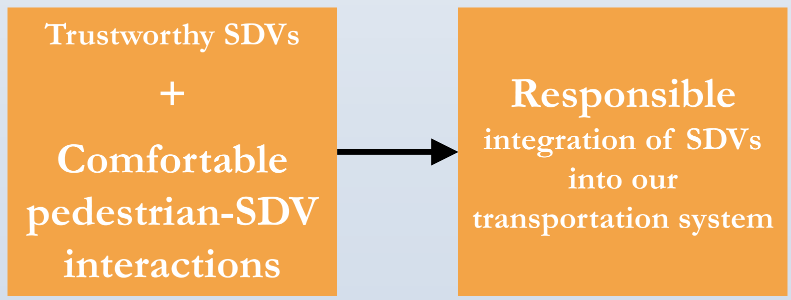

Figure 1. Integrate SDVs responsibly; SDVs should support walkability rather than degrade the walking experience

Considerable research has focused on the operation and technological reliability of SDVs, which is only part of the process of responsible introduction and integration. Another crucial aspect is ensuring the comfort of active travellers, including the quality of pedestrian-SDV interactions. While SDVs may differ in a number of ways from HDVs (human-driven vehicles), the essential defining characteristic is that vehicle control is ceded from a human to a computer. This fundamental difference, along with other changes in vehicle operation or appearance, will likely influence perceptions of safety and comfort for active travellers. Pedestrian interactions with SDV are more complex and challenging than HDV interactions because, among other reasons, pedestrian-driver communications are disrupted. Pedestrians may find it more challenging to both communicate their intentions and infer the intentions of SDVs. Moreover, because perceptions of safety vary systematically across the population, introducing SDVs may disproportionally affect comfort for certain groups of people.

The goal of this study is to inform strategies for the responsible introduction of SDVs in a way that does not degrade the walking experience. We seek to understand how a diverse and representative array of people perceive interactions between pedestrians and SDVs, in contrast to today's HDVs, and how these perceptions relate to policy support for efforts to integrate and regulate SDVs.

This study investigates three main research questions (RQ):

- RQ1. Do people perceive pedestrian interactions with SDVs as more or less comfortable and safe than interactions with HDVs, controlling for all other differences (i.e., is there an "Autonomy Bias")?
- RQ2. Does the Autonomy Bias vary systematically within the population (e.g. with age, gender, ethnicity, travel habits, and so on)?
- RQ3. Which personal attributes, including Autonomy Bias, determine support for various SDV policies?

Overview of study methods

The study methods are summarized in Figure 2. We developed a novel deception-based experiment within a web survey[1] to measure the Autonomy Bias (i.e., examine if people perceive pedestrian interactions with SDVs as more or less comfortable and safe than interactions with HDVs, controlling for all other differences). In the experiment, all survey participants watched the same 8 video clips of pedestrian-vehicle interactions at crosswalks. We identified a random half of the interacting vehicles as SDVs, and the other half as HDVs (all vehicles were in fact HDV). Each participant assessed the comfort and safety of those interactions and we developed statistical models to quantify each participant's Autonomy Bias. This unique experimental design allowed us to isolate the bias effect of vehicle autonomy on comfort and safety perceptions (RQ1), which we report as the additional seconds of passing time that would generate an equivalent effect on perceptions of safety and comfort. To address RQ2, we also collected data on participants' socio-demographics, travel habits, and attitudes toward technology and SDVs. We specified a structural equation model (SEM) with Autonomy Bias as the dependent variable and personal attributes and attitudes as independent variables. To address RQ3, we specified another SEM with SDV policies as the dependent variables and personal attributes, attitudes, and Autonomy Bias as independent variables.

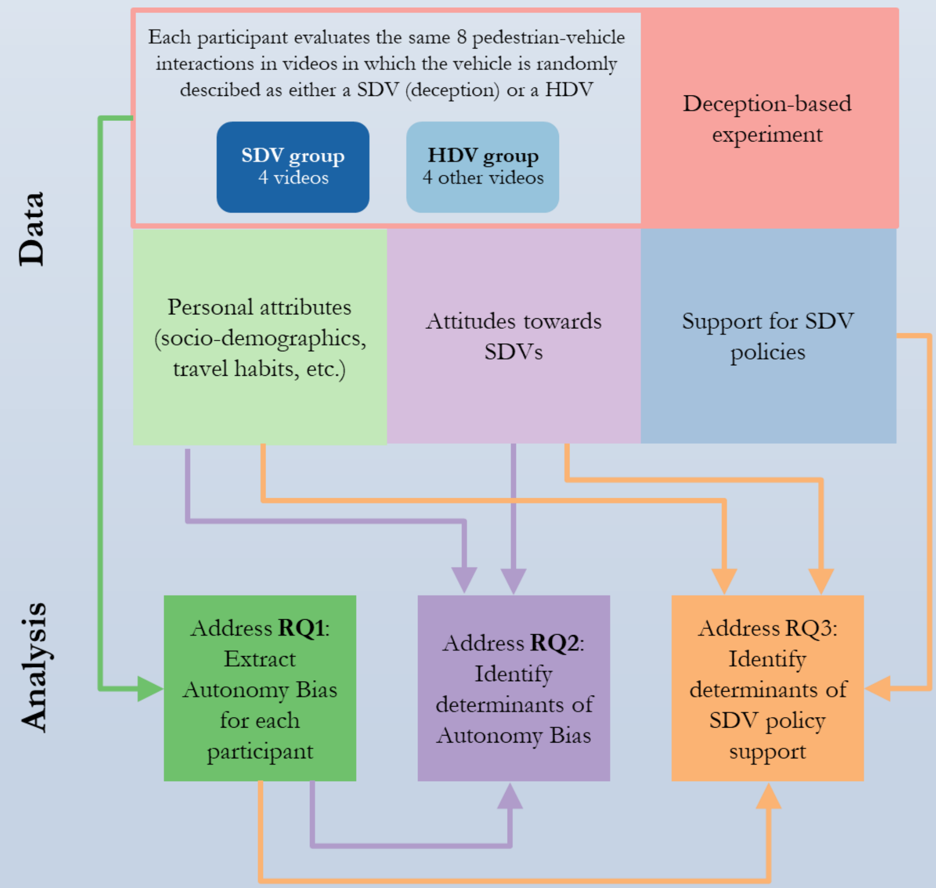

Figure 2. Study methods

[1] The survey was only advertised in BC. Raw data had 1557 participants, with a final sample of 1133 participants after filtering.

Key findings

1. Both positive and negative Autonomy Biases exist, varying substantially across BC residents, who have a small but significant negative mean bias (Figure 3). More of the population (41%) has a negative Autonomy Bias (i.e., a bias *against* SDVs), compared to 34% having a positive bias; a substantial portion (25%) has no substantial bias (smaller than 1 second equivalent passing time).

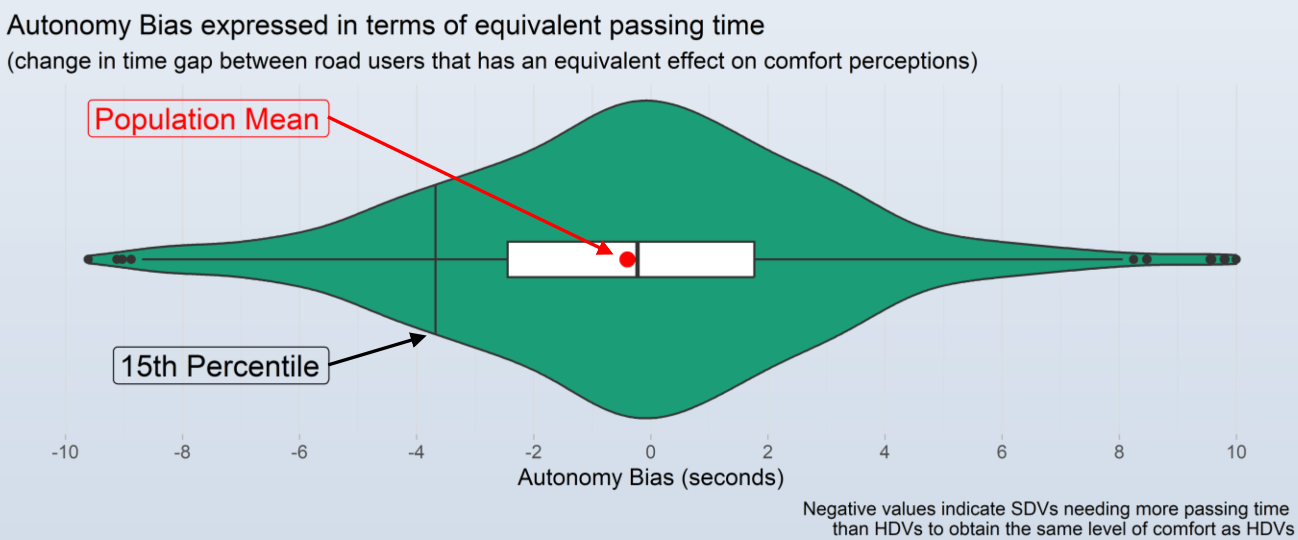

Figure 3. Autonomy Bias of survey participants, weighted to represent the BC population

2. Autonomy Bias varies systematically with gender, tech savviness, and affective response to SDV (level of anxiety or enthusiasm), but not with other socio-demographic factors or travel habits. People who are anxious about SDV technology or are uncomfortable embracing new technology (and cis-men) are more likely to have a bias *against* SDVs, which would tend to degrade their walking experience.
3. Similar to Autonomy Bias, BC residents are close to evenly split on whether they support two general SDV policies: allowing privately-owned or shared SDVs to operate on public roads (Figure 4).
4. In contrast, a large majority of BC residents want SDVs to be clearly identified, have a human "driver" present, and be restricted from entering pedestrian-dominated areas such as near schools (Figure 4).
5. Even though two SDV-related factors – being enthusiastic about SDVs and having a more positive Autonomy Bias – determine SDV policy support most consistently, socio-demographic factors persist. A few subgroups of the population (including equity-seeking groups) give less policy support; older people are less likely to favour shared SDVs, people of colour and non-cis-men want to restrict SDVs from operating without a "driver", and people with less auto mobility want to restrict SDVs from going into pedestrian priority areas.

> I am still unsure of the technologies. I feel a person needs to be available in the car to take control of the vehicle in case of emergencies however I also see self driven cars might be a help to those with disabilities. I haven't clarified these opinions yet.

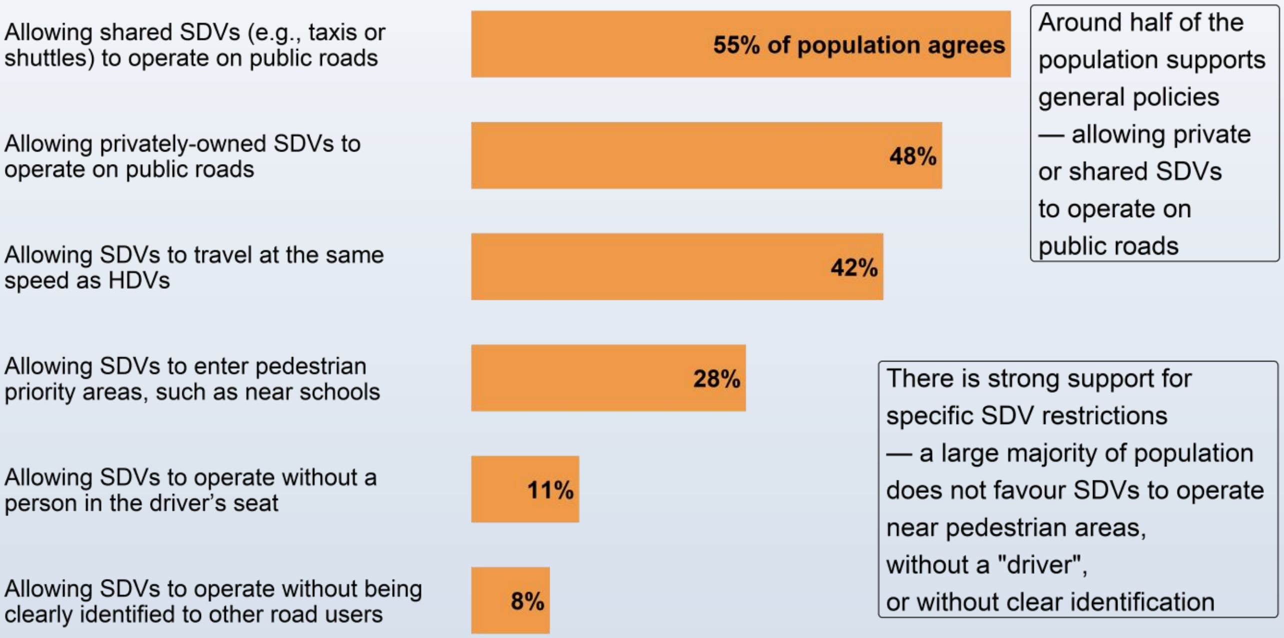

Figure 4. Level of support for self-driving vehicle policies

Recommendations

Considering the demonstrated potential for SDV to both positively and negatively impact perceptions of safety and comfort for pedestrians in BC, the divided support for SDV introduction, and the strong support for SDV restrictions, we recommend a **cautious, tiered approach to SDV introduction**, with specific restrictions to address the concerns of BC residents.

> I think I [would] start introducing more self-driving vehicles very cautiously and with quite restricted conditions before opening the roads to that technology. Just start slow to really test and then adjust.

Introduction should begin with **restrictive pilot testing**, which will allow road users to experience and observe interactions with SDVs in more limited and controlled settings. This study shows that introducing SDVs without specific restrictions might disproportionately impact the walking experience of equity-seeking groups.

- To ensure the comfort of a large proportion of the BC population, **SDVs should be programmed to operate more conservatively** than HDVs around pedestrians and other vulnerable road users. SDVs must allow 3.7 seconds additional passing time at crosswalks than typical HDVs to offset the Autonomy Bias of 85% of the population ("15th percentile" in Figure 3).

- SDVs should be required to have **external communication features** that, at the least, inform other road users that the motor vehicle they are interacting with is self-driven.
- SDVs should be required to have **a person in the driver's seat** to take control of the vehicle in emergencies and provide interacting road users a familiar human presence with an oversight function.
- **SDVs should not be initially tested in pedestrian priority areas** such as near schools.

In this initial phase, opportunities should be provided to the public to gain knowledge about SDV technology, operations, and performance. This study shows that familiarity with SDVs improves self-reported affective response to SDVs (i.e., leads to more enthusiasm), which in turn improves Autonomy Bias (i.e., leads to favourable perceptions of SDVs) and increases support for SDV policies (i.e., easing restrictions and allowing SDVs to operate on public roads). Public feedback should be sought through surveys, interviews, and focus groups to record and evaluate the level of comfort and policy support of road users before, during, and after pilot testing of SDVs. If the perceptions of a reasonably large proportion of the public shift toward comfort, then SDV restrictions can be eased accordingly.

> Even though I am enthusiastic about the idea of self-driving vehicles, I would probably feel anxious about sharing the road with them for some time. I'm sure that I would get used to them though.

> The technology is new so while I support the development of self-driving vehicles I'm not sure I'm ready to have them fully integrated with normal traffic yet. My support for them will increase as the technology matures.

CONTENTS

1. INTRODUCTION

1.1 Project background

A long-existing reliance on motor vehicles for transport (*3*) creates considerable negative environmental, social, and economic impacts (*4–6*). In response, many urban areas in Canada and throughout the world have promotional programs and policies encouraging non-motorized, physically active modes of travel such as walking and cycling because of associations with sustainability, health, and well-being (*7*). For example, the Regional Transportation Strategy for Metro Vancouver (hereafter: Transport 2050) has set a goal of at least half of all passenger trips to be made using active modes and transit by 2050 (*1*). Transport 2050 also emphasizes the role of active mode users' perceived safety and comfort (hereafter: PSC) to realize the mode share goal: "If people enjoy their transportation experience, they are more likely to travel. Walking, biking, rolling and using transit should be inviting and enjoyable experiences. A key part of this is feeling comfortable, safe, and secure when travelling" (*2*).

Many people would have heard the news, both negative and positive, about vehicles that could drive by themselves. Such vehicles are called by different names: driverless, autonomous, or self-driving. In this study, we call them self-driving vehicles (SDVs), contrasting with human-driven vehicles (HDVs). SDVs have the potential to improve the safety, efficiency and accessibility of our transportation system. Understandably, to realize those potential benefits, public agencies are preparing for the introduction of these substantially new vehicles into existing transportation systems. But SDVs should be introduced and integrated responsibly; SDV technology should be trustworthy and SDVs should support active modes of travel rather than degrade their experience (*8*).

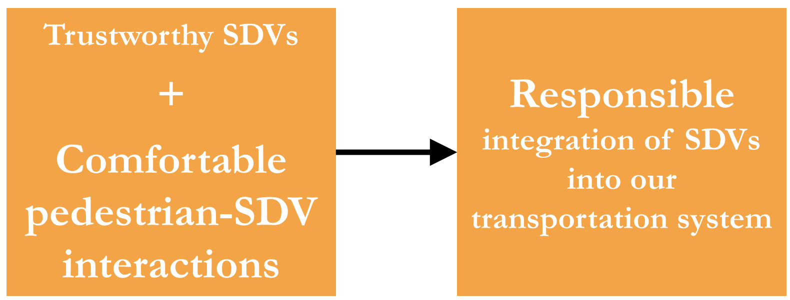

Figure 5. Integrate SDVs responsibly; SDVs should support walkability rather than degrade the walking experience

Road users who would interact with SDVs – such as pedestrians crossing the street – might perceive SDVs negatively, due to multiple reasons:

- Are SDVs able to see all pedestrians? How about unpredictable children? How about people of colour?
- How do I know a SDV would stop when I cross a street, as there will not be a driver to communicate with?
- Would a SDV hit a pedestrian to save its passenger even though the pedestrian was right?

Considerable research has focused on the operation and technological reliability of SDVs: security, intersection navigation, collision avoidance, object/pedestrian detection, and so on. But ensuring SDVs are technologically advanced is only one part of the process of responsible introduction and integration. Another crucial aspect is ensuring the comfort o active travellers, including the quality of pedestrian-SDV interactions. While SDVs may differ in a number of ways from HDVs, the essential defining characteristic is that vehicle control is ceded from a human to a computer. This fundamental difference, along with other changes in vehicle operation or appearance, will likely influence perceptions of safety and comfort for active travellers.

Pedestrian interactions with SDVs are more complex and challenging[2] than HDV interactions because, among other reasons, pedestrian-HDV communication are disrupted (*10*). Pedestrians may find it more challenging to communicate their intentions to SDVs through eye contact or other conventional gestures, and conversely, to infer the intentions of SDVs. Moreover, because perceptions of safety vary systematically across the population, introducing SDV may disproportionally affect comfort for certain groups of people. Walking facilities or environments perceived as unsafe can lead pedestrians to walk less frequently, walk during inconvenient times, or walk farther to avoid certain facilities (*11–14*).

The goal of this study is to inform strategies for the responsible introduction of SDVs in a way that does not degrade the walking experience. We seek to understand how a diverse and representative array of people perceive interactions between pedestrians and SDVs, in contrast to today's HDVs, and how these perceptions relate to policy support for efforts to integrate and regulate SDVs.

1.2 Literature review

1.2.1 Inconsistency or lack of definitions

Basic terms pertaining to SDVs – such as safety, security, trust, interest, and acceptance – are mostly not defined in SDV literature, and when defined, they are inconsistent (*15*). "Safety" could refer to low risk of crashes for riders or interacting road users (*16*), or risk from fellow riders in shared SDVs. "Security" is mostly used in the context of cybersecurity (*17*) but a few studies use it to refer to equipment or system failure (*18*). "Trust" could refer to reliance on various entities (regulators, SDV manufacturers, users) (*17*, *19*) or confidence that SDV will not hit other road users (*20*). Some studies consider "acceptance" to apply only to individuals who have experienced SDVs and "acceptability" to apply to individuals without prior experience (*21*). But most SDV literature uses "acceptance" to also imply acceptability. Beyond that, "acceptance" itself is used varyingly: to define intention to buy SDV (*17*) or ride shared SDV (*22*), or support SDV policies (*23*). Autonomous (*16*), self-driving (*23*), and driverless (*20*) are used to describe SDVs, sometimes conflating their different attributes – autonomy, electric, connected, and shared (*16*). While the variety of definitions may be useful in specific contexts, the lack of definitions across SDV literature limits our understanding of road users' perspectives about SDV, since it is difficult to generalize results across studies (*15*).

Since the focus of this study is SDV interactions for crossing pedestrians, for the rest of this paper we use "safety" to refer to the condition of a low risk from SDV crash or injury, and "acceptance" to refer to support for SDV policies: allowing shared or privately-owned SDVs to operate on public roads. As the terminology pertaining to SDVs continues to evolve, we provided a description of SDVs to the survey participants: "Self-driving vehicles use advanced technology to scan the surrounding road environment and carry out all driving tasks, including steering, speed control, following traffic signs and lights, yielding at crosswalks, etc."

1.2.2 Assessment methods to obtain perceptions towards SDVs

Researchers have adopted various methods to investigate road user perceptions toward interacting with SDVs (*24*), necessitated by the rarity of SDVs operating in real-world or realistic settings. The most straightforward method has been to ask individuals directly about their perspective on SDV technology, through the use of survey questionnaires that seek general opinions on SDVs without any specific images or illustrations (*20*, *25*). Other studies use virtual reality technology to design a virtual environment resembling a real street with regular traffic and an SDV (*26*, *27*). Participants are recruited to view the simulation from the perspective of a crossing pedestrian and then report their perceptions of the experience. In a third study

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[2] This is especially true for the interactions occurring while crossing unsignalized crosswalks where pedestrians quickly process information about the environment and coordinate nonverbally with the interacting road users to convey their crossing intentions (*9*). This study focuses on such interactions.

method, the approach of a regular (non-SDV) vehicle toward a crossing is recorded, and then edited to add "self-driving" stickers; the video is shown to participants as if it is an SDV, who then report their perceptions (*28*). The most advanced method, arguably, for examining road user behaviour and perception toward SDVs relies on illusion. A regular vehicle is fitted with a modified driver's seat to hide the driver and cameras or stickers stating "self-driving car" are installed on the car to give the impression of an SDV (*10*, *29*). Reactions of passing pedestrians are then recorded in video and intercept surveys. Very few actual SDVs have been pilot tested in controlled settings. In one such project, clarity of external communication features of SDV by conducting roadside interviews (*30*). In another study, the participants were allowed to ride the SDV but the perceptions of SDV interaction were determined through partially-imagined experience rather than actual interaction; asking participants how they would cross the road near an SDV and why they choose that behaviour (*31*).

1.2.3 Personal attributes affecting SDV acceptance

Most studies have focused on SDV acceptance from the perspective of intention to ride SDVs (privately-owned or shared) while a few studies have focused on SDV acceptance from the perspective of sharing the road with SDVs. Since the studies on potential non-users of SDVs are few, and many factors associated with potential users of SDVs could be useful in this study context, this literature review explores relevant factors from both perspectives.

The public should not be considered "a single entity" with respect to SDVs, as subgroups of the population, based on socio-demographic factors, have different opinions and perceptions about SDVs (*32*). Most of those factors are observed in the context of personal use of SDVs but sometimes in the context of sharing the road with SDVs (*33*). Individuals of older age, less educational attainment, and women perceive sharing the road with SDVs to be less safe (*16*, *20*). These subgroups, along with individuals from rural areas or lower household incomes, have less general acceptance of SDVs (*20*, *32*, *34*).

Beyond socio-demographics, a few other individual attributes and attitudes towards SDVs are also important determinants of SDV acceptance. Some of these factors mediate (explain) the relationships between socio-demographics and SDV acceptance, as summarized in the following paragraphs.

A few studies examined the role of affective response towards SDVs as a determinant of SDV acceptance (*16*, *17*, *35*, *36*), where affective responses were elicited by asking people to think about AV development, AV driving, or AV sharing. Affects are evoked moods and emotions in response to SDV technology and could be negative (anxiety, worry, fear) or positive (enthusiasm, satisfaction, relief). Positive affective response was found to be important in forming SDV acceptance – interest in riding SDVs, feeling safe while sharing the road with SDVs, and supporting SDV policies – by potential riders (*17*) as well as pedestrians, bicyclists, and drivers who would share the road with SDVs (*16*, *36*). Affective responses toward SDV technology are also found to partially explain the differences between socio-demographic subgroups in their SDV acceptance. Men are found to be more likely to accept SDV because they are more likely to experience pleasure when considering owning an SDV while women are more likely to experience anxiety (*37*).

Since self-driving is a novel technology in motor vehicles, some studies examine if individuals' use or early adoption of technology could affect SDV acceptance. Frequent users of smartphones and the internet (*38*, *39*) and individuals who drive vehicles with automation features (cruise control, lane keeping, self-parking, Tesla's autopilot) (*25*) are more likely to accept SDV or perceive SDV as safe while sharing the road (*16*). Technology use variables are also observed to explain the relationship between socio-demographics and SDV acceptance (*16*). SDV awareness differs among socio-demographic subgroups but individuals who are aware of SDV technology perceive SDVs to be safe (*40*).

Perceived concerns and benefits, both at personal and external levels, also influence SDV acceptance – with most studies focussing on potential SDV users (*18*, *22*, *41*). For example, perceived benefits were observed to be the strongest predictor, compared to trust or perceived safety, of intention to ride SDVs (*22*). Nevertheless, perceived external benefits of SDVs, such as reducing congestion (*42*) and emissions (*18*), and improving accessibility for older or disable people (*43*), could be important acceptance factors for non-SDV users. In the context of sharing the road with SDVs, a recent study (*16*) found perceived safety concerns affect support for SDV policies.

1.2.4 SDV features affecting SDV perceptions

Other than the expected operational factors (*44*), the external communication features installed on SDVs (*30*) could affect perceptions of interacting pedestrians by attempting to replicate implicit and explicit pedestrian-driver communication (*45*). The presence of external communication features that provide clear visual cues improves perceived safety for crossing pedestrians, as the SDV could provide information regarding its awareness of the presence of pedestrians (*46*) or its intentions (*26*, *47*). Moreover, anthropomorphizing SDVs – assigning them a name, gender, or human-like voice – also affects perceived safety as it helps build trust (*48*).

Research Gaps

- Existing studies have examined the effect of SDVs' communication features and operations on perceptions of interacting road users but no study has examined the core question about the effect of vehicle autonomy itself on perceptions.
- Most studies focus on users of SDVs; very few focus on pedestrians crossing near SDVs.
- Existing studies conflate many SDV-related factors such as safety, security, trust, interest, and acceptance.
- Most studies focus on self-reported perceptions about SDVs; very few focus on observations.
- Perceptions, being subjective, could be context-specific. Research lacks the examination of BC residents' perceptions.

