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DOI
10.1016/j.trf.2022.10.021

Publication date
2023

Document Version
Final published version

Published in
Transportation Research Part F: Traffic Psychology and Behaviour

Transportation Research Part F: Psychology and Behaviour 92 (2023) 1–14

Contents lists available at ScienceDirect

Transportation Research Part F: Psychology and Behaviour

journal homepage: www.elsevier.com/locate/trf

The use of monitoring and feedback devices in driving: An assessment of acceptability and its key determinants

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ARTICLE INFO

Keywords:
Driving monitoring
Feedback
Acceptability
Questionnaire study

ABSTRACT

Recent technological advancements allow monitoring of drivers' behaviour and offer the opportunity for providing feedback. While this approach has been shown to have a positive effect on driver behaviour, whether it is accepted by drivers has not yet been extensively investigated. This questionnaire study examined the opinions of a sample of 628 Dutch drivers on the potential use of a monitoring and feedback system. The focus was on (1) whether drivers would be interested in being assessed, (2) whether data collection (i.e., monitoring) could be used for this purpose, and (3) which features the potential system must have in order to get accepted. The results showed that participants were moderately enthusiastic about the prospect of receiving monitoring feedback: on average, their opinion was between neutral and positive. Professional drivers expressed slightly more positive opinions, but no demographic variable was strongly associated with acceptability. Many drivers rated themselves as good drivers already and had low sensitivity to data collection, i.e., participants indicated being used to data collection online. If they were to use a monitoring and feedback device, participants indicated a preference for data on speed and forward-facing video footage and a preference for personalisation. The use of a monitoring and feedback system can be considered as a trade-off between sharing personal data and receiving support to improve driving skills. Based on the participants' reported online behaviour, it appears that the perceived costs associated with sharing data are small. The potential benefits of driver monitoring and feedback, however, are not salient to the participants, which may limit the use of such a system on the roads.

1. Introduction

In 2020 alone, 610 people lost their lives in traffic, 19,700 people were seriously injured, and 7.8 million traffic violations were recorded in the Netherlands, for a population of 17.4 million at the time (Statistics Netherlands, 2021; Government of the Netherlands, 2021). These issues raise the question of whether drivers drive safely and how their driving should be improved. One potential solution is the use of driver behaviour monitoring and feedback systems, a topic that has received considerable interest in transportation research and industry in the past decade, driven by recent technological developments.

The effect of driver monitoring and/or feedback on behaviour has been investigated from different angles. First, the degree of intervention differs between studies: some studies focus on monitoring without specific feedback (e.g., Wouters & Bos, 2000); others

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https://doi.org/10.1016/j.trf.2022.10.021
Received 7 April 2022; Received in revised form 24 October 2022; Accepted 24 October 2022
Available online 17 November 2022

provide real-time feedback only (e.g., De Waard, Van der Hulst, & Brookhuis, 1999; Goodrich & Quigley, 2004) or post-driving feedback instead, either web-based (e.g., Toledo et al., 2008) or through human coaches (e.g., Hickman & Hanowski, 2011; Mase et al., 2020). Second, the monitoring methods can vary. Options include video footage, speed, g-forces, lane position, GPS data to assess drivers' behaviour (see Michelaraki et al., 2021, for a review), or even physiological sensors to determine drivers' state (see Begum, 2013 for a review).

Many studies on driver monitoring and feedback show improvement in drivers' behaviour (e.g., Bell et al., 2017; Dijksterhuis et al., 2015; Farah et al., 2014). However, regardless of these promising results, the ecological validity of these studies can be questioned. An issue often identified is the decrease in engagement of drivers in the long term. Toledo and Lotan (2006) observed a decrease in targeted risky behaviours in the first three months of a monitoring and feedback intervention, but this effect disappeared and even turned into a slight increase in risky behaviours compared to the pre-intervention baseline by the fifth month. Similarly, Farmer et al. (2010) observed diminished effects of monitoring on teenage drivers by the end of their six-month intervention. These examples, among others (e.g., Beusen et al., 2009 regarding eco-driving behaviour), raise the question of engagement by future users in long-term use. While a monitoring device has an effect in an experimental setting when participants have no choice but to use it, its actual use in an operational setting is not guaranteed.

Research has shown that the use of driver feedback and assistance is dependent on the system's acceptability (Van der Laan et al., 1997). The acceptability of a product can be defined as a "prospective judgement" *before* the introduction of the said product, while acceptance refers to the "attitudes and behavioural reactions" *after* users experience the product (Schade & Schlag, 2003). As a monitoring and feedback device has not yet been introduced at a societal level in the Netherlands, the term acceptability is used in this