1.3 Research questions

This study investigates three main research questions (RQ):

RQ1. Do people perceive pedestrian interactions with SDVs as more or less comfortable and safe than interactions with HDVs, controlling for all other differences (i.e., is there an "Autonomy Bias")?
RQ2. Does the Autonomy Bias vary systematically within the population (e.g. with age, gender, ethnicity, travel habits, and so on)?
RQ3. Which personal attributes, including Autonomy Bias, determine support for various SDV policies?

We start with a **simple question**:

Is self-driving technology inherently uncomfortable for other road users, even if the interactions are otherwise the same?

1.4 Overview of study methods

The primary objective of this study is to investigate whether an Autonomy Bias exists within the BC population – i.e., whether SDV interactions are perceived as inherently less safe and comfortable than the otherwise same interactions with HDV. Because it could be challenging for people to accurately evaluate their own biases, we developed a novel deception-based experiment to indirectly measure Autonomy Bias at the individual level. The Behavioural Research Ethics Board at UBC approved the study methods (#H21-02214).

Figure 6 illustrates the study framework – more detailed information is given in the subsequent sections. We designed a web survey to collect data. In the deception-based experiment, all survey participants watched the same 8 video clips of pedestrian-vehicle interactions at unsignalized crosswalks. The videos were recorded in the City of Vancouver in 2018. Only those videos were selected for the deception-based experiment that included "plausible" SDVs, i.e., dark-coloured, late-model sedans that were HDVs in reality but we believed they could pass as SDVs. Although all vehicles were in fact HDV, we described half of the interacting vehicles as SDVs in the survey, and the other half as HDVs, randomly selected for each participant using severity-based strata, so that each video was rated by roughly half the participants as an SDV and the other half as an HDV. This deception-based approach allowed us to measure if each participant systematically evaluated SDV interactions differently than HDV interactions.

To address RQs 2 and 3, we also collected participants' socio-demographics, travel habits, comfort in taking risks, comfort in embracing new technology, attitudes toward SDVs, and level of support for SDV policies. The survey included six SDV policies: two general policies about allowing private and shared SDV and four specific policies about requirements for SDV design and operation. All six policies are realistic, relevant to pedestrians, comparable to literature (*16*, *23*, *49*), and useful for near-term decisions to introduce SDVs.

Following the data collection from the web survey, we specified statistical models to address the research questions. Each participant's interaction evaluations from the deception-based experiment were used to extract the individual and population Autonomy Bias (RQ1). We then examined if that Autonomy Bias varies systematically within the population. For example, people from rural areas (vs. people from urban areas) might perceive SDV interactions as less comfortable; people who walk more frequently (vs. people who walk less frequently) might perceive SDV interactions as less comfortable; risk-tolerant (vs. risk-averse people) might perceive SDV interactions as more comfortable, and so on. To examine such relationships, we used the Autonomy Bias extracted for RQ1 and the personal attributes and attitudes toward SDVs (RQ2). Finally, we examined which personal attributes, including Autonomy Bias, determine support for SDV policies so that specific strategies could be devised to ensure responsible introduction of SDV – SDV policy should align with public comfort and support walking mode share and overall sustainability goals (RQ3).

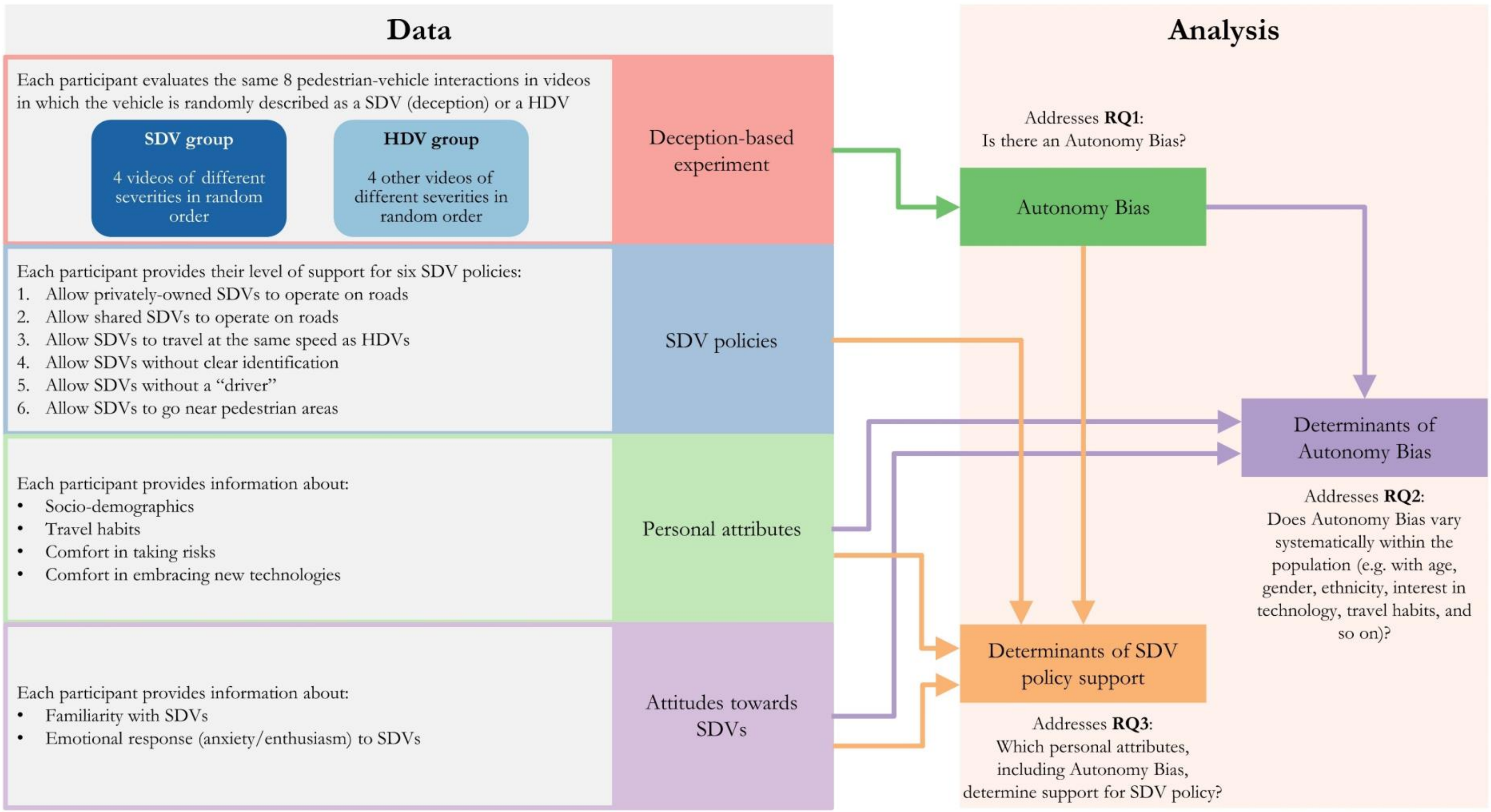


Figure 6. Study framework

2. DATA COLLECTION

2.1 Survey methods

We implemented the survey using Qualtrics. Qualtrics is an online survey platform that complies with the BC Freedom of Information and Protection of Privacy Act (FIPPA), as the survey data are kept secure and stored in Canada. The survey was opened on 10/22/2021 and closed on 12/12/2021 (51 days). The survey was advertised [3] (as illustrated in Figure 7) on Facebook and Instagram throughout BC. UBC and TransLink social channels also promoted the survey, as did 101 individuals on Facebook by re-posting it on their Facebook profile pages or groups. To minimize selection bias (i.e., not to disproportionately attract participants with strong opinions about SDVs), we did not mention SDVs in the survey advertisement. We promptly removed comments on Facebook to prevent our deception-based experiment from being revealed to potential participants.

Survey advertisement

We are looking for participants who travel in British Columbia to take our survey.

Participation requires between 10 and 15 minutes and involves viewing and rating a series of video clips of real-world interactions.

All participants will have a chance to enter into a draw for one of ten gift cards of $25 each.

To participate, or get more information, please visit tinyurl.com/react-lab-survey…

Note that if you like, follow, or comment on this post, others may associate your profile with this study.

Figure 7. Survey advertisement

The survey began with a consent form describing the goal of the study, followed by a definition of SDVs used in the study:

> Self-driving vehicles use advanced technology to scan the surrounding road environment and carry out all driving tasks, including steering, speed control, following traffic signs and lights, yielding at crosswalks, etc.

The definition was followed by prompts eliciting participants’ perspectives on SDVs:

- familiarity with SDV technology
- affective response (level of anxiety/enthusiasm) to SDV technology
- intention to ride in SDVs (privately-owned and shared)
- perceived benefits of SDVs
- support for SDV policies

These questions were selected based on consideration of the existing literature (refer to section: Literature review) on perceptions towards SDVs and this study’s research questions, balanced against considerations of participant burden.

[3] We spent around $1500 on advertisement over 51 days collecting 1557 raw responses (responses are described in the next section).

Participants then entered the deception-based experiment, prompted with the following text:

> We are investigating interactions between self-driving vehicles and pedestrians during pilot testing on public streets.
>
> In collaboration with the Department of Electrical Engineering at UBC, several passenger vehicles were modified with self-driving equipment. The vehicles travelled on an approved test route of low-traffic city streets, and their interactions with pedestrians at several crosswalks were recorded. In compliance with federal safety requirements, a driver was present to take control of the vehicle in case of an emergency. The vehicles were not labelled as self-driving to make interactions with other road users as normal as possible.
>
> You will be asked to evaluate pedestrian interactions with vehicles shown in a series of 8 short video clips. For comparison, half (4) of the interactions will be with regular (non-self-driving) vehicles at the same crosswalk locations.

In the deception-based experiment (illustrated in Figure 9), participants watched 8 videos[4] of 7-17 seconds. The selection of videos was based on interactions with "plausible" SDVs and severity of the interactions. "Plausible" SDVs were dark-coloured, late-model sedans that were HDVs in reality but we believed they could pass as SDVs. In other words, we presented HDVs as SDVs (i.e., deception). The severity level (low-moderate-high) of the interactions was assessed qualitatively by our research team, informed by our recent research on this topic using similar video data (*50*).

In the experiment, all survey participants watched the same 8 video clips of pedestrian-vehicle interactions at crosswalks. Each participant viewed videos from two groups: SDV group and HDV group (Figure 9). Videos in the SDV group were labelled as "self-driving vehicles" and in the HDV group as "regular vehicles". The order of groups and labelling of videos as "self-driving vehicles" or "regular vehicles" was random across participants. To balance the number of SDV and HDV interactions, each group randomly drew 4 videos from the 3 video strata. To generate more observations of (i.e., over-sample) relatively high severity ("high-risk" and "moderate-risk") interactions, we included only 2 videos for the "low-risk" stratum. The total number of videos (8) was selected based on consideration of the required time to complete the survey (targeting 15 min).

On each video page, participants were prompted with:

> Regarding the interaction between the crossing pedestrian and the **[road user]** shown in the video, please indicate your level of agreement with the statements below:" followed by
>
> - The [road user] yielded to the pedestrian.
> - The [road user] *should* have yielded to the pedestrian.
> - The pedestrian felt comfortable in this crossing.
> - The risk of injury for the pedestrian in this crossing was low.

[4] Raw video data were collected from September to December 2019 at 11 marked and uncontrolled crosswalk locations in the City of Vancouver. All locations were two-lane collector street corridors with no directional dividing line and substantial pedestrian and bicycle volumes. We had a total of 3176 potential pedestrian interactions with vehicles of all types (including scooters and bicycles). We then selected 36 interactions with "plausible" SDVs (dark-coloured, late-model sedans) and ≤ 4 seconds passing time. The final sample of 8 videos of "plausible" SDVs used in the survey was based on the video strata illustrated in Figure 9.

and continuous slider scale ranging from "-10 (Strongly disagree)" to "10 (Strongly agree), with a neutral "0 (Neither disagree nor agree)" and "I don't know" for each statement. For **[road user]**, we used "**regular vehicle**" and "**self-driving vehicle**" in the prompts, and "**driver**" and "**vehicle**" in the severity statements accordingly. The four prompts were designed after a comprehensive review of the literature and pilot testing, and were used previously in a Vancouver-based research project on perceptions of pedestrian comfort and safety (*50*).

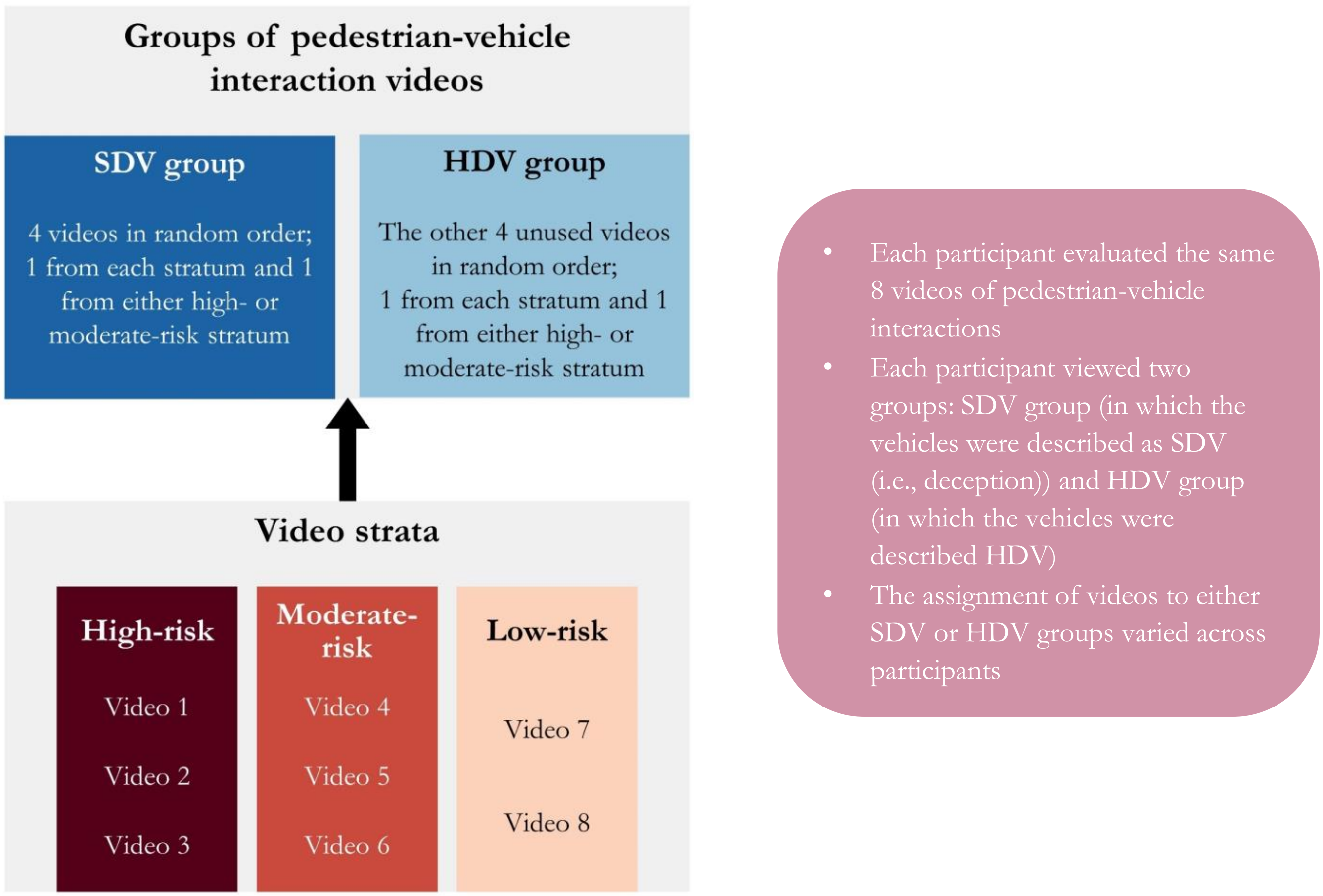


Figure 9. Deception-based experiment

Participants then answered questions about their socio-demographics (gender, educational attainment, age, household income), travel habits (frequency of travel by automobile, bicycle, walking, and public transit), and overall self-assessed risk-aversion and attitudes toward technology.

The survey concluded with an evaluation and revelation of the deception. As a "soft" measure of deception effectiveness, participants were first asked if they perceived any consistent differences between the SDVs and HDVs in the videos. Then, we revealed the deception, explained the rationale for using deception, and asked for re-consent to use their responses in our study (in accordance with the guidelines of Behavioural Research Ethics Board of UBC for deception-based research (#H21-02214)). Anyone who declined re-consent was not included in the analysis. Finally, as a "hard" measure of deception effectiveness, we asked if they had believed the vehicles were SDV when they rated the video interactions. The complete survey instrument is given in Appendix: Survey instrument; deception effectiveness is discussed in Appendix: Deception effectiveness.

2.2 Participants

The survey was only advertised in BC and the only inclusion criterion was experience travelling in British Columbia. Participants were incentivized with a chance to enter into a draw for one of ten gift cards of CA$25 each.

The first page of the survey introduced the study and asked for consent to participate. The number of collected raw responses – individuals who gave consent – was 1557 (only 6 individuals declined initial consent). The raw responses were filtered based on a few criteria (as illustrated in Figure 10). Participants who quit the survey before or at the re-consent page or declined re-consent were excluded, leading to 365 exclusions: 347 missing re-consent and 18 declined re-consent. Since the study focused on residents of BC, participants with self-reported home postal codes outside BC were excluded, leading to another 52 exclusions. Each participant rated 8 videos, where the video lengths ranged from 7 to 17 seconds. Based on the observed timing of responses, ratings were flagged as low timing if a participant spent less time on a video page than the length of that video. Entire responses were excluded if more than one of a participant's rated videos were flagged as low timing: this led to 7 exclusions (not highly sensitive to the low timing thresholds). Only 1 participant had exactly 1 rating flagged as low timing, and it was excluded while keeping the rest of their responses. The final sample size was 1133 participants.

Our deception-based experiment deceived a vast majority of the participants (1091 out of 1133, or 96%). Data from only deceived participants were used for developing statistical models (for more details, see Appendix: Deception effectiveness).

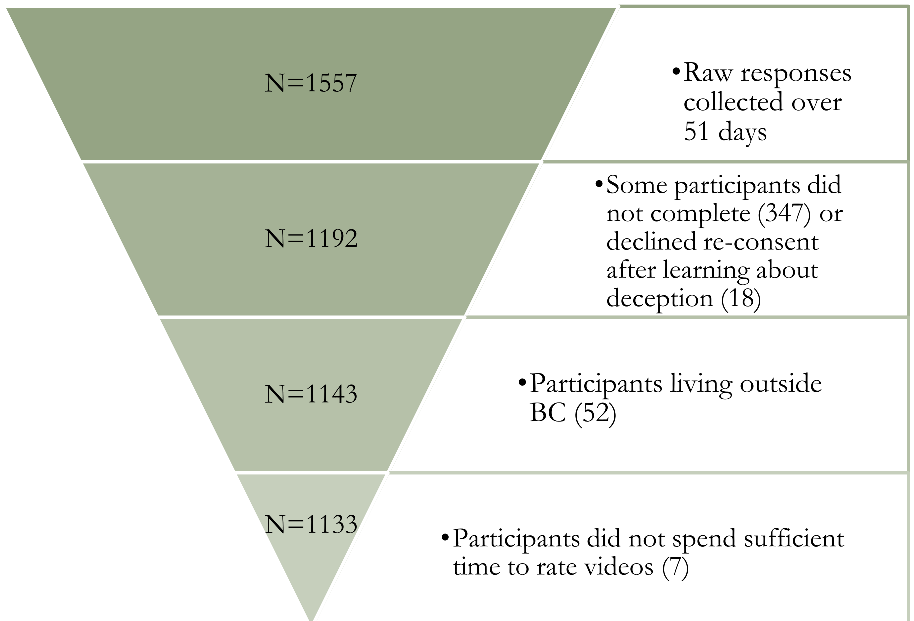


Figure 10. Data filtering process

96%

of the participants **were deceived** by our experiment, mainly because of their trust in authority (UBC researchers) and the SDVs in our videos meeting their expectations of SDV behaviour.

The participants who were **not deceived** knew too much about SDVs. They observed that our SDVs:

- Did not look like SDVs; had no visible cameras, LIDAR, sensors, etc.
- Did not behave like SDVs; did not comply with traffic rules, yielded inadequately, drove aggressively
- Were operating in BC even though they were not allowed to operate on BC roads

Many participants **appreciated** the deception-based experiment but a few raised **doubts** regarding our selection of SDV videos. But as described earlier, each participant saw the same set of 8 videos, 4 randomly labelled as “self-driving vehicle” and the other 4 as “regular vehicle”, stratified based on severity.

By using bad drivers as the self driving cars doesn't that purposely give a negative bias to the perceived self driving cars?

How did I literally fall for this agaaaaain. Even after participating in countless HSP studies during undergrad. The study is really well done and unfortunately (for me) very believable. :)

That's fair. At least you were honest about the deception. Thanks for that.

I respect the dis-information in this case. Thank you for the explanation.

The goal of this study makes a lot of sense. I think it was executed well.

You introduced a very strong bias into the study by the type of driver behaviour you chose for the videos. You presented different driving behaviour for the two groups. I don't know how useful this is on account of that. At least randomize it. Not cool.

I believe the video selection was biased in favor of attempting to support the purported safety and law-abidingness of self-driving vehicles compared to normal vehicles. "Good" drivers who yielded to pedestrians (while managing to capture some movement patterns that one might deem more "mechanical" or "computerized", so I have to congratulate the study designers on thinking on that level of granularity) were shown more often in the "self-driving" series, while "worse" drivers were clearly used to depict human drivers.

Aha thank you for clarifying. It is an interesting survey to gather information on people perception of the interactions and their prejudices. I look forward to any further results if you are willing to share them.

Awesome :-D Now it's clear why you had to do it that way ...

Awesome deception!

I feel silly but definitely fell for it and saw differences that I now know do not exist. Thank you for the opportunity to take part in the research, it was certainly interesting.

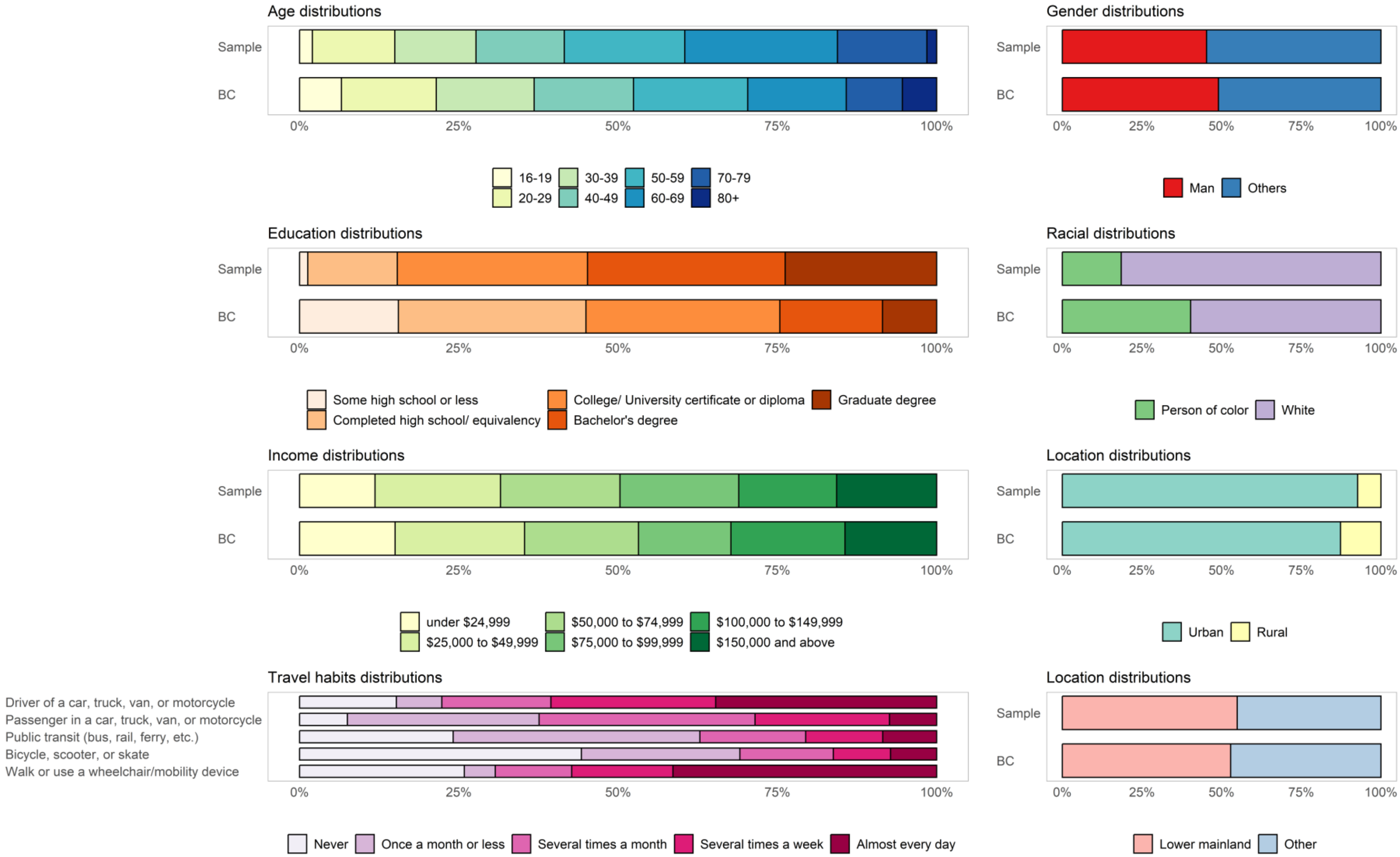
57%

of the participants provided their email addresses to hear about the findings, indicating broad interest about the study.

Figure 11 summarizes the socio-demographics and travel characteristics of the sample data, and compares them to 2021 Census data for British Columbia. The sample differs in some ways from the socio-demographic characteristics of the province, likely due to the online survey methods. The statistical analysis uses sampling weights (based on person of colour[5], education, and rural location) to account for demographic differences between the sample and the BC population.

Beyond responses to socio-demographic and travel characteristics and other survey questions are summarized in the Appendix: Responses to survey questionnaire.

[5] A "person of colour" is defined as someone who is not white. We acknowledge that this colour-related terminology groups multiple cultural identities together that are disproportionately affected by racism. However, this terminology serves the purpose of this study since we are examining if people with darker skin tones perceive SDVs differently, as there have been some discussion regarding the perceived challenges faced by SDVs to acknowledge dark-skinned pedestrians (examples: here, here, and here). Research has found that "person of colour" is "a simpler and potentially better measure of racialization, when that is the construct of interest" (*51*). We also received unprompted comments from the survey participants expressing doubts about the capability of SDVs to identify people of colour, validating our inclusion of this variable.



Notes:
1. Data source for BC: Statistics Canada, 2021 Census of Population
2. Sample travel habits are not compared to BC because such data are not available for BC

Figure 11. Sample characteristics

RQ1: Is there an Autonomy Bias?

(i.e., do people perceive pedestrian interactions with SDVs as more or less comfortable and safe than interactions with HDVs, controlling for all other differences)

In this section, we examine if individuals' survey responses reveal biases *against* SDVs (negative) or *in favour of* SDVs (positive). We also examine how the Autonomy Bias is distributed in the population overall.

3.1 Methods

3.1.1 Conceptualization of Autonomy Bias

We discussed earlier how it is challenging to observe the Autonomy Bias; we cannot simply ask participants if they would be biased *against* or *in favour of* SDVs (given SDVs look and operate the same as HDVs), as participants might not be aware of their bias. Since we cannot observe Autonomy Bias directly, we need to infer it indirectly from something observable. In statistics, the variables that cannot be observed directly are called latent variables and are inferred from some observable variables called indicators.

To understand latent variables, consider the example of fitness. Fitness[6] is a latent variable as it cannot be observed directly, but it can be inferred (approximated) indirectly by observing how much weight a person could lift (physical strength), how long they could run (endurance), their body weight, etc. The observed variables of physical strength, endurance, and weight indicate a person's fitness; hence, they are called indicators. Other examples of latent variables from daily life are happiness, intelligence, quality of life, etc.

In this study, we consider the construct of Autonomy Bias to be latent and we posit that it manifests (emerges) itself in the form of three observed indicators: perceptions of adequate yielding[7], safety, and comfort, as illustrated in Figure 12. This underlying Autonomy Bias causes the participants to respond to the perception questions in specific ways, as shown by the direction of arrows going from Autonomy Bias toward the three indicators. For example, if a person has a bias *in favour of* SDVs, then they would rate vehicles as more adequately yielding, and interacting pedestrians as safer and more comfortable, when they believed the vehicle was an SDV versus an HDV (see Figure 13). Another challenge here is that we cannot directly measure our indicators, because participants can only rate each video once. But because many people rated the same 8 videos, we can use a statistical model to measure if an individual consistently rated their 4 SDV videos differently.

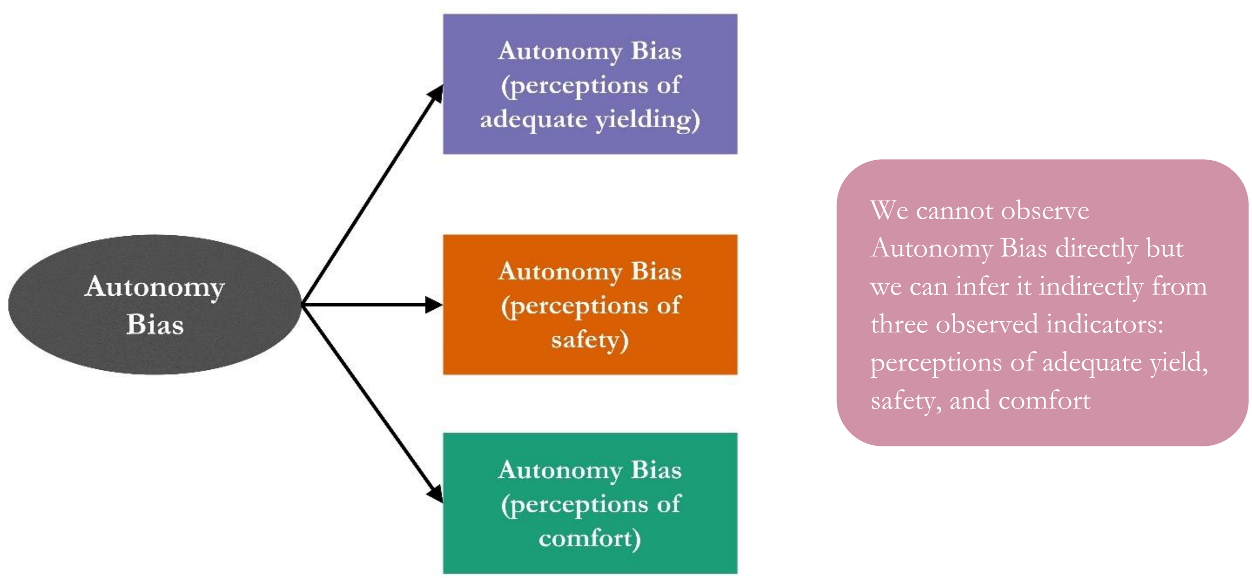


Figure 12. Autonomy Bias and its indicators

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[6] This is not an accurate way of measuring fitness but we provide the example merely to convey the meaning of latent variables.

[7] "Adequate yield" was calculated from the two statements on yielding by subtracting the rating of "The [road user] should have yielded to the pedestrian" from the rating of "The [road user] yielded to the pedestrian". The adequate yield scale ranges from −10 (severely inadequate yielding) to 10 (excessive yielding), consistent in range with the scales for perceived safety and comfort.

What exactly does "Autonomy Bias" mean?

- The screenshots on the right (from the survey) show the same video with different descriptions; the first is labelled "self-driving vehicle" while the second is labelled "regular vehicle".
- Each participant saw just one of these two screens and rated yielding, comfort, and safety.
- With no Autonomy Bias, their ratings would have been the same for either version, because the appearance of the interactions is exactly the same.
- People who would rate the same interaction as less comfortable and less safe with an SDV than with a HDV have **a negative Autonomy Bias** (i.e., bias *against* SDVs for pedestrian comfort and safety).
- People who would rate the same interaction as more comfortable and safer with an SDV than with a HDV have a **positive Autonomy Bias** (i.e., bias *in favour of* SDVs for pedestrian comfort and safety).
- Participants could not reliably rate both versions of the same video, but by having many people rate the same videos, we could measure an individual's systematic deviation for their set of SDV ratings.

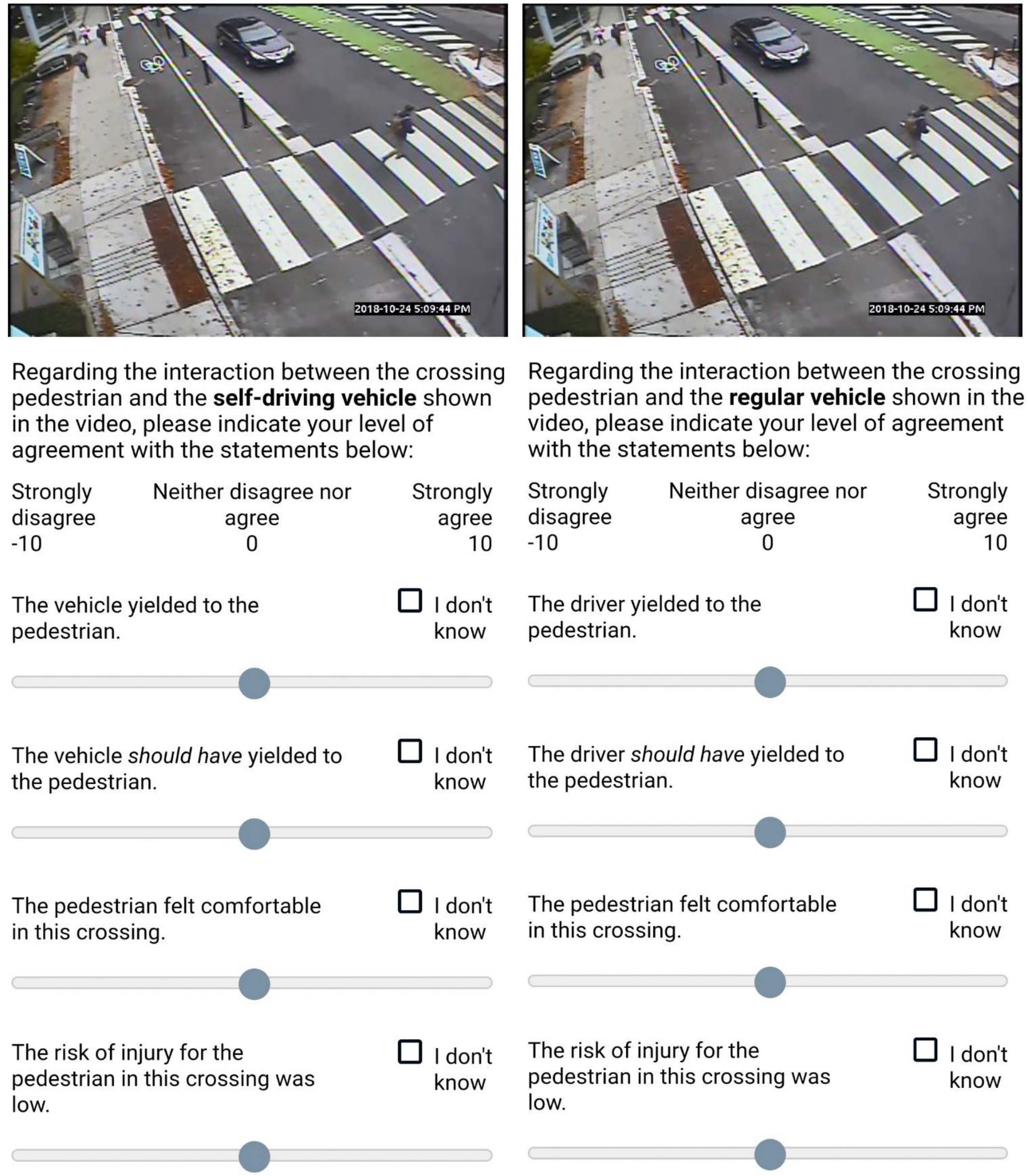

Figure 13. Conceptualization of Autonomy Bias

3.1.2 Extracting indicators of Autonomy Bias

The sample differed in some ways from the socio-demographic characteristics of the province; race, education, and rural location were different between the sample and Census data based on Chi-squared tests at a significance threshold of $p < 0.05$. To account for those differences, sampling weights for each participant were created using iterative proportional fitting (*52*) using the "survey" package in R (*53*, *54*). Target marginal distributions were taken from the Census data along three dimensions: race (binary for person of colour), education (five-level factor), and rural location (binary). The survey responses for race and education had a few responses of "Prefer not to answer" (7% and 4%, respectively). We maintained "Prefer not to answer" as a synthetic marginal category in the comparison population data. Weights were trimmed (strictly) at lower and upper bounds of 0.3 and 3.0 times the median weight, respectively (0.222 and 2.22). This led to trimming of 57 (5%) of the weights and a final median weight of 0.941. All statistical analyses used these sampling weights.

Figure 14 illustrates the analysis framework for extracting three indicators of Autonomy Bias for each participant. The ratings of adequate yield, safety, and comfort are the dependent variables. The independent variables potentially influencing ratings are passing time[8], video fixed effects, participant fixed effects, a dummy variable for SDV video (i.e., whether the participant rated video with the vehicle described as SDV), and an interaction term (indicating each participant's individual bias when rating SDV videos vs. HDV videos). The passing time is included for two reasons: (1) it was partially used to stratify the videos in the survey and (2) it allows us to express the indicators of Autonomy Bias in terms of equivalent passing time (discussed later). Since each participant rated adequate yield, safety, and comfort, the interaction term provides three indicators of Autonomy Bias. To implement the analysis framework from Figure 14, we specified a weighted multivariate fixed effects regression model[9] in RStudio (*55*) using data from the deception-based experiment in the survey.

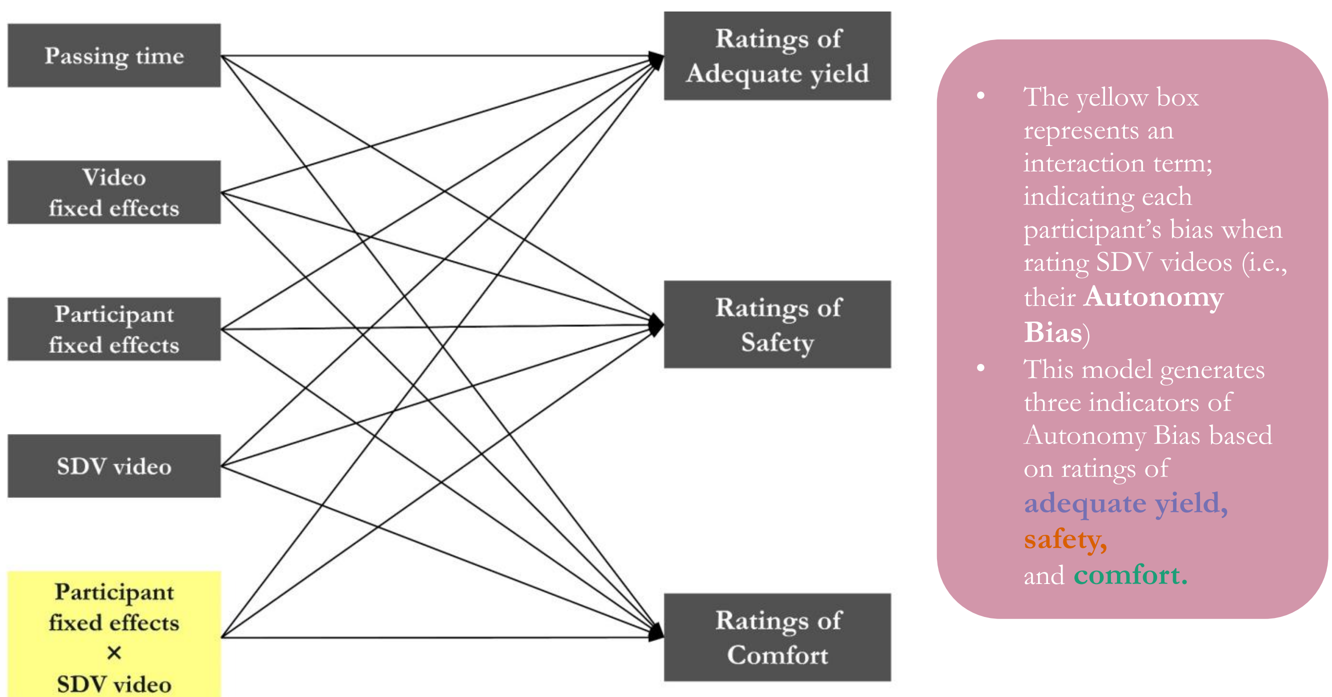

Figure 14. Analysis framework to extract indicators of Autonomy Bias for each participant

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[8] Passing time, also called post encroachment time (PET), is defined as the time gap between when the first road user exits the point at which their paths intersect and when the second road user enters it.

[9] Model fit: Adjusted R-squared of 0.56.

3.2 Results

The violin plots in Figure 15 illustrate the distribution of the three indicators of Autonomy Bias (obtained from the interaction term in Figure 14) in the BC population (for detailed model-estimated results, see Appendix: RQ1). The width of each plot represents the frequency of observations in a region. Each violin plot contains a boxplot representing the median, mean and interquartile range (i.e., the spread) of the distribution. The boxplots summarize the data while the violin plots allow us to check for the presence of multiple peaks. For ease of interpretation, the Autonomy Bias is represented in terms of equivalent passing time[10].

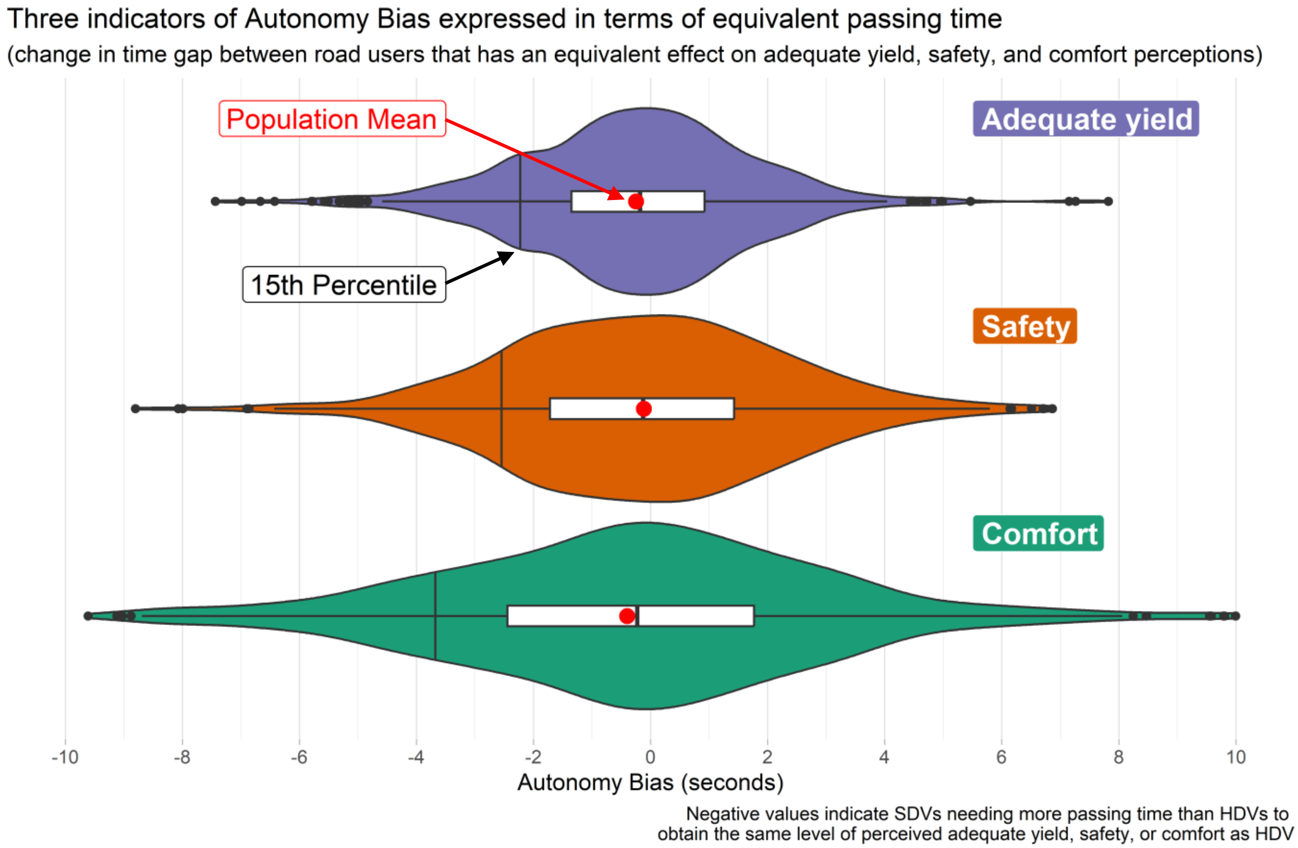

Figure 15. Distribution of Autonomy Bias[11] within the BC population

[10] Recall from the analysis framework (Figure 14) that we included passing time as an independent variable in the model that extracted indicators of Autonomy Bias (the indicators were represented by the interaction term). The ratio of the model-estimated coefficients of the interaction term and passing time allows us to represent the indicators of Autonomy Bias in terms of equivalent passing time.

[11] The distribution represents the coefficients of the interaction term, obtained for each participant. The purpose of showing the distribution is to examine the population-level pattern from the individual-level (i.e., participant) values. The proportion of participants whose individual estimates of Autonomy Bias were significantly different ($p<0.05$) from zero were: 10.6% for adequate yield, 10.8% for safety, and 13.5% for comfort. This result suggests the presence of "false negative", which we describe in Appendix: RQ2.

The population means of Autonomy Bias for all three measures are similar and slightly negative, indicating that, as a whole, the BC population has a bias *against* SDVs (i.e., perceives SDVs less favourably than HDVs). The population mean Autonomy Bias for all three indicators is significantly different from zero at a 95% confidence level[12] – in other words, we are confident that there is a negative Autonomy Bias at the population level. At the individual level, the distribution of Autonomy Bias on both negative and positive sides demonstrates the wide variety of perceptions of SDVs. Note that we do not observe multiple peaks in any of the violin plots; meaning, even though there are BC residents with a relatively strong negative or positive bias towards SDVs, such residents are few. The indicator of comfort has the largest magnitude and variability of Autonomy Bias, followed by safety and then adequate yield. This result indicates that when comparing pedestrian-SDV and pedestrian-HDV interactions, people perceive the strongest difference in comfort.

The vertical line within each violin plot – the 15th percentile line – is selected to highlight the extra passing time required for 85% of the population to have equivalent perceptions between pedestrian-SDV and pedestrian-HDV interactions. The 85th percentile is selected as a common threshold in transportation engineering practice[13]. The comfort plot illustrates that SDVs need to travel 3.7 seconds slower than HDVs (i.e., give more time) for 85% of the population to feel the same level of comfort.

For 85% of the population to feel as comfortable with SDVs as HDVs, SDVs would need to give at least 3.7 seconds more than HDVs when interacting with pedestrians.

[12] We also estimated a simpler specification without the interaction term to verify the presence of population-level Autonomy Bias (see Figure **29** in Appendix: RQ1). The coefficients for all three indicators were similar to the population means shown in Figure 15 and significant at $p<0.05$, hence providing evidence that Autonomy Bias exists.

[13] Other summary statistics of these distributions are provided in TABLE 5 of Appendix: RQ1.

RQ2: Does the Autonomy Bias vary systematically within the population (e.g. with age, gender, ethnicity, travel habits, and so on)?

In this section, we first separate the BC population into three groups based on their Autonomy Bias. We then examine how subgroups of population are distributed among those three groups. Finally, we examine if Autonomy Bias varies systematically based on personal attributes.

4.1 Three groups of population based on Autonomy Bias

Recall that we now know each participant's bias towards SDVs in the form of three indicators: adequate yield, safety, and comfort. Comfort had the largest variability (refer to Figure 15), indicating that when comparing pedestrian-SDV and pedestrian-HDV interactions, people perceive the strongest difference for comfort. Hence, we used Autonomy Bias (comfort) to categorize the sample into three groups: negative bias, no bias, and positive bias. The thresholds to define those three groups were based on equivalent passing time (for details about the selection of these thresholds, see Appendix: RQ2).

TABLE 1. Three groups of sample based on Autonomy Bias (comfort) and defined by equivalent passing time

Groups	Description	Equivalent passing time
Skeptics	People who have a bias *against* (negative) SDVs	-1 second or less
Neutrals	People who have no bias towards SDVs	between -1 and 1 second
Believers	People who have a bias *in favour of* (positive) SDVs	1 second or more

Figure 16 illustrates the proportion of BC population within the three groups. The largest proportion is skeptics (people having a negative Autonomy Bias).

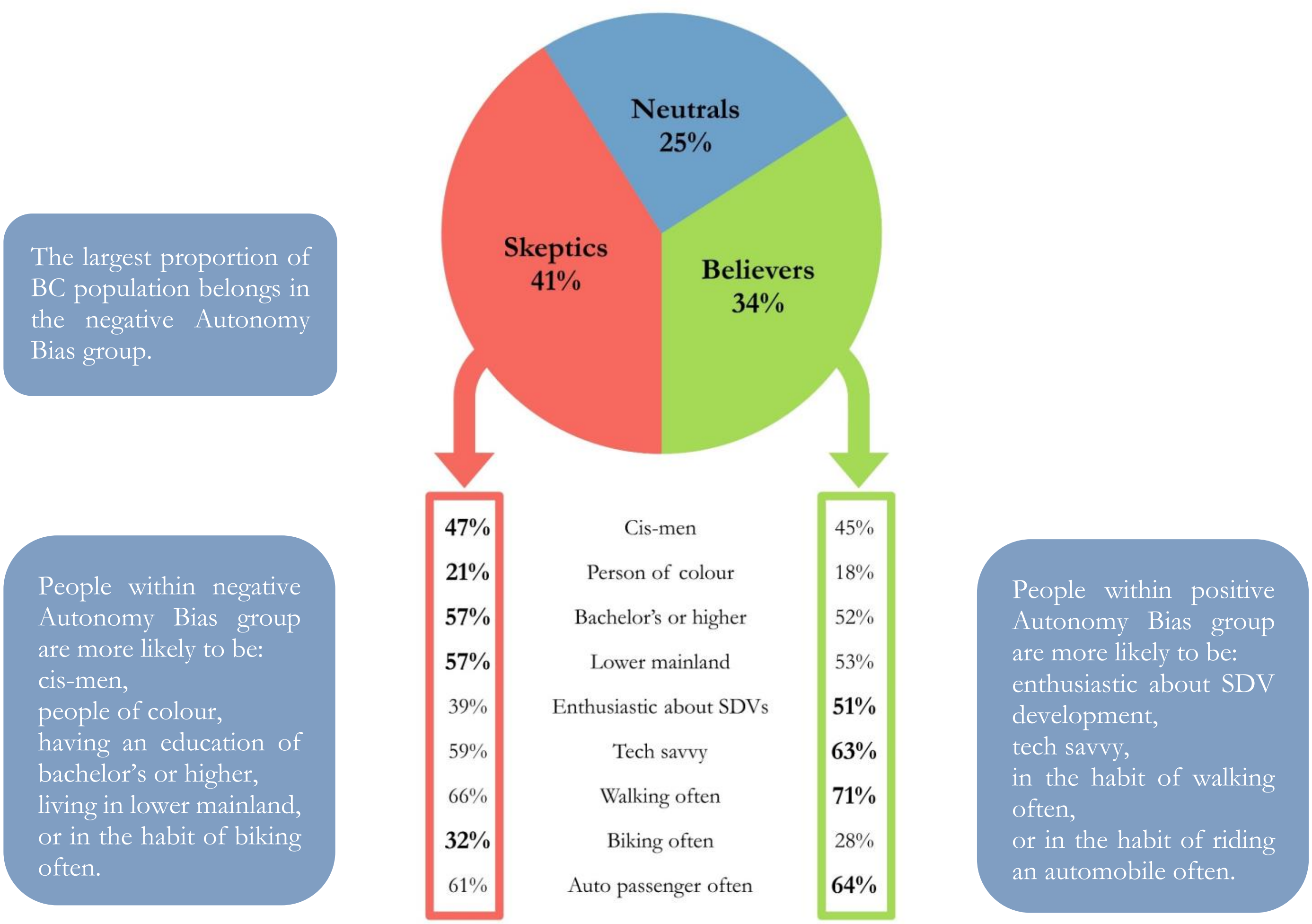

Figure 16: Three groups of sample based on Autonomy Bias

The next obvious question is: who belongs to these three groups? More specifically, are there any subgroups of population that are more common in one of the Autonomy Bias groups? For example, maybe the negative bias group predominantly has people older than 40 years while the positive bias group has younger people. Recall from earlier (see Survey methods) that we collected multiple personal attributes (socio-demographics, attitudes towards SDVs, travel habits, etc.) from participants using the web survey. We define population subgroups using those attributes.

Figure 16 summarizes the proportion of subgroups within each of the three Autonomy Bias groups[14]. Considering socio-demographic subgroups, people belonging to the negative autonomy group are more likely to be cis-men, people of colour, or have an education of bachelor's or higher. Beyond socio-demographics, people within positive autonomy group are more likely to be enthusiastic about SDV development and tech savvy. In terms of travel habits, people within positive autonomy group are more likely to be frequent walkers or frequent automobile passengers while within negative autonomy group people are more likely to be frequent bikers. The subgroups other than the ones shown in the figure had similar distributions across negative and positive bias groups, hence not included in the figure.

4.2 Determinants of Autonomy Bias

Visually examining the relationship between personal attributes and Autonomy Bias (as illustrated and described above) presents a limiting and sometimes misleading picture of the real phenomenon. A statistical model allows us to examine the existence of systematic variation of Autonomy Bias within the population with relatively high confidence. Figure 17 illustrates the analysis framework, in which Autonomy Bias is the dependent variable. Autonomy Bias – being a latent variable – is approximated by the three indicators obtained from RQ1. The independent variables potentially influencing Autonomy Bias are the participant's socio-demographics, travel habits, affective response (level of anxiety and enthusiasm), comfort in taking risks, and comfort in embracing technology.

We specified an SEM[15] (structural equation model) model to examine the relationships illustrated in Figure 17. We selected the SEM model because it allows for the representation of Autonomy Bias as a latent variable. Before model development, independent variables were checked for multicollinearity, but no independent variables were removed. Since our focus was an exploratory analysis of Autonomy Bias rather than creating a parsimonious prediction model, we retained all the independent variables (rather than step-wise addition or subtraction of independent variables).

[14] We did not conduct any statistical tests to compare the distributions of subgroups among the Autonomy Bias groups because we develop a statistical model (described in the next section) that tests the association of those subgroups with Autonomy Bias.

[15] SEM model was created in RStudio using the lavaan package (*56*).

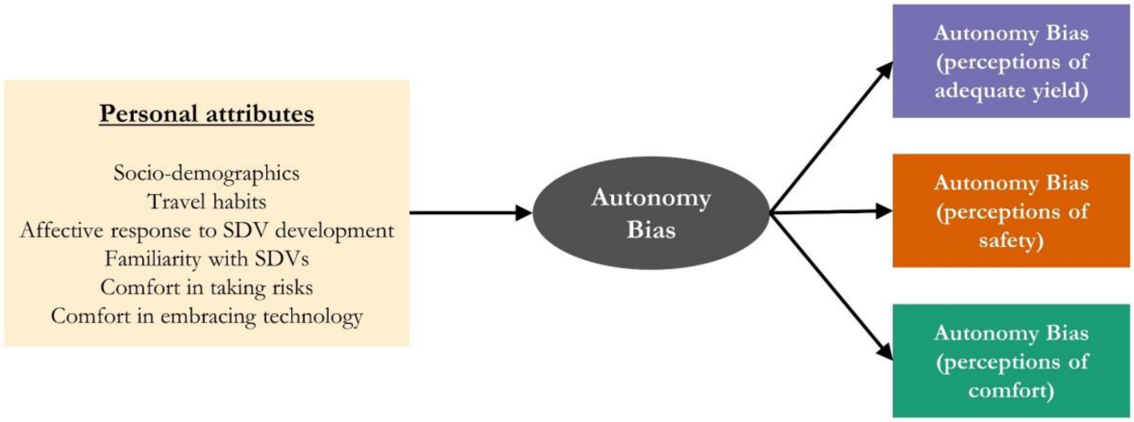

Figure 17. Analysis framework to examine determinants of Autonomy Bias

Figure 18 illustrates the results from the SEM model[16]. The model had a good fit to the data[17]. The model was specified using all independent variables but only the ones with a significant ($p<0.05$) relationship with Autonomy Bias are illustrated[18]. Out of the nine variables earlier observed as differently distributed across negative and positive bias groups (see Figure 16), only three turn out to be significantly ($p<0.05$) related to Autonomy Bias[19]. Increased enthusiasm towards SDV development or increased comfort in embracing new technologies is associated with an increase in Autonomy Bias (i.e., increasing these factors makes it more likely that people would perceive SDVs favourably). Not being a cis-man also increases Autonomy Bias. But the other personal attributes, including being a person of colour or travel habits are not significantly (at $p<0.05$) related to Autonomy Bias.

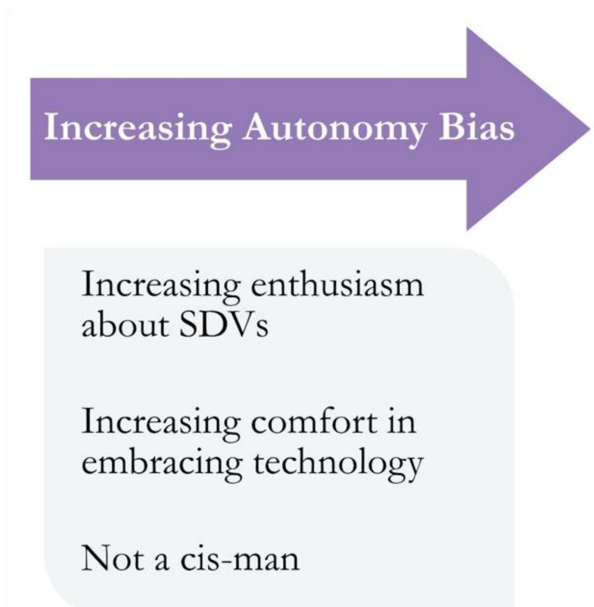

Figure 18. Determinants of Autonomy Bias

[16] Cronbach's alpha for the latent variable of Autonomy Bias was 0.70. The acceptable value depends on context but even as low as 0.50 is considered acceptable for exploratory analysis. This result indicates reliability of our indicators. The indicator with the highest standardized loadings was safety (0.77); the lowest was adequate yield (0.52).

[17] Model fit statistics: Standardized Root Mean Squared Residual (SRMR) of 0.01, Root Mean Square Error of Approximation (RMSEA) of 0.03, Comparative Fit Index (CFI) of 0.96, and Tucker–Lewis Index (TLI) of 0.94.

[18] All results from the model are given in Appendix: RQ2.

[19] We only report results in this section but offer discussion of these results in the section of Key findings.

RQ3: Which personal attributes, including Autonomy Bias, determine support for various SDV policies?

In this section, we observe what proportion of BC population supports each of the six SDV policies. We then identify the personal attributes that determine support for those policies.

5.1 Level of policy support

Recall that we considered six SDV policies in this study: two general SDV policies (allowing shared SDVs or privately-owned SDVs to operate on public streets) and four specific policies about SDV design and operations. These policies are realistic, relevant to pedestrians, comparable to literature, and useful for near-term decisions to introduce SDVs. Survey participants provided their responses using a sliding scale ranging from -10 ("strongly disagree") to 10 ("strongly agree"), with a neutral at 0 ("Neither disagree nor agree") and an "I don't know" option[20].

Figure 19 summarizes the level of support for those six SDV policies[21]. The general policies have the largest "pro-SDV" support out of all six policies considered. Around half of the BC population supports allowing shared or privately-owned SDVs to operate on public roads. The support for shared SDVs is more than privately-owned SDVs but only by 7%, indicating the absence of a substantial difference in policy support between privately-owned and shared SDVs.

The support for most of the specific policies is strong but in the opposite direction, i.e., there is strong support to place specific restrictions on SDVs. Note the long bars for the extreme value of -10 ("strongly disagree") for a few of the policies, indicating a relatively large proportion of participants in strongest-possible disagreement with those policies[22]. Around a quarter (28%) of the population agrees to support the policy allowing SDVs to enter pedestrian-priority areas; the majority wants to restrict SDVs from entering such areas. Only 11% of the population agrees to allow SDVs to operate without a person in driver's seat; a large majority does not want SDVs to operate "driverless". The lowest support (8%) is for the policy allowing SDVs to operate without being clearly identified as an SDV to other road users; a large majority wants SDVs to be clearly identified. This policy also has the lowest percent (5%) of participants choosing "I don't know", indicating that a large majority of the population has an opinion about this policy and that opinion is to require SDVs to be clearly identified.

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[20] The phrasing of the prompts of four specific policies given in Figure 19 is slightly different from the ones used in the survey (Appendix: Survey instrument). The scale was also reverse-coded for those policies. These changes were made to create consistent responses to all six policies for easier interpretation of results; the rating of "agree" in Figure 19 represents a "pro-SDV" rating across all six policies.

[21] Not shown in Figure 19 but a portion of participants selected "I don't know" in response to the policy prompts:

Policy	Percent of "I don't know"
Allowing shared SDVs to operate on public roads	7%
Allowing privately-owned SDVs to operate on public roads	7%
Allowing SDVs to travel as the same speed as HDVs	12%
Allowing SDVs to enter pedestrian priority areas, such as near schools	12%
Allowing SDVs to operate without a person in the driver's seat	7%
Allowing SDVs to operate without being clearly identified to other road users	5%

[22] A relatively large proportion of participants selecting "strongly disagree" could also be attributed to extreme responding, a type of response bias where the participants select the extreme options available. However, we reviewed the literature extensively and conducted pilot testing before finalizing the phrasing of policy prompts to minimize such response bias.

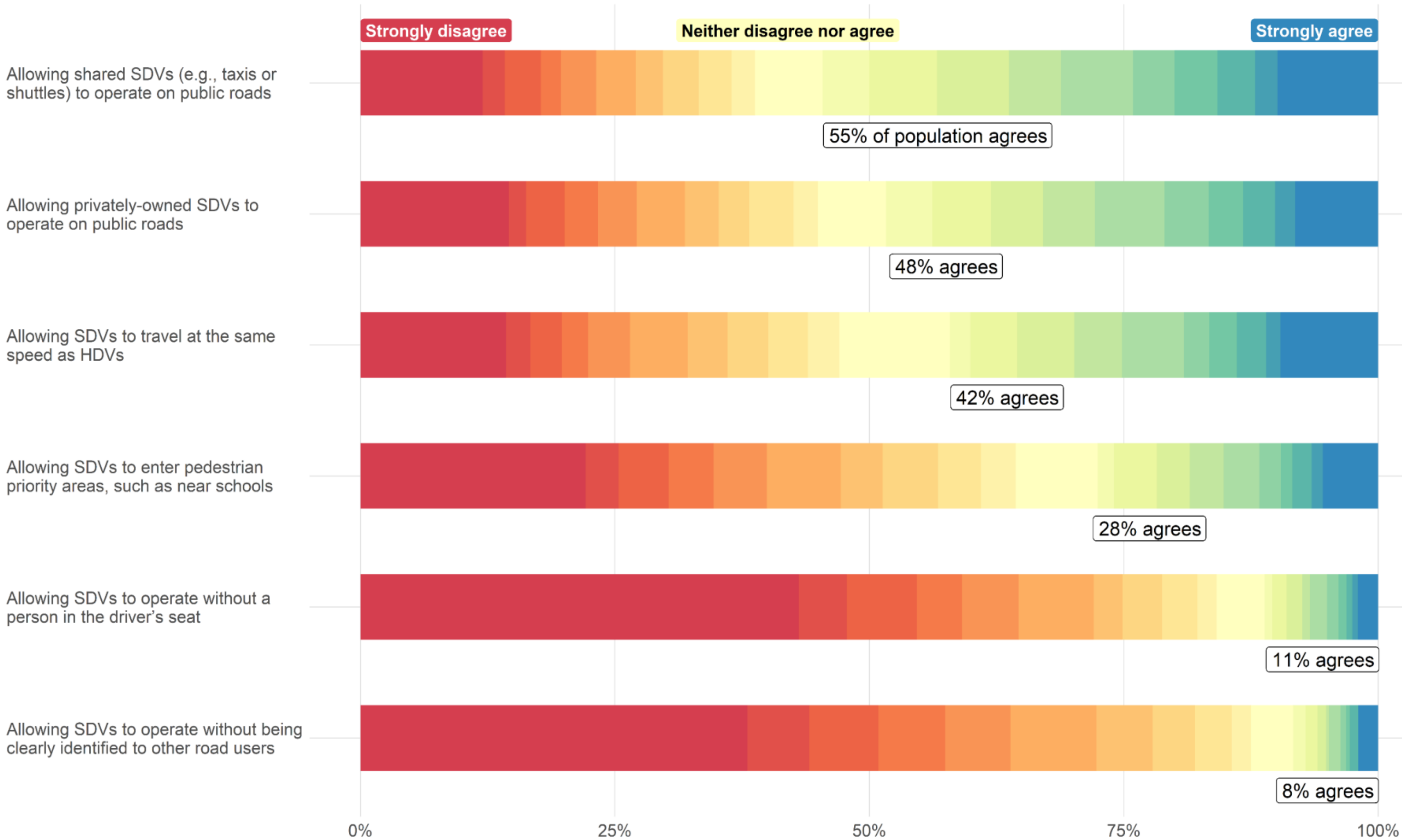

Figure 19. BC residents' level of support for SDV policies

5.2 Determinants of policy support

After learning about the level of support for each of the six SDV policies, the next question is: why would a person support a policy? Specifically, are there any personal attributes systematically driving support for those policies? We created an SEM model[23] (illustrated in Figure 20) to examine those relationships; six SDV policies as dependent variables and personal attributes, including Autonomy Bias, as independent variables. We selected the SEM model as it allowed us to specify a latent variable and jointly estimate the six policies.

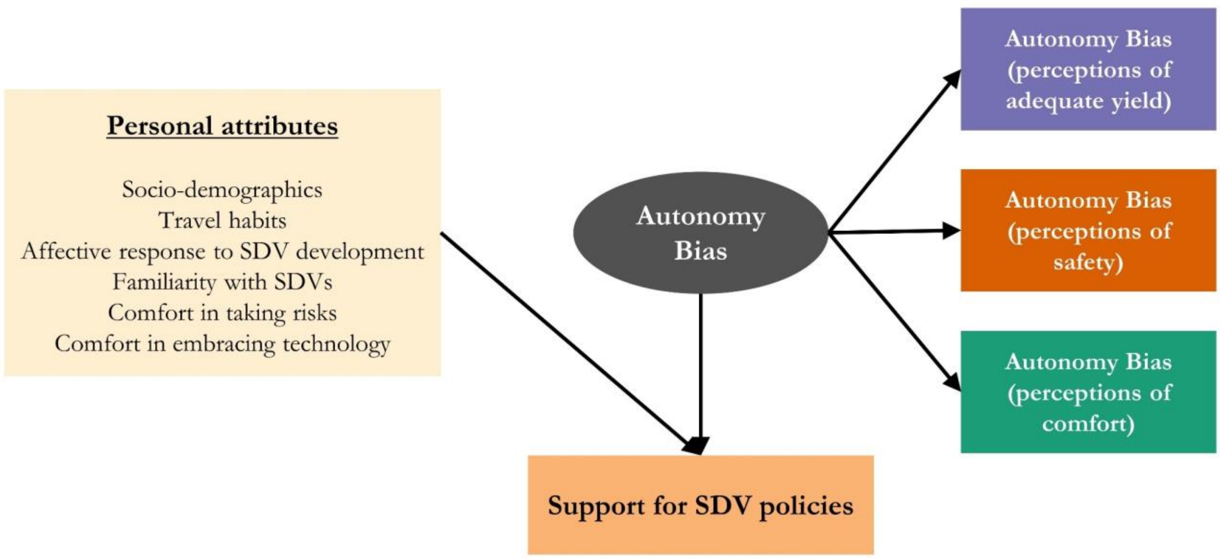

Figure 20. Analysis framework to examine determinants of SDV policies

Figure 21 summarizes the results from the SEM model[24]. The model had a good fit to the data[25]. The model was specified using all independent variables but only the ones with significant ($p<0.05$) relationships are illustrated. The size of each factor represents the size of its effect on policy.

Being enthusiastic about SDV development leads to increase in support for all six SDV policies. Increasing Autonomy Bias (i.e., moving towards perceiving SDVs favourably) increases the support for three SDV policies: allowing shared SDVs, allowing SDVs to travel at the same speed as HDVs, and allowing SDVs near pedestrian priority areas. Being familiar with SDVs was another SDV-related factor we considered but it did not turn out to be significant ($p<0.05$), indicating that familiarity with SDVs is not an important driver of SDV acceptance (i.e., policy support) compared to other SDV-related factors such as affective response and Autonomy Bias. Another technology-related factor – being tech savvy – determines support for allowing both shared and privately-owned SDVs, indicating that people who are generally comfortable embracing new technologies are also likely to accept SDVs.

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[23] SEM model was created in RStudio using the lavaan package (*56*).

[24] We only report results in this section but offer discussion of these results in the section of Key findings.

[25] Model fit statistics: Standardized Root Mean Squared Residual (SRMR) of 0.02, Root Mean Square Error of Approximation (RMSEA) of 0.03, Comparative Fit Index (CFI) of 0.96, and Tucker–Lewis Index (TLI) of 0.98.

Among the socio-demographic factors, being younger than 40 increases support for allowing both shared and privately-owned SDVs to operate on public roads. Interestingly, we observe gender differences for only one policy; being a cis-man increases support for allowing SDVs to operate without a "driver". In other words, not being a cis-man increases support for restricting SDVs from operating without a "driver". Note that even after controlling for general risk-aversion[26], tech savviness, and affective response (factors that are sometimes speculated to explain differences among age groups or genders), we still observe age and gender significantly ($p<0.05$) affecting SDV policy support. Racial differences are also present for the same policy; white people (vs. people of colour) are more likely to allow SDVs without a "driver" while people of colour want to restrict SDVs from operating without a "driver". People living outside lower mainland[27] (vs. people living in lower mainland) are more likely to allow SDVs to travel at the same speed as HDVs and operate without being clearly identified as SDVs. Finally, travel habits also affect policy support but contrary to expectations those habits are not about the frequency of active modes but rather the frequency of automobile use. People who often ride an automobile support privately-owned SDVs while people who rarely drive an automobile support shared SDVs.

To summarize the policy results, the two SDV-related factors – being enthusiastic about SDVs and increasing Autonomy Bias – are more consistent determinants of support for SDV policy than the socio-demographic factors or travel habits. But socio-demographics and travel habits persist as influencing factors, even after controlling for anxiety/enthusiasm and Autonomy Bias. These influential factors demonstrate that the equity-seeking groups are less likely to support "pro-SDV" policies; people older than 40 are less likely to allow shared SDVs, people of colour and non-cis-men want to restrict SDVs from operating without a "driver", and people who rarely drive an automobile want to restrict SDVs from going into pedestrian priority areas. These results suggest that if SDVs are introduced without specific restrictions then those equity-seeking groups could be disproportionately affected in terms of degradation of walking experience.

[26] General risk aversion (i.e., comfort in taking risks) was not significant ($p<0.05$) for any policy.

[27] We also tested for another location variable, rural (vs. urban), but it was not significant ($p<0.05$) for any policy.

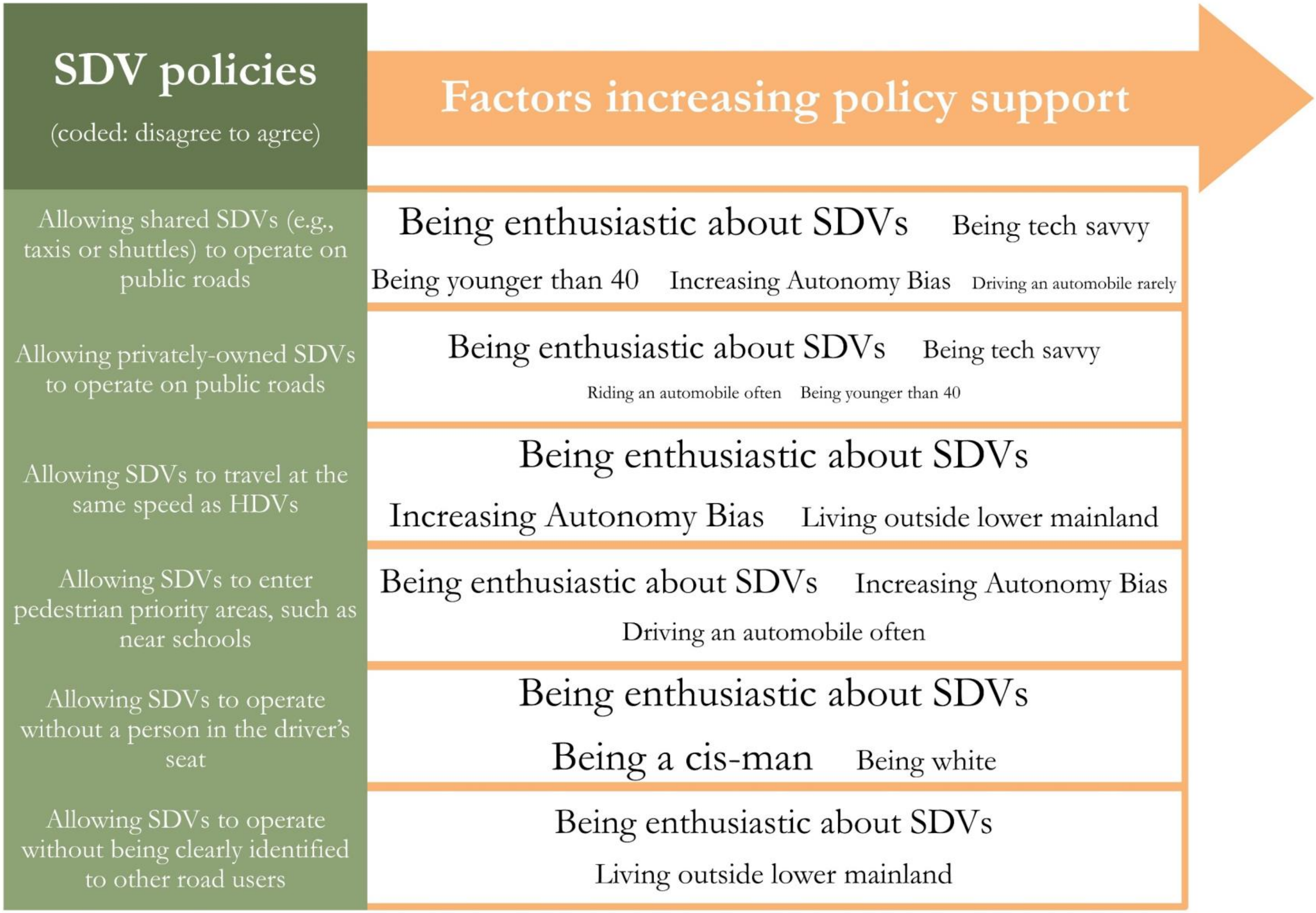

Figure 21. Determinants of support for SDV policies (text size of factors is reasonably proportional to the standardized effect magnitude)

We already know from earlier (refer to section: Determinants of Autonomy Bias) that to increase Autonomy Bias (i.e., make it more positive) people need to be enthusiastic about SDVs and comfortable embracing new technology. Additionally, we have now learned that being enthusiastic about SDVs is the largest and most common determinant of people's level of support for SDV policies. To allow policymakers to devise strategies for addressing anxiety among people, we need to examine what personal attributes determine these feelings. Therefore, we estimated a linear regression model (refer to Appendix: Determinants of Affective Response) to examine the causal factors that influence how anxious or enthusiastic a person feels thinking about SDV development. We found that being familiar with SDVs and being comfortable embracing new technologies improves how people feel about SDVs (i.e., people become less anxious). Interestingly, being familiar with SDVs did not turn out to be a significant ($p<0.05$) determinant of any SDV policy (this result is in line with (*23*)), even though being enthusiastic about SDVs is significant ($p<0.05$) for all SDV policies. This result indicates that the relationship between familiarity and policy support is mediated by how anxious or enthusiastic a person feels about SDV technology.

Being enthusiastic about SDVs determines SDV policy support. But what determines enthusiasm?

- Being familiar with SDVs
- Being comfortable in embracing new technologies

5.3 Qualitative analysis of policy comments

The analysis until now was quantitative in nature. But our survey also included an open text box on the same page where we asked policy support questions. The prompt in the survey for the open text box was:

> If you have any comments regarding self-driving vehicle policies, please provide them here.

We received 326 comments from our sample of 1133 participants. Note that even though we provided an open comment box, we did not *require* participants to provide comments. In other words, these comments might not be representative of the whole sample as there could be selection bias. For example, participants who have negative opinions about SDVs or participants who are more vocal and care more[28] about the subject of SDV may be more likely to provide comments. However, we did not observe any substantial selection bias based on the three groups of Autonomy Bias. Among the people who provided comments, 42% were skeptics (with negative Autonomy Bias), 36% were believers (with positive Autonomy Bias, and 22% were neutrals (with no Autonomy Bias). This distribution is similar among the people who did not provide comments: 40% were skeptics, 33% were believers, and 27% were neutrals. These open-ended comments are unconstrained expressions of participants' perspectives on SDVs. We manually conducted a qualitative analysis using those comments to identify the sentiments (i.e., polarity) and common themes.

5.3.1 Sentiments

Figure 22 illustrates the distribution of sentiments and exemplar comments associated with each sentiment. Negative and positive sentiments are self-explanatory. Ambivalent refers to comments with both negative and positive sentiments and off-topic are comments that did not have a sentiment. The comments with negative sentiments are around 1.5 times more common than the ones with positive sentiments.

[28] Some participants might have cared about SDVs but did not provide comments because of ineloquence.

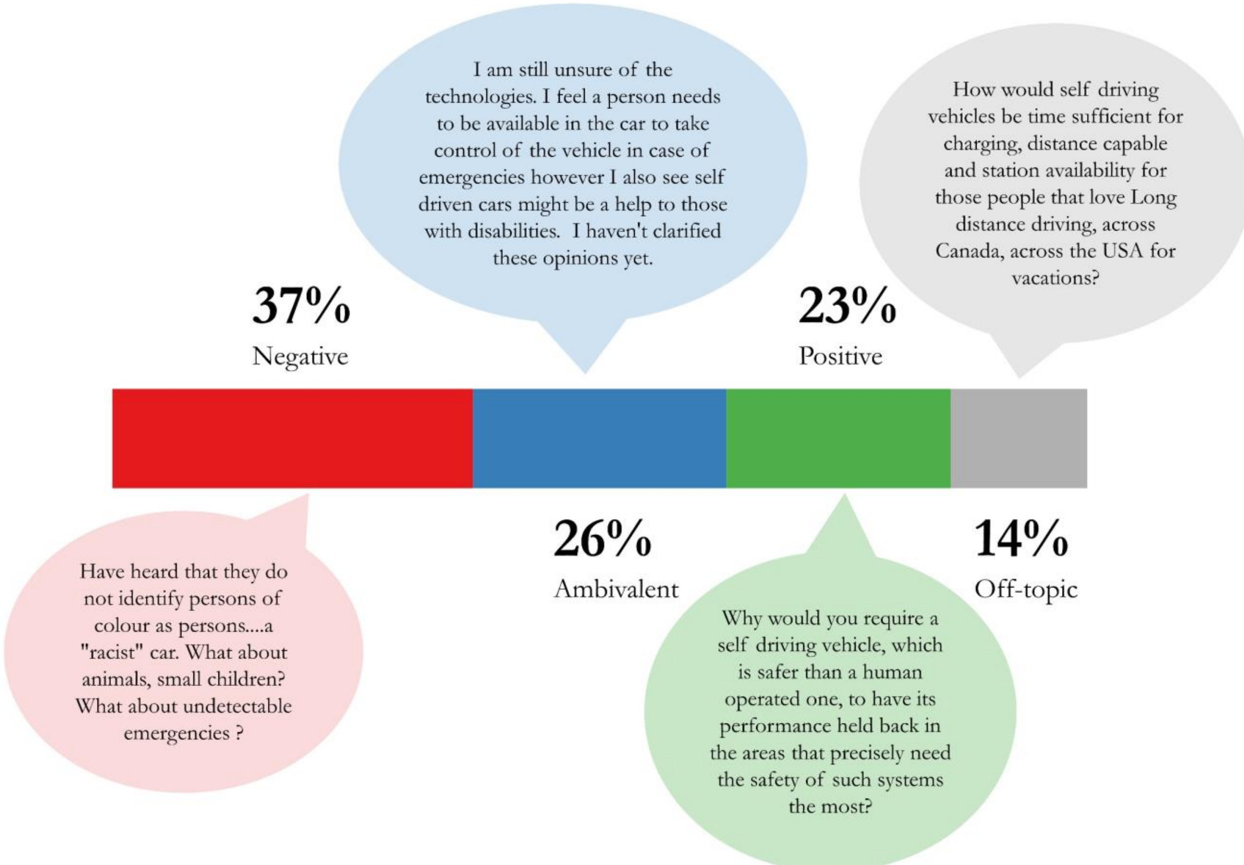

Figure 22. Distribution of sentiments, with exemplar comments

5.3.2 Themes

We identified five themes from the comments, as illustrated in Figure 23. The majority of the participants opined on the "automation capability" of SDVs – about both trust and doubt in SDV technology. Participants compared the capabilities of SDVs and drivers and that comparison manifested in two ways: (1) some participants trust SDVs to be safer than human drivers and this knowledge is sufficient for them to support SDVs, rather than expecting SDVs to be perfect, (2) conversely, participants who doubt SDVs do not think SDVs could match the skills of human drivers. The first subgroup seems to consider drivers bad while the second subgroup seems to consider drivers in high regard. Meaning, that trust or doubt in SDVs seems to be partially dependent on how a participant perceives the skills of human drivers. Participants also doubt SDVs' automation capability in challenging environments (e.g., different weather conditions, interactions with pedestrians, interactions with pets, children, or pedestrians using mobility-assisted devices). The doubts mostly stem from hearing negative news about SDVs or personal struggles with computers or in-vehicle electronics. Conversely, a few participants trust SDVs because SDVs are computers.

The second theme is about "cautious policy"; participants are willing to support SDV policies but are waiting for more development and testing of SDVs before full acceptance. In the meantime, such participants may support the introduction of SDVs with some restrictions. The third theme of "SDVs not needed" reflects participants' belief that policymakers' focus on SDVs is misplaced; the focus should be on promoting active modes of travel and transit, not SDVs. Most participants seem to conflate privately-owned and shared SDVs, as the issues raised in comments primarily pertain to privately-owned SDVs, and relate aversion to private motor vehicles. A few comments (8%) refrained from providing strong opinions and showed interest in learning more about SDVs. Even though we did not ask any policy questions on laws or ethics, 7% of the comments were about those topics; how the SDVs would decide the distribution of harm in some situations and who will be held accountable for crashes involving SDVs.

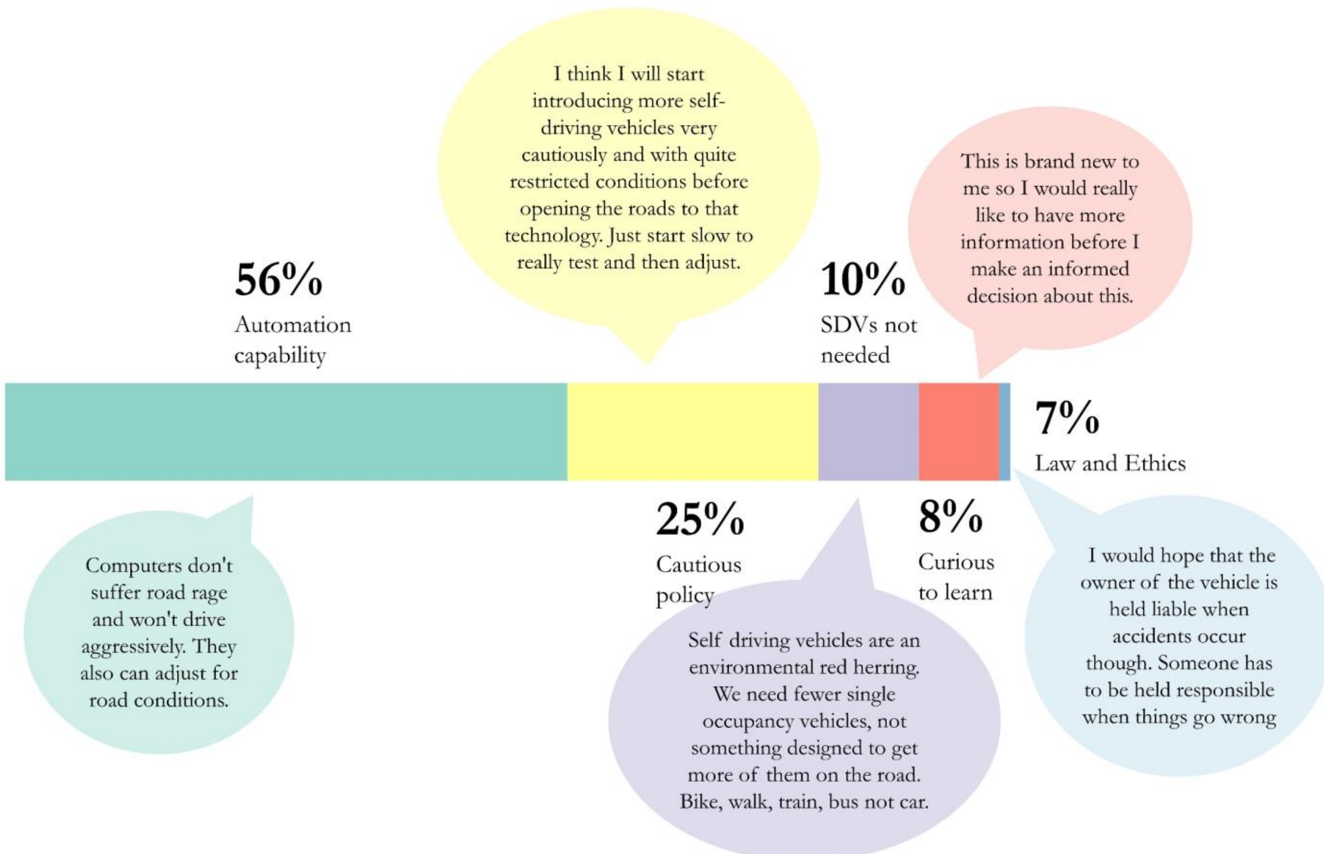

Figure 23. Distribution of themes, with exemplar comments (note the themes add to more than 100% because a few comments had multiple themes)

5.3.3 Sentiments and themes

TABLE 2 gives the distribution of comments based on both sentiments and themes. Negative sentiments are more common than positive, mainly because of automation capability; comments with negative sentiments doubt SDVs' capabilities while comments with positive sentiments trust SDVs' capabilities. People providing ambivalent comments are curious to learn more but support a cautious policy for now.

TABLE 2. Cross-tabulation of themes and sentiments

Sentiments	Themes	Automation capability 56%	Cautious policy 25%	SDVs not needed 10%	Curious to learn 8%	Law and Ethics 7%
Negative	37%	30%	3%	4%	0%	3%
Ambivalent	26%	5%	15%	1%	7%	3%
Positive	23%	19%	4%	0%	0%	0%
Off-topic	14%	1%	3%	5%	2%	2%

6. KEY FINDINGS

1. Autonomy Bias is negative but varies widely across BC residents

The average Autonomy Bias in the BC population is negative. In other words, if we randomly stop a BC resident, it is more likely that they have a negative Autonomy Bias (i.e., they have a bias *against* SDVs, or they feel interactions with SDVs (vs. HDVs) are less comfortable and less safe, and SDVs yield inadequately). Autonomy Bias – being an individual's attribute rather than a population attribute – has substantial variability among BC residents; even though a larger proportion of the population (41%) has a negative Autonomy Bias, it is not the majority. Interestingly, 34% of the population has a positive Autonomy Bias, i.e., they perceive pedestrian interactions with SDVs to be more comfortable, safer, and more adequate yielding than HDVs. No other study has conceptualized or examined Autonomy Bias but one study examined the level of perceived safety on sharing the road with SDVs (*16*). The study observed 53% of the participants considered sharing the road with SDVs as safe while 47% considered it unsafe. Our study shows a similar division but the opposite dominant group.

We observed that how comfortable a participant feels in embracing new technology determines their Autonomy Bias; participants who are not tech savvy are more likely to have a negative Autonomy Bias. Going a step further speculating about why a negative Autonomy Bias exists, maybe some people have an aversion to algorithms/computers (*57*). These people might think that computers are not able to replicate the complexities of how humans observe and process the world around them and behave accordingly. This aversion becomes strong in the case of driving when people assign a moral dimension to the act of driving, as driving could have harsh consequences and a computer (which seemingly lacks subtle human complexities) might not understand the

> Too many variables in the environments of roads, sidewalks, and wildlife for computers to best the human brain.

> I don't think we will ever reach the point of where we have a perfect system that responds to all the input that a human driver can absorb and evaluate in micro-seconds.

> I have doubts about the reality of the computers, have experienced many problems upgrading software on computers, phones etc.

high stakes (*58*). This sympathy with humans, and not with algorithms, is partially why a crash involving a SDV could be perceived as a more intense tragedy than a crash involving a human-driven vehicle (*58*, *59*). On the other hand, positive Autonomy Bias could also be explained by aversion, but this time towards humans. People with positive Autonomy Bias might perceive humans to be prone to conditions (intoxication, distraction, tiredness, etc.) that do not affect computers.

Computers don't suffer road rage and won't drive aggressively. They also can adjust for road conditions.

2. Autonomy Bias is similarly distributed across most subgroups of the BC population

Even though Autonomy Bias is an individual attribute, we suspected there could be some patterns of inequities – people belonging to a specific subgroup of population (e.g., people of colour) might feel more strongly about pedestrian-SDV interactions than other subgroups.

The major concern I have with autonomous vehicles is that they are often unable to discern a person of colour vs someone who is caucasian.

Without controlling for other factors, five subgroups of the population were more likely to have negative Autonomy Bias, including people of colour and people who bike more often. However, after controlling for other factors, we identified only three subgroups across which the Autonomy Bias is spread disproportionately. People perceive SDVs differently mostly based on how SDVs make them feel (the level of anxiety or enthusiasm) and how comfortable they are in embracing new technologies in general. In other words, people who are anxious about SDV technology or are generally not comfortable embracing new technology are more likely to have a bias against SDVs and this bias might degrade their walking experience.

We observed only one socio-demographic factor – gender – to significantly affect Autonomy Bias. Controlling for other factors, being a cis-man is associated with decreasing (or more negative) Autonomy Bias. This result is contradictory to our expectations – cis-men generally are more tech savvy, and have more familiarity and positive attitudes towards SDVs compared to non-cis-men, as observed in our study (refer to Appendix: Gender and Attitudes) and the literature (*16*, *20*, *32*). We speculate that because of familiarity and trust in SDV technology, cis-men (vs. others) held SDVs to a higher standard and judged the "SDVs" in our survey videos more harshly as the performance did not meet cis-mens' expectations of SDVs.

Another possible rationale stems from cis-men's perceived degradation of walking experience when interacting with SDVs (vs. HDVs). Cis-men might be more entitled pedestrians and enjoy enhanced comfort as pedestrians when interacting with HDVs[29]. But cis-men might suspect that SDVs would be less accommodating than human drivers, hence cis-men perceive interactions with SDVs as less privileged, leading to more negative Autonomy Bias (vs. non-cis-men). Conversely, non-cis-men may presume better (fairer) treatment from SDV vs. HDV, despite less enthusiasm or familiarity with SDV, leading to a more positive Autonomy Bias.

To summarize, the gender effect appears to be inconsistent among different facets of attitudes toward SDVs. Cis-men, while being more familiar, enthusiastic, and in consistent support of SDV policies, perceive interactions with SDVs more negatively, as revealed by their Autonomy Bias. Note that all those facets are self-reported – except Autonomy Bias, which is revealed through ratings of adequate yield, safety, and comfort for pedestrian-SDV interactions. The professed "pro-SDV" attitude does not show cis-mens' revealed Autonomy Bias, suggesting that perhaps cis-men are overstating their pro-SDV perceptions

[29] Research has observed mixed results; sometimes gender of pedestrian affects their crossing behaviour and driver's yielding behaviour (*60*, *61*), and sometimes not (*62*), but those studies observed pedestrian behaviour and did not examine how cis-men perceived themselves as a crossing pedestrian

in the self-reported measures. There are clearly some complex causal pathways between gender's effects on receptivity to SDVs, and such relationships are not entirely represented by self-reported perceptions. More research is needed to better understand those relationships.

3. BC residents are split on introducing SDVs

Similar to the division in Autonomy Bias, around half the population supports allowing privately-owned or shared SDVs to operate on public roads, while the other half does not. The support for allowing shared SDVs (55%) is larger than privately-owned SDVs (48%), probably because 40% plan to ride shared SDVs while only 20% plan to purchase SDVs (refer to the section: Intention to purchase or ride SDVs).

The subgroups of the population that are less likely to support SDV introduction are people who are anxious about the development of SDVs, not comfortable embracing new technology, or are older than 40. These results are in line with existing studies on SDV acceptance, however acceptance is defined (*16*, *37*).

I would never ever trust self driving vehicles. There is already a history of accidents caused by them.

We have a vehicle capable of driving itself way better than any human can. Let's embrace it. It's way better for our future, cut down human mistakes, and keep everyone safer on our road.

4. A vast majority of BC residents wants a "driver" to be present in the SDVs

Around 90% of the population wants a "driver" to be present in the SDVs. This finding is consistent with the literature (*16*). The primary reason for requiring a person could be the feeling of comfort knowing that the SDV has not been handed full control of the vehicle; a human is monitoring the behaviour of SDV and will take control in an emergency.

Another reason to want a "driver" could also be due to an expectation of improved comfort but in normal conditions (not emergency). Interactions at unsignalized crossings are complex; a pedestrian needs to process a lot of information coming from multiple directions at the same time, and the motor vehicle driver does the same, and both negotiate the order of crossing. During that negotiation, pedestrians generally look towards the driver for communication (*63*). But in the case of SDVs, this essential, comforting communication will be disrupted (*10*) because pedestrians will no longer be able to communicate their intentions to SDVs through eye contact or other conventional gestures, and conversely, find it challenging to infer the intentions of SDVs (*31*). Including a "driver" in SDVs might provide a semblance of normalcy, when interacting pedestrians will assure themselves of human presence (i.e., normalcy) seeing through the windshield. A few studies suggest installing human-like communication features on the SDV (*64*) or a robot in the driver's seat of SDV (*65*) to simulate pedestrian-HDV interaction.

I feel a person needs to be available in the car to take control of the vehicle in case of emergencies however I also see self driven cars might be a help to those with disabilities. I haven't clarified these opinions yet.

Self driving vehicles must not be allowed on roads if a human on standby is required. In the early introduction however, a real-life looking mannequin might aid in the building of trust. At their peak of development, self driven in a school zone would probably be safer!

5. A vast majority of BC residents wants the SDVs to be clearly identified

This study observed that around 90% of the population wants SDVs to be clearly identified. This result is in line with existing research that found external communication features to improve the perception of safety for crossing pedestrians (*26*, *27*, *46*, *66*), as communication without a human driver could be challenging for the interacting road users (*67*). A few studies have observed that SDVs could build more trust with road users if communication features beyond only clear identification are installed (*46*, *47*). Such features communicate more comforting information about SDVs' state, such as telling when it is stopping, starting to move, allowing pedestrians to cross, etc. (*68*). In our study, too, we observed that 57% of the participants indicated that they observed "SDV's clarity of intentions" to be less than HDVs in the videos of our deception-based experiment even though all videos showed HDVs (see section: "Soft" questions to infer participant deception). Some manufacturers already install such external communication features but others might refrain from doing so to prioritize aesthetics. The human-human interaction from pedestrian-HDVs could be recreated to some extent for human-machine interaction in case of pedestrian-SDVs by providing human-like features (called anthropomorphism) and help build trust in SDVs (*48*).

6. Most BC residents do not want SDVs to go near pedestrian areas

Around 75% of the population does not agree to allow SDVs to go near pedestrian priority areas. A study conducted in the US observed the disagreement to be 65% (*16*). The unpredictability of pedestrians in general and children in particular might be the reason for opposition to this policy (*67*). However, a few survey participants, who implied knowledge of SDV technology, had an opposing opinion, arguing that we need SDVs urgently and specifically for such areas to fully realize the safety capabilities of SDVs. This argument is in line with SDV manufacturers who market SDVs promising improved safety for both passengers and other road users.

> How well can self-driving vehicles identify pedestrians? Can the SDV recognize a child darting into traffic? Can it respond quickly?

> Why would you require a self driving vehicle, which is safer than a human operated one, to have its performance held back in the areas that precisely need the safety of such systems the most?

7. SDV-related factors – being enthusiastic about SDVs and increasing Autonomy Bias – are more consistent determinants of SDV acceptance than the socio-demographic factors or travel habits

We included six SDV policies in our survey to assess BC residents' level of support for different policies. After learning about the level of support for each of those policies, it was an obvious question to learn which personal attributes determine that support. Compared to socio-demographics and travel habits, the affective response (i.e., being anxious or enthusiastic about SDV development) and Autonomy Bias more consistently determined the level of support for SDV policies. This finding is in line with other studies that also observed that affects are stronger than logical reasoning (e.g., whether a person perceives SDVs to be beneficial or not) or socio-demographics for SDV

> Even though I am enthusiastic about the idea of self-driving vehicles, I would probably feel anxious about sharing the road with them for some time. I'm sure that I would get used to them though.

acceptance formation, however acceptance is defined (*16*, *17*). No other study has examined Autonomy Bias but two studies examining perceived safety on sharing the road with SDVs also observed perceived safety to be a determinant of SDV policy support (*16*, *23*). The continued presence of Autonomy Bias as a determinant of policy support, even after controlling for affective response, highlights the need to be cognizant about understanding road users' perceptions towards SDVs for a responsible introduction of SDVs.

8. A few subgroups of population, including equity-seeking groups, are less likely to support "pro-SDV" policies

We observed that even after controlling for affective response and Autonomy Bias, a few factors representing subgroups of population – including equity-seeking groups, persisted as determinants of SDV policy support. People within these groups are less likely to support "pro-SDV" policies; older people are less likely to favour shared SDVs, people of colour and non-cis-men want to restrict SDVs from operating without a "driver", and people with less auto mobility (i.e., who rarely drive an automobile) want to restrict SDVs from going into pedestrian priority areas. Most existing SDV policies address the safety and economic impacts but rarely address impacts on marginalized groups (*69*). But understanding the concerns of such groups is important to provide a balanced policy approach that would try to alleviate the concerns while allowing SDVs introduction to proceed. The results from our study suggest that if SDVs are introduced without specific restrictions then those equity-seeking groups could be disproportionately affected in terms of degradation of walking experience. This finding is useful for developing context-specific SDV policies in BC.

7. RECOMMENDATIONS

The findings of this study yield practical implications for policymakers and SDV developers. Since the ultimate goal is responsible introduction of SDVs, we **recommend a cautious, tiered approach** to SDV introduction. This tiered approach is justified considering the demonstrated potential for SDV to both positively and negatively impact perceptions of safety and comfort for pedestrians in BC, the divided support for SDV introduction, and the strong support for SDV restrictions. A similar precautionary approach to introducing SDVs is also recommended in the literature (*70*).

> I'd like more information before I make a decision about some of these policies. Also, I think that it might be wise to instate some additional safety rules for first-generation self-driving vehicles that are eventually removed once the technology has been in use for some time.

7.1 SDV Testing

We recommend that introduction should begin with **restrictive pilot testing** to allow road users to experience and observe interactions with SDVs in more limited and controlled settings. During pilot testing, a few restrictions should be observed. To ensure the comfort of a large proportion of the BC population, **SDVs should be programmed to operate more conservatively** than HDVs around pedestrians and other vulnerable road users;

> Although intriguing, autonomous vehicles should be sufficiently trustworthy that separate policies just for them aren't necessary. Until then policies should seek to minimize danger to other road users.

SDVs must allow 3.7 seconds of additional passing time at crosswalks than typical HDVs to offset the Autonomy Bias of 85% of the population.

> I think I will start introducing more self-driving vehicles very cautiously and with quite restricted conditions before opening the roads to that technology. Just start slow to really test and then adjust.

SDVs should be required to have **external communication features** that, at the least, inform other road users that the motor vehicle they are interacting with is self-driven. Even if the SDV manufacturers claim that their technology is sufficiently advanced so as not to require a person in the driver's seat of an SDV, SDVs should be required to have **a person in the driver's seat** to take control of the vehicle in emergencies, meanwhile assuring the interacting road users of a familiar, human-presence. **SDVs should not be initially tested or deployed in pedestrian priority areas** such as near schools.

> The technology is new so while I support the development of self driving vehicles I'm not sure I'm ready to have them fully integrated with normal traffic yet. My support for them will increase as the technology matures.

In this initial phase, opportunities should be provided to the public to gain knowledge about SDV technology, operations, and performance, especially to the equity-seeking groups who might be disproportionately affected by SDVs. Judging from the number of open-ended comments we received during this study, people have varying sentiments based on multiple themes about SDVs and they should have access to relevant information.

7.2 SDV Introduction

This study shows that familiarity with SDVs improves self-reported affective response to SDVs (i.e., leads to more enthusiasm), which in turn improves Autonomy Bias (i.e., leads to favourable perceptions of SDVs) and increases support for SDV policies (i.e., easing restrictions and allowing SDVs to operate on public roads). Other studies have also shown that giving adequate time to all road users to experience interactions with SDVs increases the safety perceptions (*71*) by slowly building trust (*17*). Therefore, public feedback should be sought through surveys, interviews, and focus groups to record and evaluate the level of comfort and policy support of road users before, during, and after pilot testing of SDVs. If the perceptions of a reasonably large proportion of the public shift towards comfort, then SDV restrictions can be eased accordingly. Other pilot studies identified a few general (software limitations, not anticipated to handle mixed traffic) and context-specific (infrastructure gaps, winter conditions) challenges during the testing. Such challenges should be addressed before introduction.

> Our Motor Vehicle Act should be considered and amended before this begins.

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9. APPENDIX: SURVEY INSTRUMENT

Perceived comfort and safety of road users in real-world interactions with self-driving vehicles

Thank you for considering participation in this study. The study is being conducted by Dr. Alex Bigazzi (Principal Investigator), Dr. Jordi Honey-Rosés, and their research team at the University of British Columbia (UBC), with funding from TransLink.

We are investigating interactions between self-driving vehicles and pedestrians during pilot testing on public streets. In collaboration with the Department of Electrical Engineering at UBC, several passenger vehicles were modified with self-driving equipment. The vehicles travelled on an approved test route of low-traffic city streets, and their interactions with pedestrians at several crosswalks were recorded. In compliance with federal safety requirements, a driver was present to take control of the vehicle in case of an emergency. The vehicles were not labelled as self-driving to make interactions with other road users as normal as possible.

In this survey, you will be asked to evaluate pedestrian interactions with vehicles shown in a series of 8 short video clips. For comparison, half (4) of the interactions will be with regular (non-self-driving) vehicles at the same crosswalk locations. You will also be asked basic questions about yourself, your travel habits, and your general opinions on self-driving vehicles.

This survey should take between 10 and 15 minutes to complete. Participation is voluntary, and you can withdraw at any time. Your responses will remain confidential, and any identifying information will be removed before the results are presented to TransLink, or in transportation conferences and journals.

You may enter a drawing for 1 of 10 gift cards of $25 each by entering your email address on the next page. Your email address will not be shared or used for any other purpose. Everyone who takes the survey and enters their email address will be considered in the prize draw (even those who withdraw or do not answer every question). All gift cards will be given to British Columbia residents. The odds of winning a gift card are 1 in 200.

If you have any questions about this study, please contact Dr. Alex Bigazzi at alex.bigazzi@ubc.ca or 604-822-4426. If you have accessibility needs to take the survey, please email gurdil.gill@ubc.ca. If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or email RSIL@ors.ubc.ca or call toll free at 1-877-822-8598 (ethics ID: H21-02214).

Click on “I agree” below to indicate your consent to participate in this survey and proceed.

○ I agree

○ I disagree

Q2.1 Self-driving vehicles use advanced technology to scan the surrounding road environment and carry out all driving tasks, including steering, speed control, following traffic signs and lights, yielding at crosswalks, etc.

Q2.2 Please indicate your response to the following questions related to self-driving vehicles:

(*adjust the sliders to answer*)

	Not familiar at all	Very familiar	I don't know
	0	10	
How familiar are you with the development of self-driving vehicles?			

Q2.3

	Very anxious	Neutral	Very enthusiastic	I don't know
	-10	0	10	
When you think about the development of self-driving vehicles, you feel...				

Q2.4

<u>While answering the following questions, consider a world where the risks of COVID are eliminated and social distancing measures are fully removed.</u>

Please indicate your level of agreement with the statements below:

	Strongly disagree	Neither disagree nor agree	Strongly agree	I don't know
	-10	0	10	
I plan to purchase a self-driving vehicle when they are available.				
I plan to ride in shared self-driving vehicles when they are available (e.g., as a taxi or shuttle).				
Self-driving vehicles will reduce traffic congestion.				
Self-driving vehicles will reduce pollution emissions from transportation.				
Self-driving vehicles will improve mobility for people with a limited ability to drive (e.g., the elderly, children, people with disabilities).				

Q2.5

<u>Public agencies are weighing the pros and cons of policy changes that may facilitate the introduction of self-driving vehicles on public roads.</u>

Please indicate your level of support for the policies below.

I support policies...

	Strongly disagree	Neither disagree nor agree	Strongly agree	I don't know
	-10	0	10	
Allowing shared self-driving vehicles (e.g., taxis or shuttles) to operate on public roads.				
Allowing privately-owned self-driving vehicles to operate on public roads.				
Requiring self-driving vehicles to be clearly identified to other road users.				
Requiring self-driving vehicles to travel slower than human-operated vehicles.				
Requiring self-driving vehicles to have a person in the driver's seat who can take control in an emergency.				
Preventing self-driving vehicles from entering pedestrian priority areas, such as near schools.				

Q2.6 If you have any comments regarding self-driving vehicle policies, please provide them here.
[open text box]
Q3.1 We are investigating interactions between self-driving vehicles and pedestrians during pilot testing on public streets.

In collaboration with the Department of Electrical Engineering at UBC, several passenger vehicles were modified with self-driving equipment. The vehicles travelled on an approved test route of low-traffic city streets, and their interactions with pedestrians at several crosswalks were recorded. In compliance with federal safety requirements, a driver was present to take control of the vehicle in case of an emergency. The vehicles were not labelled as self-driving to make interactions with other road users as normal as possible.

You will be asked to evaluate pedestrian interactions with vehicles shown in a series of 8 short video clips. For comparison, half (4) of the interactions will be with regular (non-self-driving) vehicles at the same crosswalk locations.

Q4.1
You will now watch four videos of interactions between **self-driving vehicles** and crossing pedestrians during pilot testing on public streets.

Q17.2 Regarding the interaction between the crossing pedestrian and the **self-driving vehicle** shown in the video, please indicate your level of agreement with the statements below:

	Strongly disagree	Neither disagree nor agree	Strongly agree	I don't know
	-10	0	10	
The vehicle yielded to the pedestrian.				
The vehicle *should have* yielded to the pedestrian.				

The pedestrian felt comfortable in this crossing.	
The risk of injury for the pedestrian in this crossing was low.	

Q17.3 Please provide comments if you wish to clarify your rating, or describe any confusion/difficulty you had with rating this video
[open text box]

Q9.1
You will now watch four videos of interactions between **regular vehicles** (NOT self-driving vehicles) and crossing pedestrians.
Q21.2 Regarding the interaction between the crossing pedestrian and the **regular vehicle** shown in the video, please indicate your level of agreement with the statements below:

	Strongly disagree	Neither disagree nor agree	Strongly agree	I don't know
	-10	0	10	
The driver yielded to the pedestrian.				
The driver *should have* yielded to the pedestrian.				
The pedestrian felt comfortable in this crossing.				
The risk of injury for the pedestrian in this crossing was low.				

Q21.3 Please provide comments if you wish to clarify your rating, or describe any confusion/difficulty you had with rating this video
[open text box]

Q22.1 On this last page of survey, please answer the following questions about yourself

Q22.2 What is your age?

- <16
- 16-19
- 20-29
- 30-39
- 40-49

- 50-59
- 60-69
- 70-79
- 80+
- Prefer not to answer

Q22.3 What is your current gender?

(<u>select all that apply</u>)

- Man
- Non-binary
- Not listed (*please specify*) ____
- Woman
- Prefer not to answer

Q22.4 Which of the following census categories best describes you?

(*<u>select all that apply</u>*)

- Métis, First Nations, or Indigenous
- White
- Asian (East, West, or South)
- Other (*please specify*) ____
- Black
- Latin American

☐ Arab

☐ Prefer not to answer

Q22.5 What is the highest level of education you have completed?

○ Some high school or less

○ Completed high school/ equivalency

○ College/ University certificate or diploma

○ Bachelor’s degree

○ Graduate degree (master’s degree or doctorate)

○ Prefer not to answer

Q22.6 What is your gross annual household income? (in CAD)

○ under $24,999

○ $25,000 to $49,999

○ $50,000 to $74,999

○ $75,000 to $99,999

○ $100,000 to $149,999

○ $150,000 and above

○ Prefer not to answer

Q22.7 What are the first 3 digits of your home postal code? (or other location identifier, if you prefer)

____

Q22.8 How often do you use the following modes to travel?

(<u>consider your travel **without** any COVID-related risks or social distancing restrictions</u>)

(<u>*select one in each row*</u>)

	Never	Once a month or less	Several times a month	Several times a week	Almost every day
Walk or use a wheelchair/mobility device	○	○	○	○	○
Bicycle, scooter, or skate	○	○	○	○	○
Public transit (bus, rail, ferry, etc.)	○	○	○	○	○
Driver of a car, truck, van, or motorcycle	○	○	○	○	○
Passenger in a car, truck, van, or motorcycle	○	○	○	○	○

Q22.9
Please indicate your level of agreement with the statements below:

	Strongly disagree	Neither agree nor disagree	Strongly agree	I don't know
	-10	**0**	**10**	
I am comfortable taking risks.				
I tend to embrace technology before most other people do.				

Q23.1 In your opinion, did the self-driving vehicles behave differently than the regular vehicles in the videos you watched?

○ Yes

○ No

Q23.3 Adjust the scales below to indicate the differences you observed between self-driving vehicles and regular vehicles in the videos.

	Much less than regular vehicles	Same as regular vehicles	Much more than regular vehicles	I don't know
	-10	**0**	**10**	

Self-driving vehicle's speed	
Self-driving vehicle's aggressiveness	
Self-driving vehicle's clarity of intentions	
Self-driving vehicle's compliance with traffic rules	
Others (*Please briefly describe*)	

Q23.4 How did the self-driving vehicles in the videos compare with your expectations?

[open text box]

Q24.2 The goal of this study is to investigate different perspectives on interactions between pedestrians and self-driving vehicles on public streets. To measure this, we had to give you some false information. Because self-driving vehicles are not yet allowed to operate on any public street in British Columbia, we used videos of regular vehicles and presented them as self-driving vehicles in the survey. This deception research design was the only way to investigate perceptions of self-driving vehicles in a real-world setting in BC. We apologize for any inconvenience caused and expect that the findings from this study will provide important insights for policymakers to provide a safe and comfortable introduction of self-driving vehicles in our transportation system.

To use your responses, we need to know that the survey deception was successful. Please answer the following question.

I believed that the videos in the survey showed self-driving vehicles when I responded to the questions above.

○ Agree

○ Disagree

Q24.3 If you have any comments, please provide them here.

[open text box]

Q24.4 Now that you understand the true nature of this study, we need your consent again to use the data you provided. Please consider clicking "I agree" below. Your responses will remain confidential, and any identifying information will be removed before the results are presented. You may also refuse the use of the data you provided by clicking on "I disagree" below.

Because this experiment is ongoing, we request that you not share our study's deception research design with others who might participate.

Click on "I agree" below to allow the use of your data from this survey for our research.

○ I agree

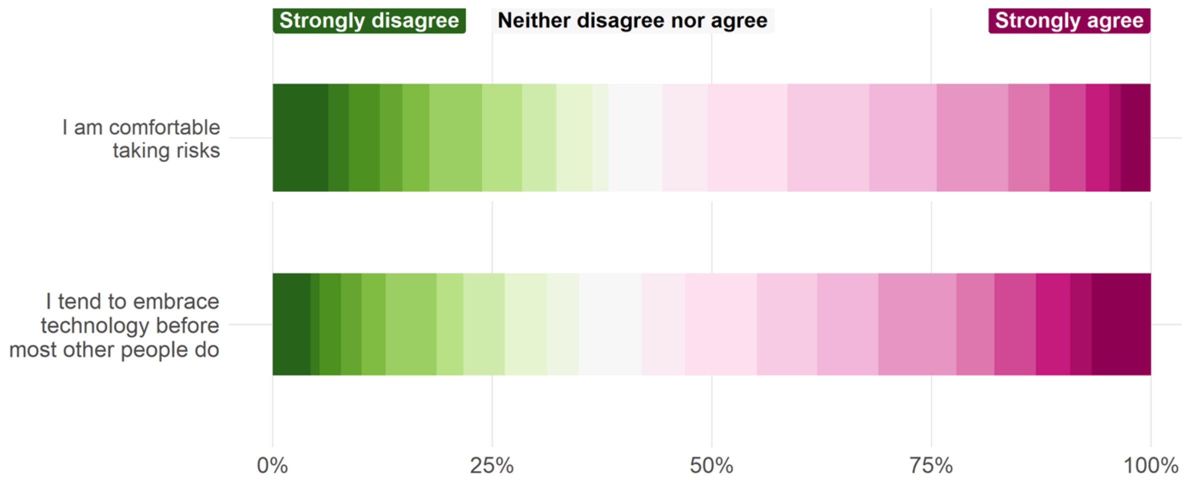
○ I disagree

Q24.5 If you have any questions about this study, please contact Dr. Alex Bigazzi at alex.bigazzi@ubc.ca or 604-822-4426. If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or email RSIL@ors.ubc.ca or call toll free at 1-877-822-8598 (ethics ID: H21-02214).

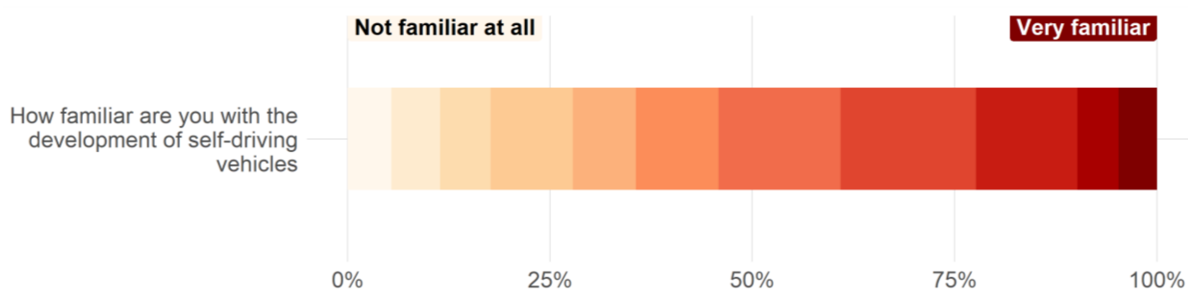
Q25.1 Thank you for participating. The survey is now complete.

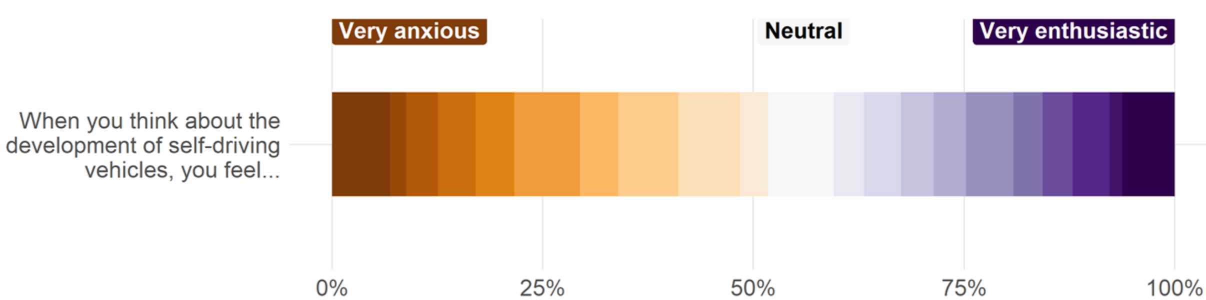
10. APPENDIX: RESPONSES TO SURVEY QUESTIONNAIRE

10.1 Other personal attributes



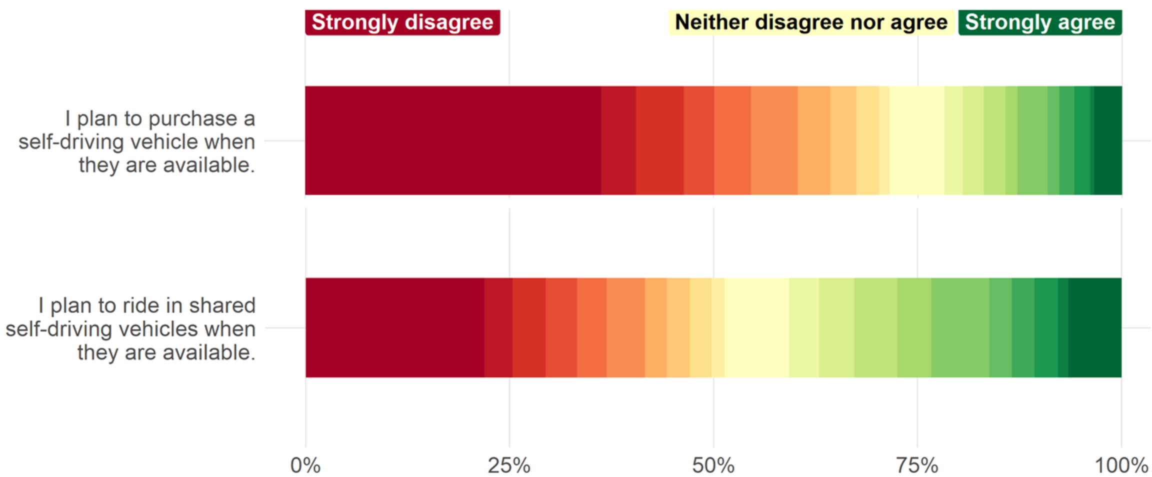
10.2 Attitude towards SDVs





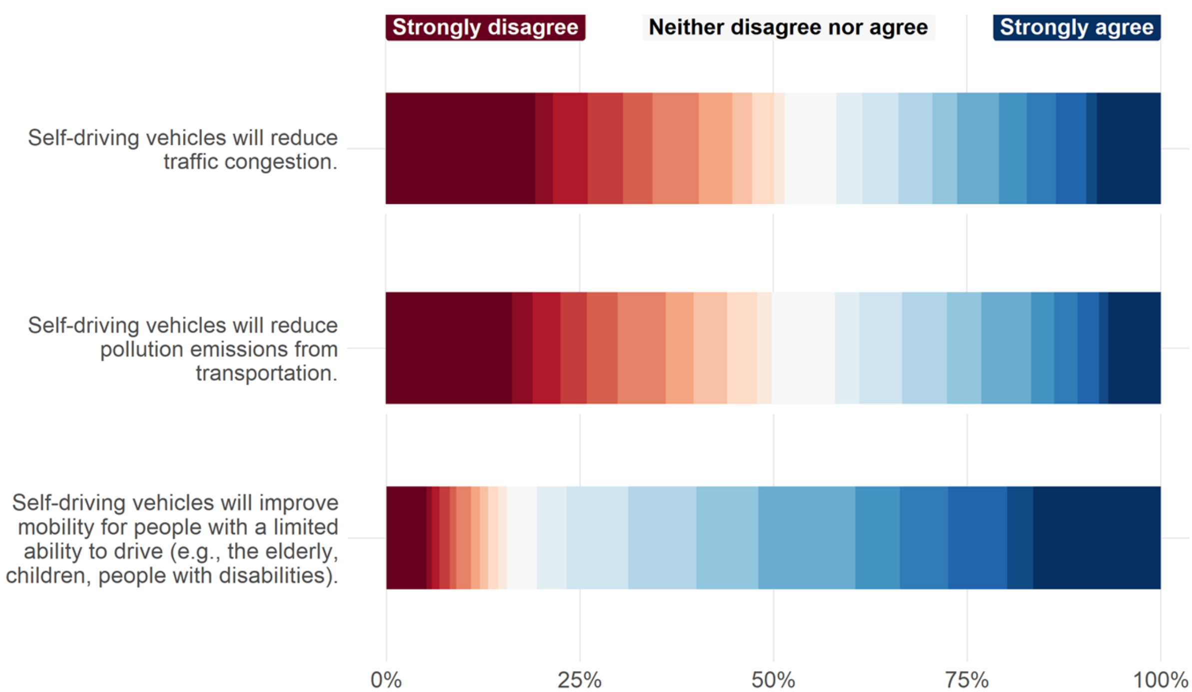
10.3 Intention to purchase or ride SDVs

40% participants agree they plan to ride shared SDVs but only 20% agree to purchasing a SDV.



10.4 Perceived benefits of SDVs

Around 80% of participants agree that SDVs will improve mobility but only 40% agree that SDVs will reduce congestion and pollution emissions. Around 23% of the participants selected "I don't know" (not shown in the figure) for congestion and emissions compared to only 8% for mobility benefits, indicating more participants have a clear opinion about mobility benefits compared to the other two benefits.



10.5 Interaction ratings

The survey also collected data from the pedestrian-vehicle interaction videos where the participants rated the yielding of the vehicle and the safety and comfort of the pedestrians. Since these videos were part of the deception-based experiment, participant ratings were divided based on whether the vehicle in the interaction video was described as an SDV or HDV when shown that video to a participant. As illustrated in Figure 24, the aggregate ratings between pedestrian-SDV and pedestrian-HDV interactions differ, but only slightly; fewer participants agreed that SDVs yielded adequately, or the pedestrian was comfortable or safe in the crossing.

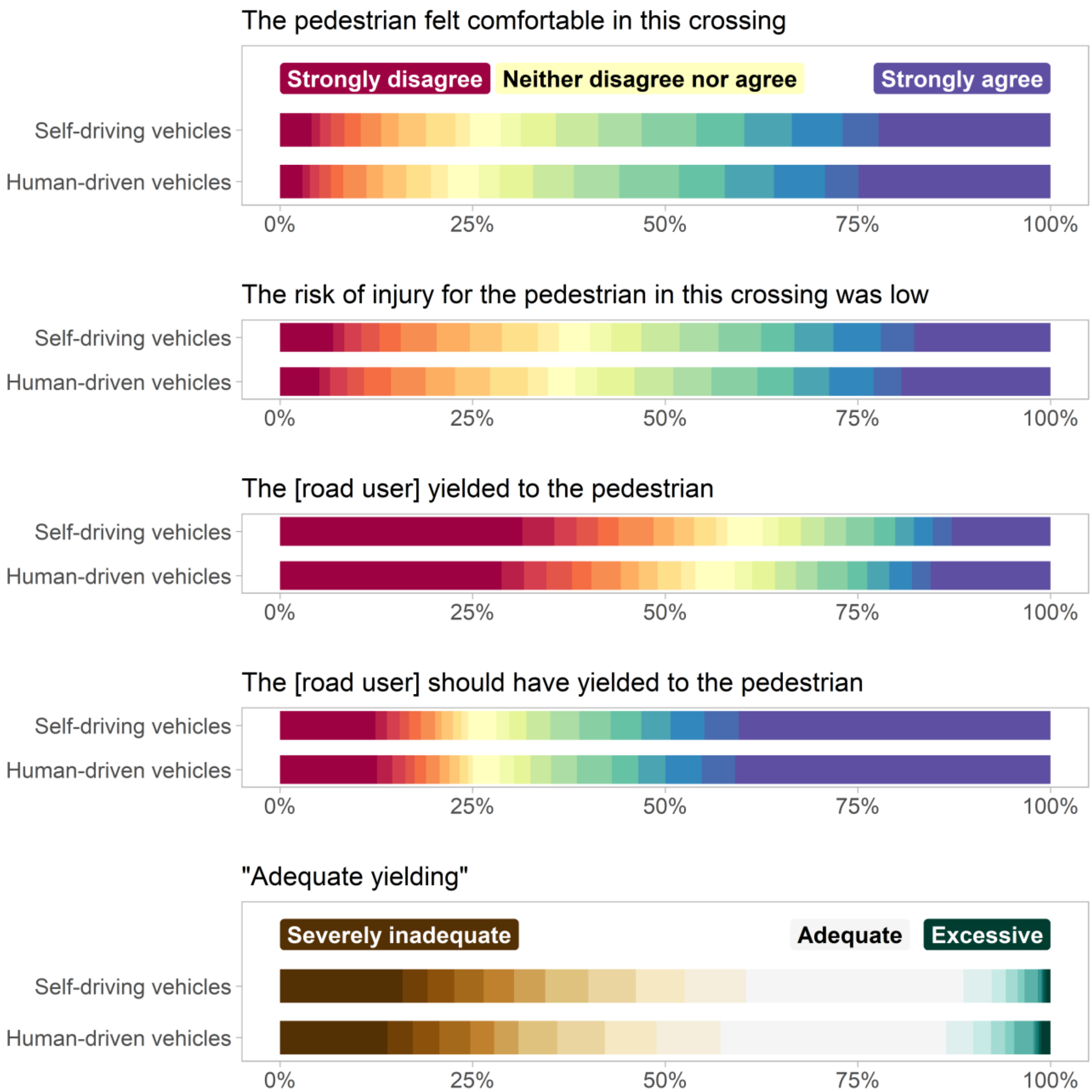
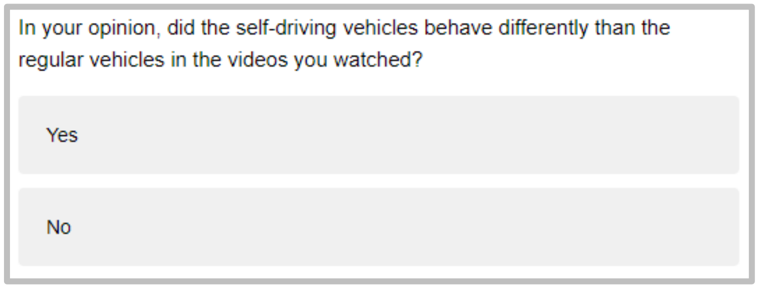


Figure 24. Distribution of interaction ratings for SDV and HDV videos

10.6 “Soft” questions to infer participant deception

After the deception-based experiment, the survey had a few subtle “soft” questions that allowed us to infer if a participant was deceived or not. The question below asks the participants if they observed any differences between SDVs and HDVs.

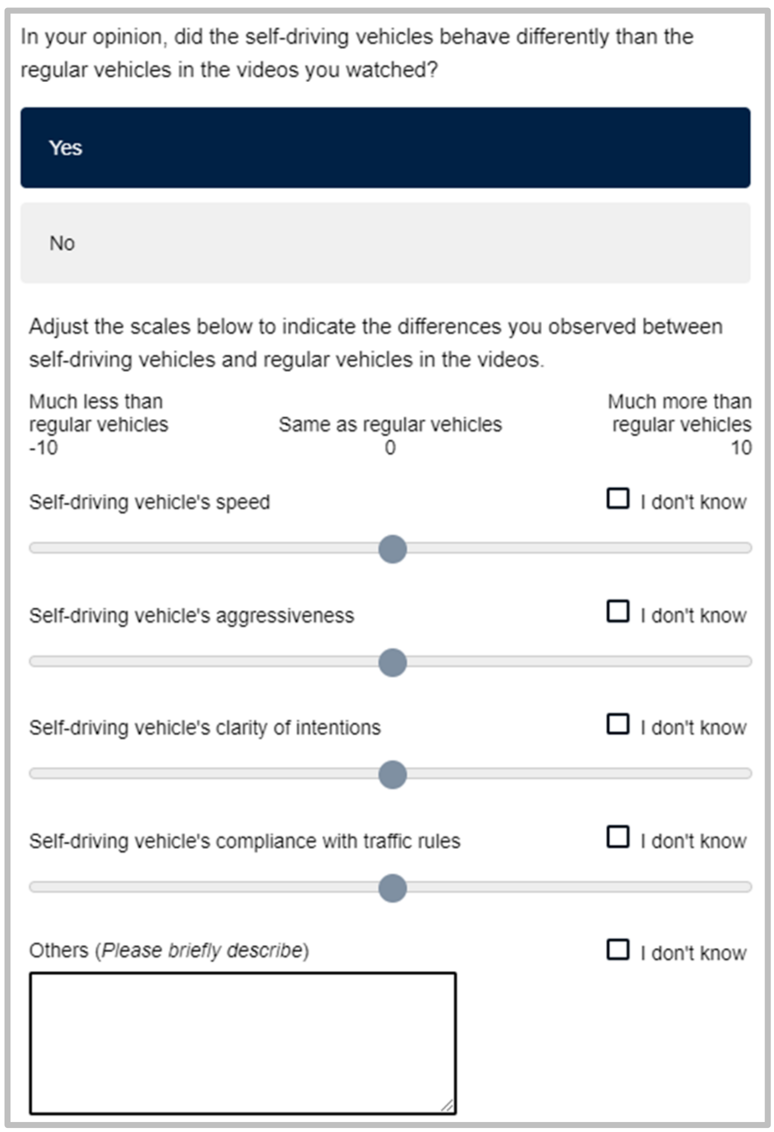


In your opinion, did the self-driving vehicles behave differently than the regular vehicles in the videos you watched?

Yes

No

Out of 1133 participants, 788 (70%) replied “Yes”. Those participants were shown the following follow-up question to specify the type and extent of behavioural differences they observed between SDVs and HDVs:



In your opinion, did the self-driving vehicles behave differently than the regular vehicles in the videos you watched?

Yes

No

Adjust the scales below to indicate the differences you observed between self-driving vehicles and regular vehicles in the videos.

Much less than regular vehicles -10 | Same as regular vehicles 0 | Much more than regular vehicles 10

Self-driving vehicle's speed — I don't know

Self-driving vehicle's aggressiveness — I don't know

Self-driving vehicle's clarity of intentions — I don't know

Self-driving vehicle's compliance with traffic rules — I don't know

Others (*Please briefly describe*) — I don't know

The distribution of responses is illustrated in Figure 25.

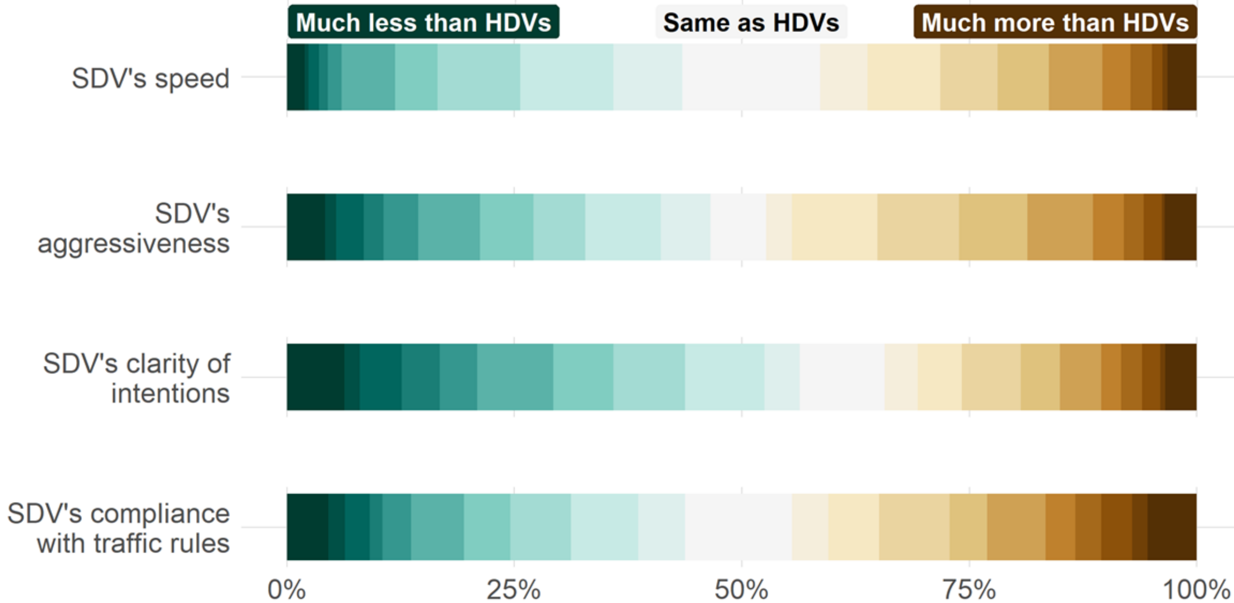
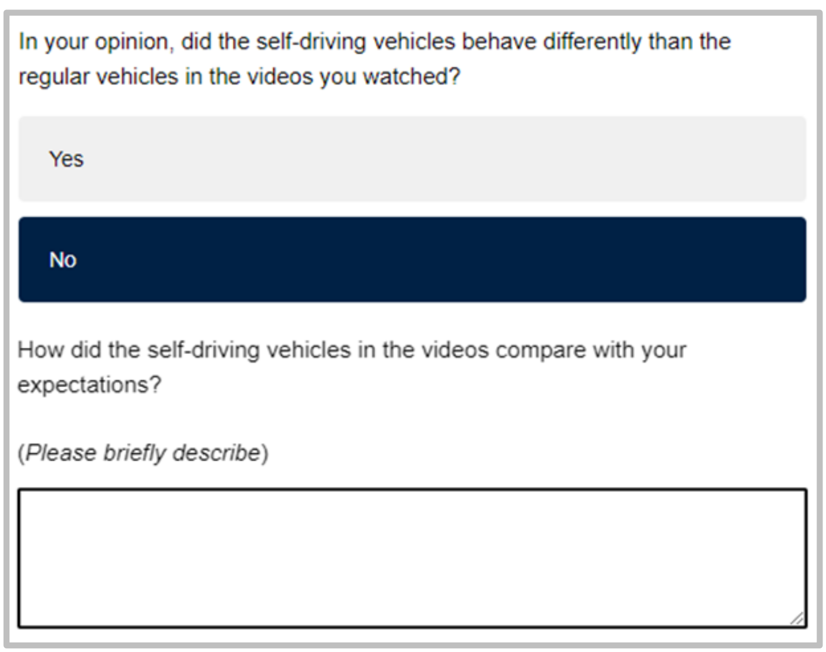


Figure 25. Distribution of responses to "soft" question

If a participant replied "No", they were shown a follow-up question, given below:



10.7 Comments after deception reveal

After the deception-based experiment was revealed to the participants, we provided an open text box with a prompt: "If you have any comments, please provide them here". Out of 1031 participants, 279 provided comments.

Many participants gave insights into why they were deceived but a few participants also mentioned other SDV-related things. We identified a few topics by summarizing those comments, given below:

Topics	Description
Trust in authority	Many participants seem to have believed the deception because of authority bias: they trusted UBC researchers to have actually used self-driving vehicles because those researchers said so in the survey. A few of those participants seem to be aware of the limitations of AV technology or restrictions on their operations, yet still believed deception because of authority bias.
Behaviour of SDVs	Many participants "observed" (perceived) SDVs to behave differently than HDVs. They "observed" SDVs to be more aggressive and travelling at a higher speed than HDVs. A few participants found our SDVs to meet their expectations of how SDVs operate.
Appreciated the study design	Many participants gave positive comments even though they may have felt embarrassed to fall for the deception.
Doubted the study design	Very few participants (4) doubted the study design: they thought we purposely selected videos for SDVs that either favoured SDVs or showed SDVs in poor light.
Automation capability	A few participants wondered about the capabilities of SDVs in environments different from the ones shown in our videos (e.g., different weather conditions, interactions with pedestrians during turning movements of SDVs, interactions with pets, children, or pedestrians using mobility-assisted devices).

11. APPENDIX: DECEPTION EFFECTIVENESS

The success of this study relied on the effectiveness of the deception-based experiment; if participants were not deceived into believing that the SDVs shown in the videos were actually SDVs then we could not have measured the Autonomy Bias or measured it inaccurately. To assess the effectiveness of deception, we included two questions in the survey: a direct question asking participants if they were deceived and a subtle "soft" question to infer if a participant was deceived. Both these questions are described in the following sections.

11.1 Directly asking participants if they were deceived

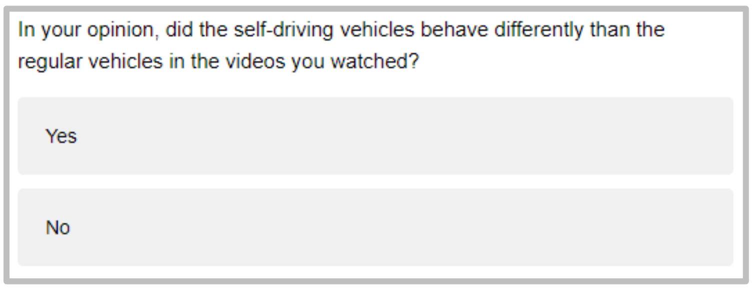
In accordance with the guidelines of BREB, the participants were informed about the deception after watching and rating the interaction videos in the survey. Participants were then asked directly if they believed the videos in the survey showed actual SDVs. The prompts in the survey about revealing deception and inquiring about the success of deception are given below:

> The goal of this study is to investigate different perspectives on interactions between pedestrians and self-driving vehicles on public streets. To measure this, we had to give you some false information. Because self-driving vehicles are not yet allowed to operate on any public street in British Columbia, we used videos of regular vehicles and presented them as self-driving vehicles in the survey. This deception research design was the only way to investigate perceptions of self-driving vehicles in a real-world setting in BC. We apologize for any inconvenience caused and expect that the findings from this study will provide important insights for policymakers to provide a safe and comfortable introduction of self-driving vehicles in our transportation system.
>
> To use your responses, we need to know that the survey deception was successful. Please answer the following question.
>
> *I believed that the videos in the survey showed self-driving vehicles when I responded to the questions above.*
>
> Agree
>
> Disagree
>
> If you have any comments, please provide them here.

As described earlier (see section Participants), we had 1557 raw responses (participants who gave consent) and got a final sample of 1133 after filtering (declined or missing re-consent, participant outside BC, low timing of responses on video pages). Out of those 1133 participants, 102 reported NOT being deceived to the direct question after learning about the deception-based experiment.

11.2 Subtly asking participants if they were deceived

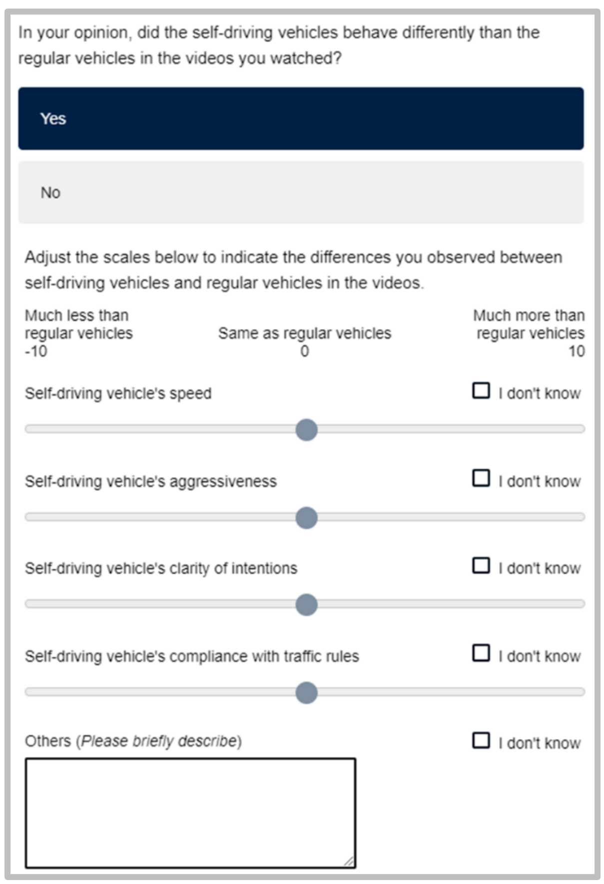
We presumed a few participants might not be forthcoming about being deceived when asked directly after learning about the deception. Therefore, after showing the interaction videos but before revealing the deception, we had a few subtle "soft" questions that allowed us to infer if a participant was deceived or not. The question below asks the participants if they observed any difference in the behaviour of SDVs and HDVs.


In your opinion, did the self-driving vehicles behave differently than the regular vehicles in the videos you watched?

Yes

No

If a participant replied "Yes", they were shown a follow-up question to specify the type and extent of behavioural differences they observed between SDVs and HDVs:


In your opinion, did the self-driving vehicles behave differently than the regular vehicles in the videos you watched?

Yes

No

Adjust the scales below to indicate the differences you observed between self-driving vehicles and regular vehicles in the videos.

Much less than regular vehicles -10

Same as regular vehicles 0

Much more than regular vehicles 10

Self-driving vehicle's speed — I don't know

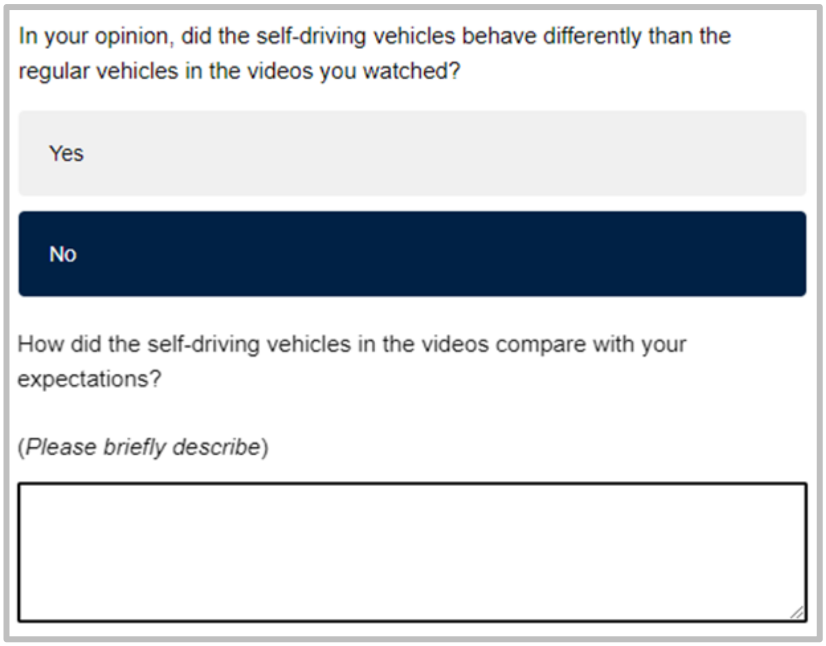
Self-driving vehicle's aggressiveness — I don't know

Self-driving vehicle's clarity of intentions — I don't know

Self-driving vehicle's compliance with traffic rules — I don't know

Others (*Please briefly describe*) — I don't know

If a participant replied “No”, they were shown a follow-up question, given below:


In your opinion, did the self-driving vehicles behave differently than the regular vehicles in the videos you watched?

Yes

No

How did the self-driving vehicles in the videos compare with your expectations?

(*Please briefly describe*)

Recall that 102 participants reported NOT being deceived to the direct question. To determine if those 102 participants were indeed not deceived, we investigated their responses to the “soft” questions. Out of 102 participants, 60 reported observing behavioural differences between SDVs and HDVs (i.e., they reported “Yes” to the first “soft” question) while 42 reported not observing any differences (i.e., they reported “Yes” to the first “soft” question). We considered all those 60 participants to be deceived because either they reported observing differences between SDVs and HDVs for at least two out of four specific behavioural prompts, or they provided comments about the differences they observed between SDVs and HDVs. The data from these 60 participants were included in the statistical analyses. Regarding the other 42 participants who reported not observing any behavioural differences between SDVs and HDVs, 8 participants provided comments indicating that they were not deceived. The other 34 participants did not provide any indication in the “soft” question about being deceived or not deceived, so we had to rely on their reporting of the direct question and consider them as not deceived.

To summarize, the filtered sample contained 1133 participants but 102 of them reported not being deceived. After investigating the responses of those 102 participants to the “soft” questions, we determined only 42 out of 102 were indeed not deceived. The data from those 42 participants were not included in the statistical analyses. Our final sample contained 1091 participants, who we believe were deceived.

11.3 Why were participants deceived?

Themes	Description
Trust in authority	• Many participants simply trusted us (UBC researchers) to have actually used self-driving vehicles. • A few such participants were aware of the limitations of SDV technology, yet still believed the deception because of trust.
Behaviour of SDVs	• Many participants "observed" (perceived) SDVs to be more aggressive, travelling at a higher speed than non-SDVs. • A few participants found our SDVs to meet their expectations of how SDVs operate.

11.4 Why were the participants not deceived?

Themes	Description
“SDVs” did not look like SDVs	A few participants were expecting our SDVs to be equipped with visible external features (Lidar, cameras, etc.)
“SDVs” did not behave like SDVs	Our SDVs did not comply with traffic rules, yielded inadequately, and drove aggressively.
SDVs not allowed in BC	A few participants knew SDVs were not allowed on BC roads

12. APPENDIX: SURVEY DATA PROCESSING

12.1 Missing data

Data for all personal attributes were not available (as illustrated in Figure 26) for all participants because a few participants selected "Prefer not to answer". Income, emissions, and congestion were the variables missing substantial observations (20% of the sample), so they were excluded from the analysis.

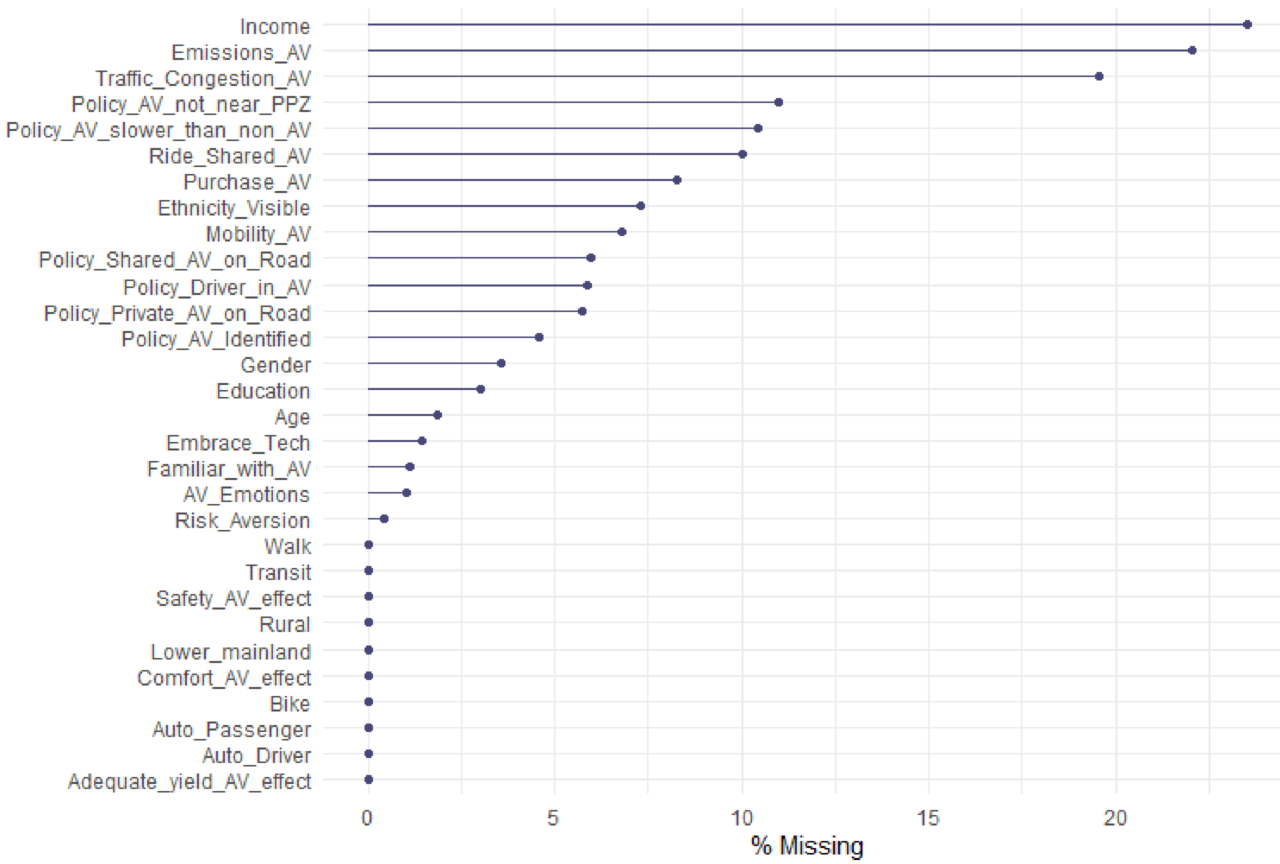


Figure 26. Extent of missing data in the sample

12.2 Correlation analysis

Before model development, we conducted a correlation analysis of all variables, as illustrated in Figure 27. If two independent variables had a coefficient of more than 0.6 then one of those variables was dropped from the model specification.

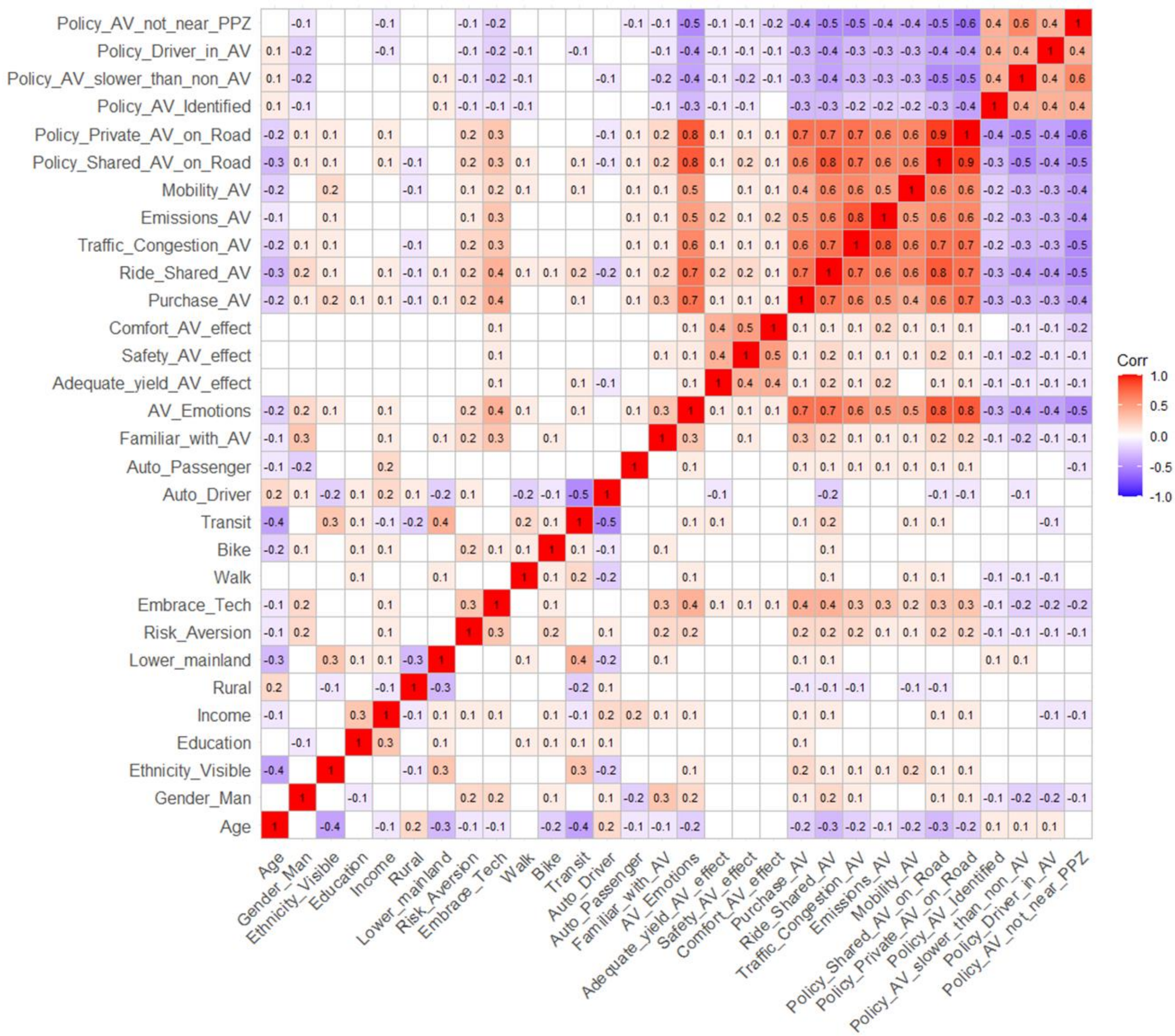


Figure 27. Pearson correlation coefficient between variables (blank cells represent the correlation is not significant at p<0.05)

13. APPENDIX: RQ1

The analysis framework illustrated in Figure 28 was used to extract the three indicators of Autonomy Bias for each participant.

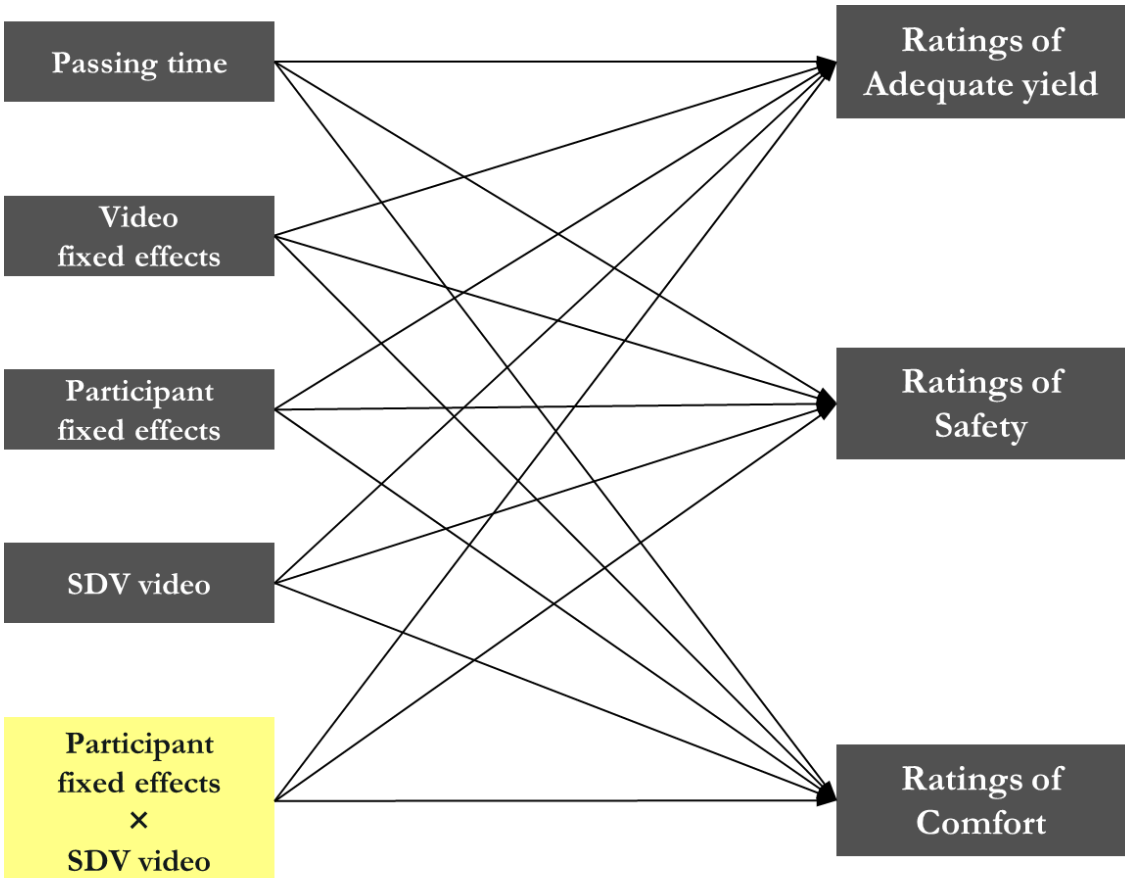


Figure 28. Analysis framework to extract indicators of Autonomy Bias for each participant

TABLE 3. Estimates from the model specified in Figure 30

Parameter estimates:	Coefficients	Standard error	p-value
Ratings of Adequate yield ~			
PET	1.40	0.08	<0.01
Participant fixed effect * SDV video (i.e., participant's indicator of Autonomy Bias) – mean (SD)	-0.35 (2.71)	2.42 (0.64)	0.48 (0.31)
Video fixed effects – mean (SD)	1.24 (0.15)	NA	NA
Participant fixed effects – mean (SD)	-0.12 (2.35)	NA	NA
Ratings of Safety ~			
PET	1.75	0.12	<0.01
Participant fixed effect * SDV video (i.e., participant's indicator of Autonomy Bias) – mean (SD)	-0.20 (4.24)	3.65 (0.96)	0.45 (0.30)
Video fixed effects – mean (SD)	1.30 (0.22)	NA	NA
Participant fixed effects – mean (SD)	-0.26 (3.54)	NA	NA
Ratings of Comfort ~			
PET	1.12	0.10	<0.01
Participant fixed effect * SDV video (i.e., participant's indicator of Autonomy Bias) – mean (SD)	-0.45 (3.84)	3.16 (0.83)	0.47 (0.32)
Video fixed effects – mean (SD)	0.37 (0.19)	NA	NA
Participant fixed effects – mean (SD)	0.24 (3.06)	NA	NA

Notes: (1) For brevity, only mean values of video fixed effects, participant fixed effects, and the interaction term are shown in the table; (2) The proportion of participants whose indicators of Autonomy Bias were significantly different ($p<0.05$) from zero were: 10.6% for adequate yield, 10.8% for safety, and 13.5% for comfort; (3) SD: standard deviation.

The ratio of coefficients (interaction term/PET) allows us to express the coefficients of the three indicators of Autonomy Bias in terms of PET-equivalence.

TABLE 4. Expressing Autonomy Bias in terms of PET-equivalence

Indicators of Autonomy Bias (i.e., interaction term)	Mean coefficient	PET-equivalence (seconds)	PET-equivalence (seconds) for a 1 unit change in the indicator of Autonomy Bias
Adequate yield	-0.35	-0.25	0.71
Safety	-0.20	-0.11	0.57
Comfort	-0.45	-0.40	0.89

TABLE 5. Summary statistics of distributions of Autonomy Bias indicators (distributions are given in Figure 15)

Indicators of Autonomy Bias	15th percentile	25th percentile	Mean	Median	75th percentile	85th percentile
Adequate yield	-2.19	-1.35	-0.25	-0.18	0.92	1.62
Safety	-2.43	-1.72	-0.11	-0.13	1.43	2.30
Comfort	-3.73	-2.45	-0.40	-0.23	1.69	2.89

Note: All statistics are shown in terms of PET-equivalence (seconds).

Figure **29** illustrates a simpler specification to extract the indicators of Autonomy Bias at the population level instead of individual-level.

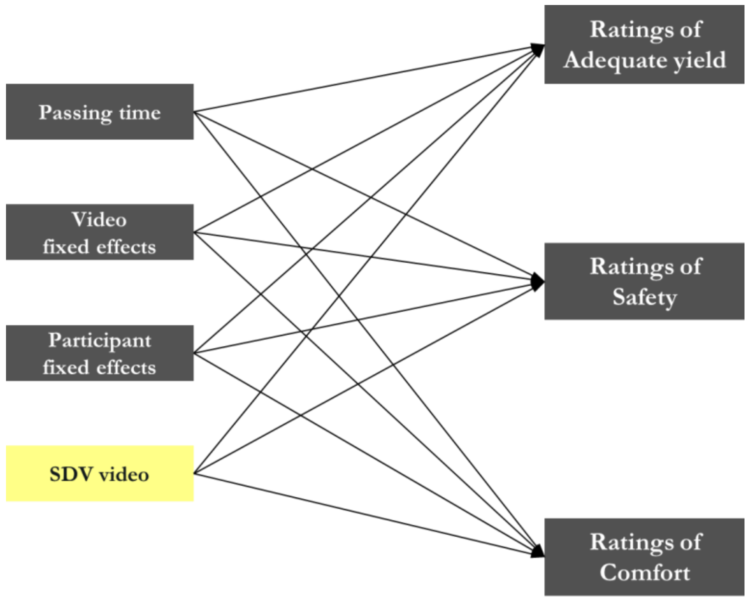


Figure 29**. Analysis framework to extract indicators of population-level Autonomy Bias**

TABLE 6. Estimates from the model specified in Figure 29

Parameter estimates:	Coefficients	Standard error	p-value
Ratings of Adequate yield ~			
PET	1.35	0.07	<0.01
SDV video (indicator of Autonomy Bias)	-0.33	0.07	<0.01
Video fixed effects – mean (SD)	1.25 (0.14)	NA	NA
Participant fixed effects – mean (SD)	-0.33 (1.73)	NA	NA
Ratings of Safety ~			
PET	1.83	0.11	<0.01
SDV video (indicator of Autonomy Bias)	-0.25	0.11	0.03
Video fixed effects – mean (SD)	1.40 (0.21)	NA	NA
Participant fixed effects – mean (SD)	1.38 (2.64)	NA	NA
Ratings of Comfort ~			
PET	1.26	0.10	<0.01
SDV video (indicator of Autonomy Bias)	-0.44	0.10	<0.01
Video fixed effects – mean (SD)	0.42 (0.18)	NA	NA
Participant fixed effects – mean (SD)	1.27 (2.30)	NA	NA

14. APPENDIX: RQ2

We wish to categorize the sample into three groups based on Autonomy Bias: negative bias, no bias, and positive bias. However, as noted in TABLE 3, only 11%-14% of the estimates for individual Autonomy Bias reached statistical significance (at $p<0.05$). The high p-values for these estimates are indicative of type II error ("false negatives") resulting from low statistical power for individual-level hypothesis tests in the multi-level model. Each participant rated only 8 videos, resulting in high standard errors for the individual-level estimates. A post-hoc power test indicates a power of around 3% for a difference of at least 0.1 second in individual Autonomy Bias estimates (i.e., a 97% Type II error rate). At 80% power (a common threshold) we would only detect significant differences (at $p<0.05$) for Autonomy Biases over 1.9 to 3.4 seconds (across different outcomes).

Given these limitations, a practical approach was adopted to identify meaningful thresholds to categorize Autonomy Bias based on equivalent passing time. Informed by past research on passing time (PET) effects on comfort and safety (*50*), and the use of 1 second PET threshold for identifying critical conflicts for safety evaluations of unsignalized intersections (*72*), we select +/- 1 second of equivalent passing time as the threshold to categorize the sample into three groups of negative bias, no bias, and positive bias. The 1-second threshold is a perceptually meaningful quantity, and 2.5 to 9.1 times larger than the mean population Autonomy Bias. Thus, we consider 1 second to be a conservative threshold, likely over-representing the "no bias" category. This threshold also aligns with the risk-based stratification of 8 videos in our experiment, for which the highest-risk stratum included interactions with passing times of 1-2 seconds. If a participant's Autonomy Bias is 1 second or more (equivalent passing time), then that participant belongs to the group of positive bias; if the Autonomy Bias is -1 second or less, then that participant belongs to the group of positive bias; and if the Autonomy Bias is between -1 to 1 second, then that participant belongs to the group of no bias.

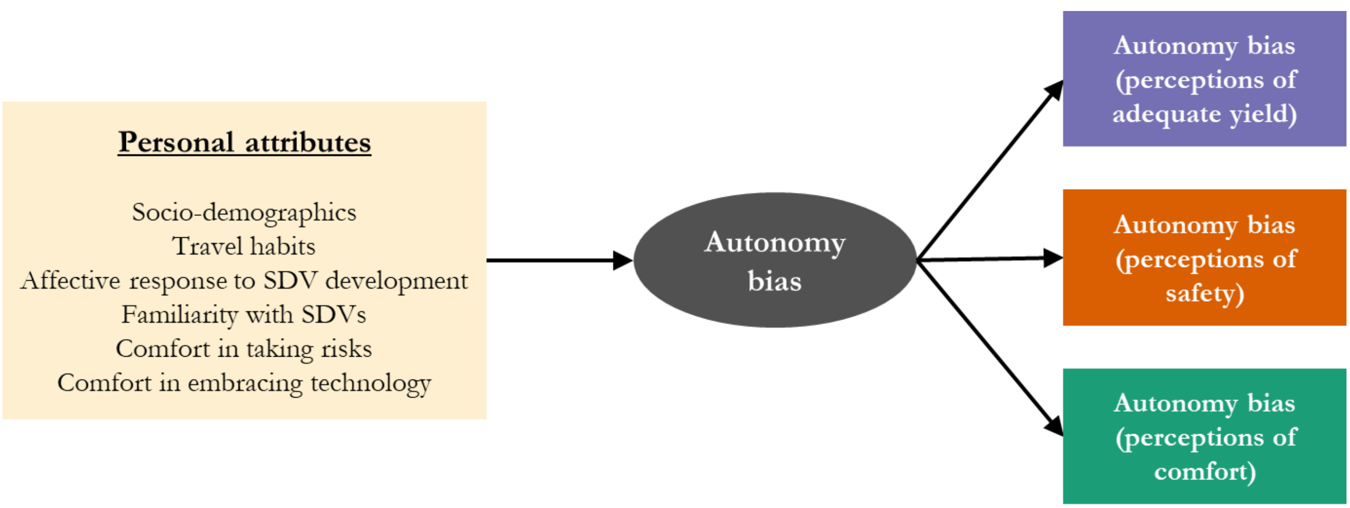


Figure 30. Analysis framework to examine determinants of Autonomy Bias

TABLE 7. Estimates from the model specified in Figure 30

Parameter estimates:	Coefficients	Standard error	p-value
Autonomy Bias ~			
Affective response (anxious to enthusiastic)	0.028	0.012	0.018
Familiarity with AV	0.033	0.027	0.217
Comfort in taking risks	0.000	0.013	0.980
Comfort in embracing technology	0.032	0.014	0.024
Age	0.021	0.043	0.626
Not a Cis-man	0.288	0.137	0.035
Person of color	-0.014	0.181	0.937
Education	-0.065	0.060	0.279
Living in a rural area	0.092	0.213	0.666
Living in lower mainland	-0.168	0.147	0.250
Walk frequency	-0.016	0.039	0.674
Bike frequency	0.049	0.056	0.383
Auto (driver) frequency	-0.069	0.051	0.173
Auto (passenger) frequency	0.008	0.061	0.894

The coefficients in TABLE 7 show the change in Autonomy Bias with a 1-unit increase in the independent variables. We can also express the results from TABLE 7 in terms of PET-equivalence. Recall (see Figure 30) that Autonomy Bias is a single latent variable with the three indicators of perceptions of adequate yield, safety, and comfort. The loadings produced by those indicators are given in TABLE 8.

TABLE 8. Loadings of indicators of Autonomy Bias

Indicators of Autonomy Bias	Loadings (i.e., change in the indicator of Autonomy Bias with 1 unit increase in Autonomy Bias)
Adequate yield	1
Safety	2.30
Comfort	1.80

The loadings indicate that a 1 unit increase in Autonomy Bias results in a 1 unit increase for the perception of adequate yield, 2.30 units for safety, and 1.80 units for comfort. Previously (see TABLE 4), we obtained the PET-equivalence for 1 unit change in each of those indicators:

TABLE 9. Loadings of indicators of Autonomy Bias expressed in terms of PET-equivalence

Indicators of Autonomy Bias (i.e., interaction term)	PET-equivalence (seconds) for a 1 unit change in the indicator of Autonomy Bias
Adequate yield	0.71
Safety	0.57
Comfort	0.89

By multiplying the indicator loadings and the corresponding PET-equivalence for 1 unit increase in the three indicators, we can obtain the effects of 1 unit change in Autonomy Bias on three indicators of Autonomy Bias in terms of PET-equivalence:

TABLE 10. Effect of a unit change in Autonomy Bias on indicators of Autonomy Bias

Indicators of Autonomy Bias	Loadings	PET-equivalence (seconds) for a 1 unit change in the indicator of Autonomy Bias	PET-equivalence (seconds) for a 1 unit change in the Autonomy Bias
Adequate yield	1	0.71	0.71
Safety	2.3	0.57	1.31
Comfort	1.8	0.89	1.61

The use of the above table could be illustrated using an example of "Not a cis-man". Not being a cis-man increases the Autonomy Bias by 0.29 (see TABLE 7). To express that increase for the three indicators of Autonomy Bias in terms of PET-equivalence, we multiply 0.29 by 0.71 (using TABLE 10) to obtain the effect of 0.21 on adequate yield, 0.29 by 1.31 to obtain the effect of 0.38 on adequate safety, and 0.29 by 1.61 to obtain the effect of 0.47 on comfort. These results, along with the other two significant variables, are illustrated in Figure 31.

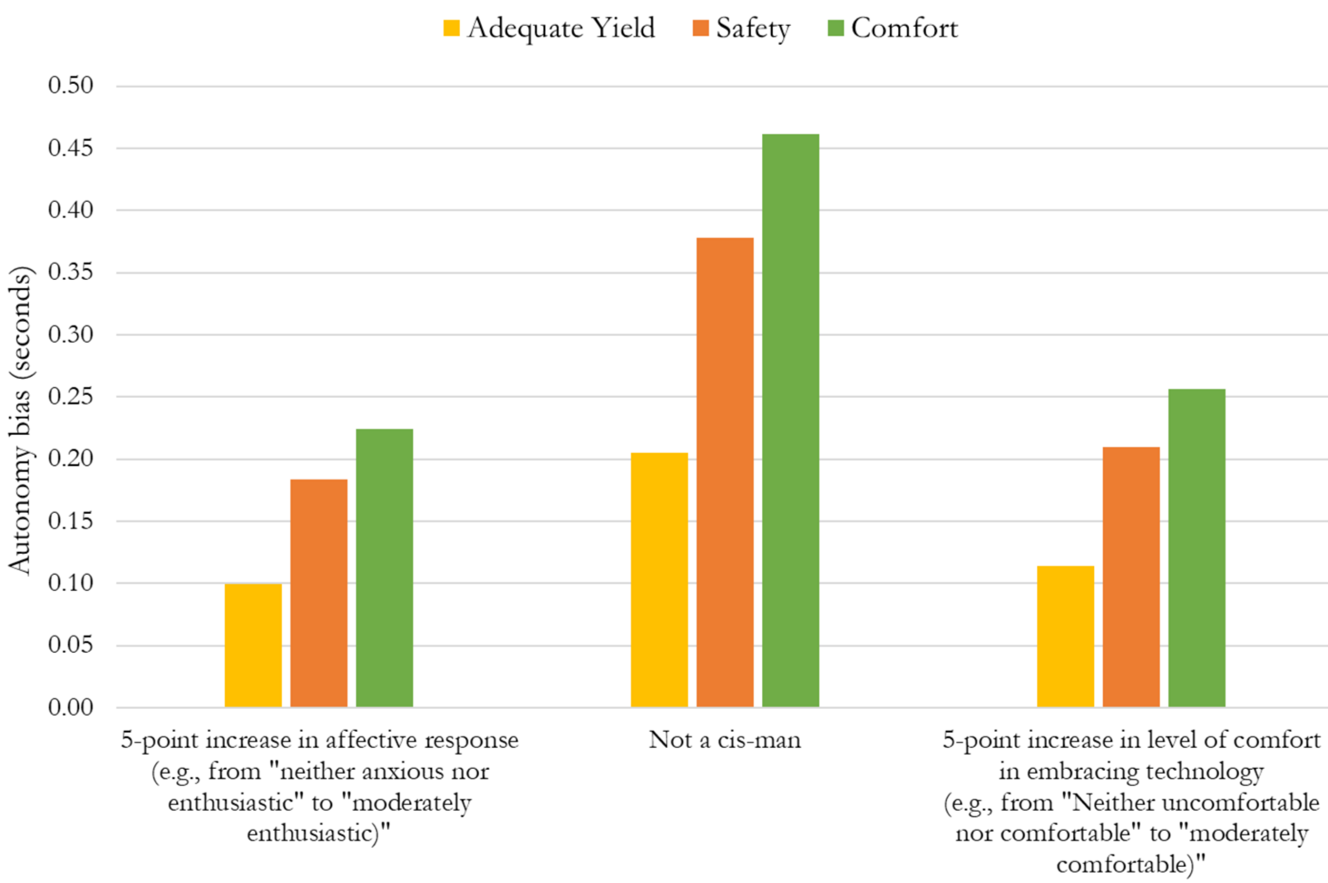


Figure 31. Determinants of Autonomy Bias

Results from the SEM model could be used to estimate the Autonomy Bias based on any personal attribute. Continuing the example of gender, Figure 32 illustrates how both an average cis-man and not a cis-man have a negative Autonomy Bias but cis-man is more negative (i.e., cis-men are *more strongly against* SDVs than non-cis-men).

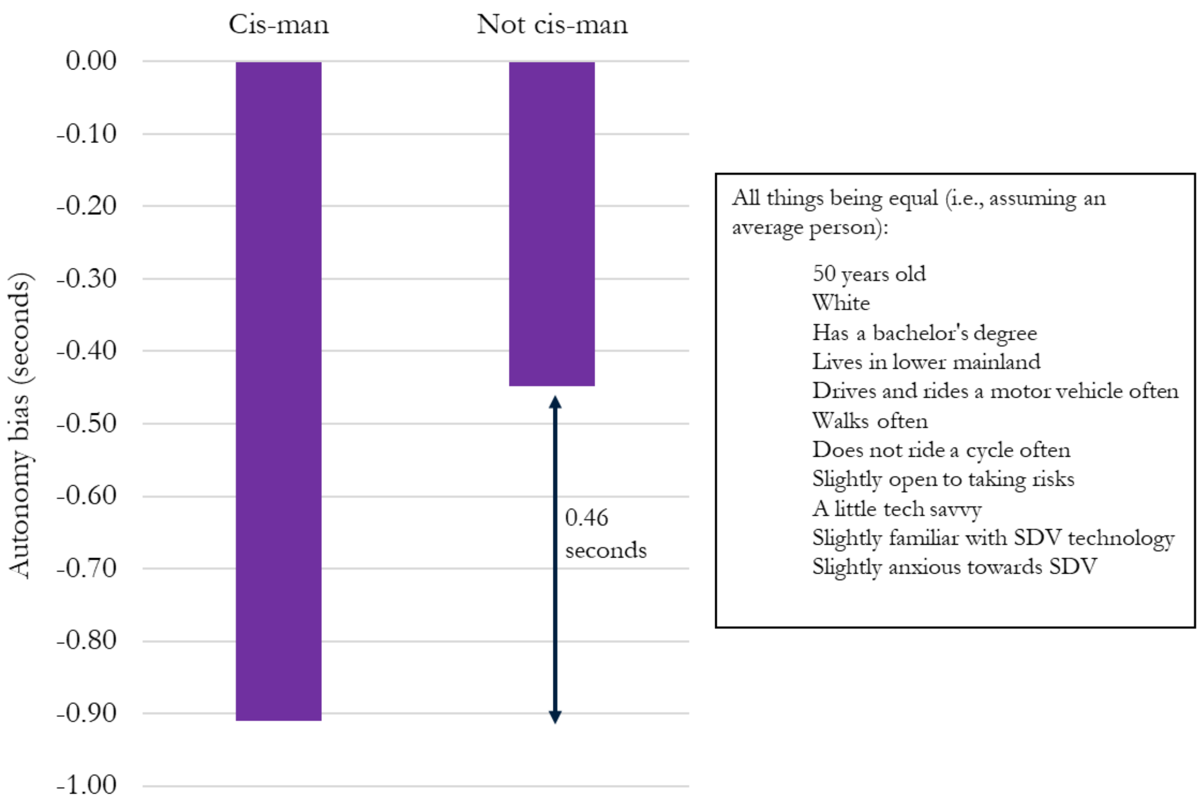


Figure 32. Estimated Autonomy Bias of a cis-man and not cis-man

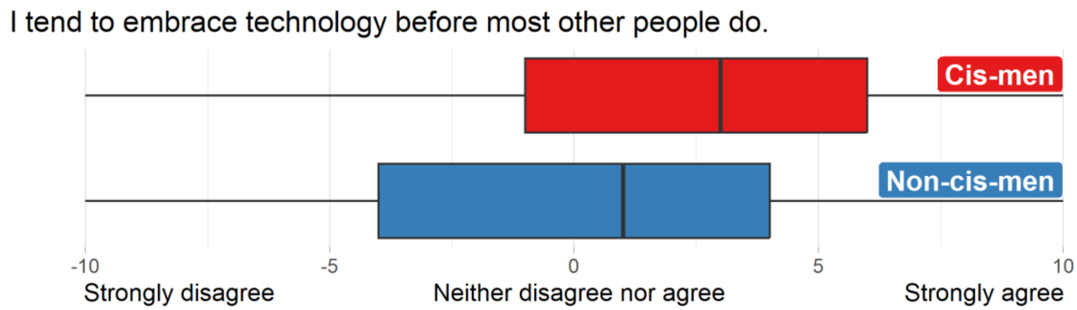
15. APPENDIX: DETERMINANTS OF AFFECTIVE RESPONSE

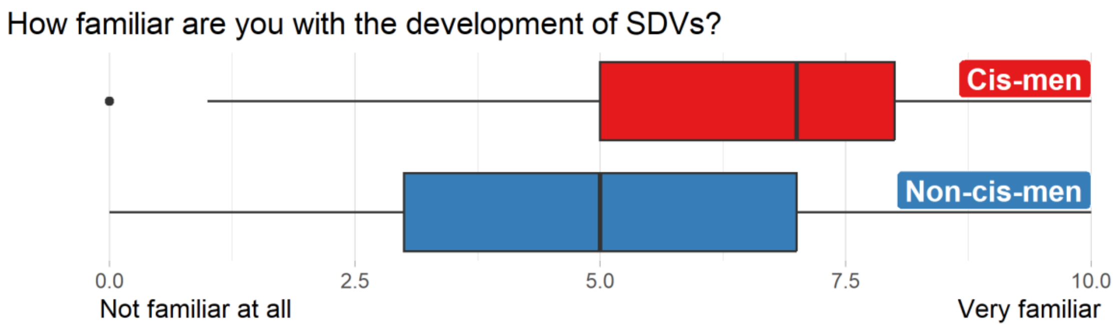
TABLE 11. Estimates from the model examining determinants of affective response

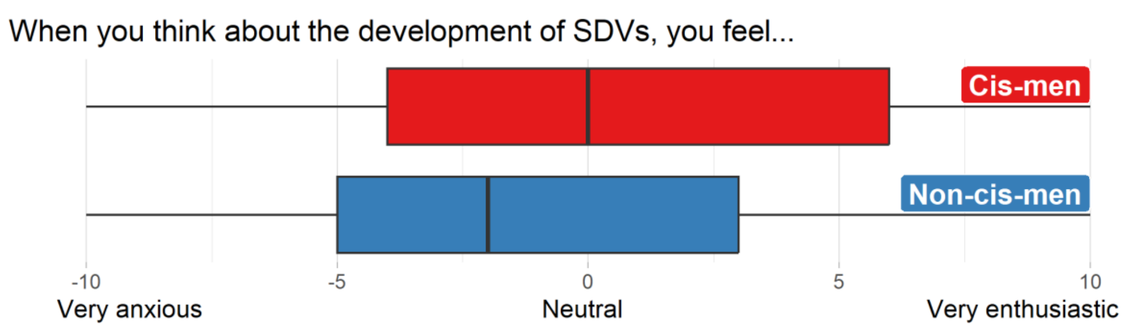
Parameter estimates:	Coefficients	Standard error	p-value
Affective response (anxious to enthusiastic) ~			
Familiarity with AV	0.349	0.084	0.000
Comfort in taking risks	0.048	0.044	0.268
Comfort in embracing technology	0.323	0.045	0.000
Age	-0.427	0.125	0.001
Not a Cis-man	-0.993	0.430	0.021
Person of color	-0.134	0.583	0.818
Education	0.150	0.185	0.418
Living in a rural area	0.395	0.722	0.584
Living in lower mainland	-0.628	0.431	0.145
Walk frequency	0.198	0.127	0.118
Bike frequency	-0.079	0.163	0.629
Auto (driver) frequency	-0.150	0.148	0.310
Auto (passenger) frequency	0.569	0.200	0.005

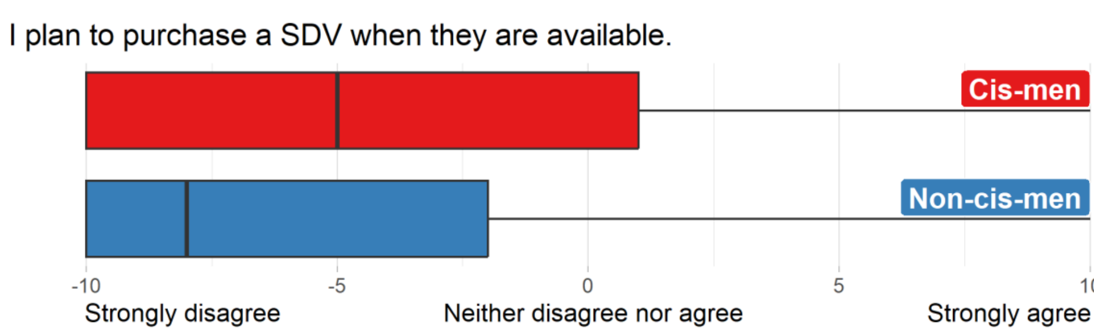
16. APPENDIX: GENDER AND ATTITUDES

On average, we observed that cis-men (vs. non-cis-men) are more open to embracing technology, more familiar with SDV development, more enthusiastic about SDV development, and more willing to purchase or ride SDVs and support SDV policies (as illustrated in the boxplots below).

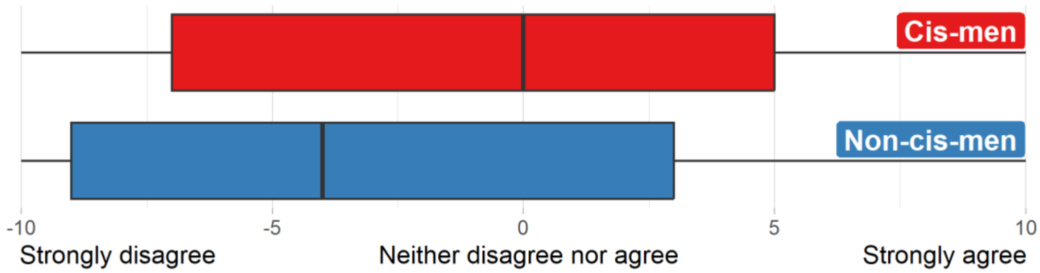






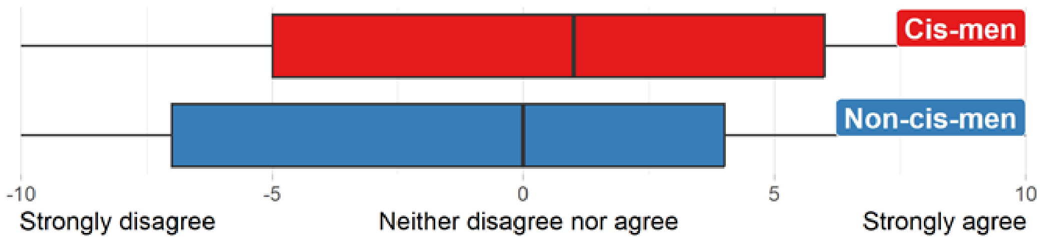


I plan to ride in shared SDVs when they are available (e.g., as a taxi or shuttle).



I support policies...

Allowing privately-owned SDVs to operate on public roads.



Allowing shared SDVs (e.g., taxis or shuttles) to operate on public roads.