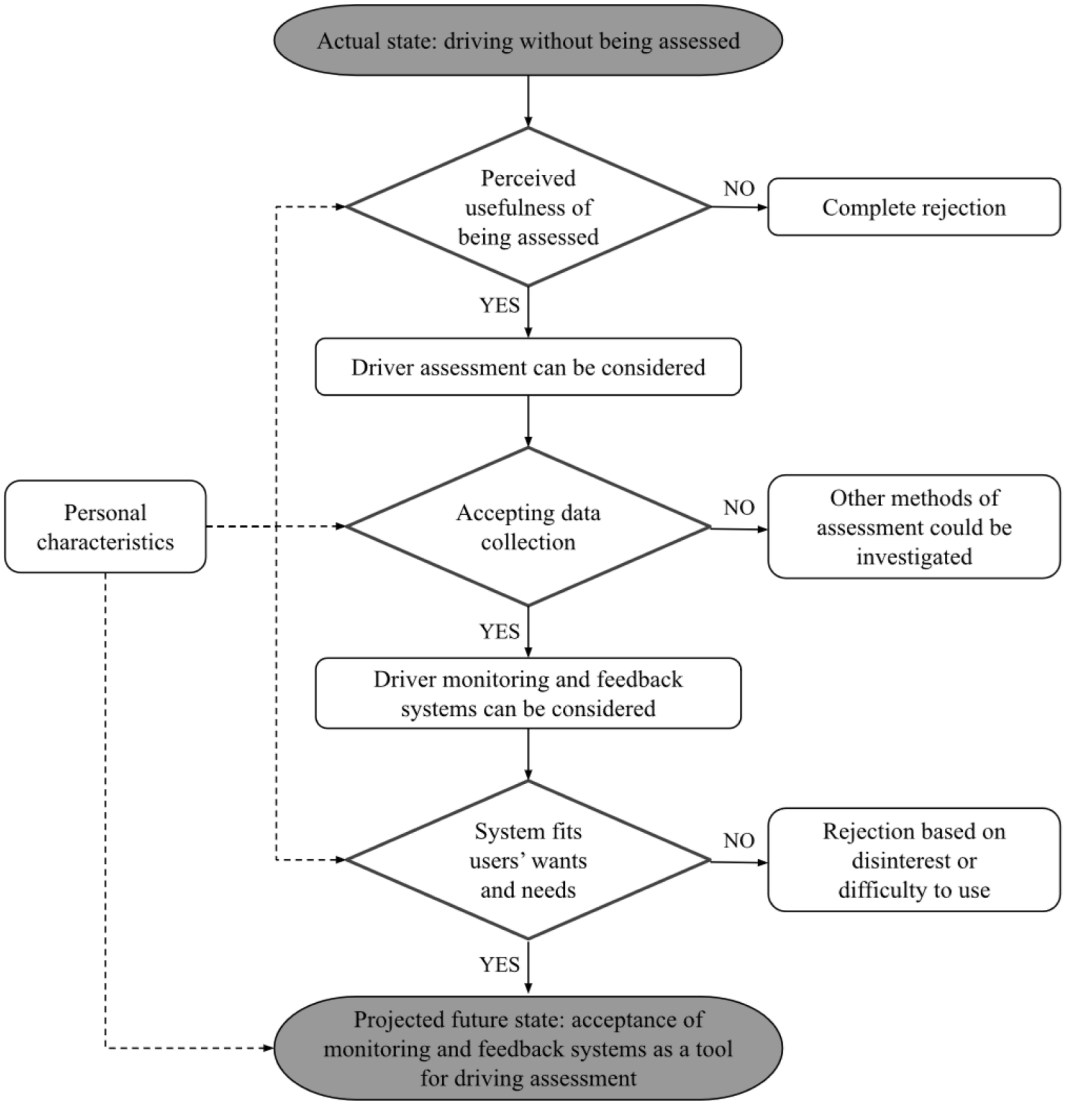

Fig. 1. Flowchart of Hypothesised Acceptability of a Driver Behaviour Monitoring and Feedback System.

paper. Indicators of acceptability abound in the literature (see Adell, Nilsson, & Várhelyi, 2014, for a presentation of measures of driver acceptance and acceptability of new technologies); therefore, more research should be directed to the factors influencing acceptability, rather than to measuring or defining acceptability. Focusing on the determinants of acceptability allows for a deeper understanding of drivers' needs and attitudes towards the device, which may subsequently result in a better-adapted product.

The acceptability of a monitoring and feedback system can be divided into three components. More specifically, we hypothesise that the system could be rejected at three different levels: the first level would concern the complete rejection of the assessment of driving behaviour, regardless of the method used. Indeed, the notion that driving can be judged and assessed is relatively uncommon outside the research field: apart from particular cases such as pay-as-you-drive insurance, drivers can drive for years or decades without their driving skills being assessed or questioned. Although the novelty of a system can spark interest in potential users and stimulate positive opinions, long-term engagement and acceptability are determined by usability (Alexandre et al., 2018) or perceived usefulness (Marangunić & Granić, 2015). The introduction of a driver assessment system could be rejected as a whole if 'being assessed' is not perceived as useful, considering that it is relatively common that change is met with resistance (Pardo Del Val & Martínez Fuentes, 2003).

The second level would be the rejection of the system based on the fact that it involves data collection: previous studies showed that there are participants who are concerned about data collection and hacking in self-driving cars (e.g., Kyriakidis, Happee, & De Winter, 2015; Schoettle & Sivak, 2014). Bloom et al. (2017) observed that 85% of their participants expressed discomfort with the idea that their vehicles were tracked, a likely scenario in the case of driving monitoring. Hence, protecting one's own privacy can be considered a personal aim, and a factor that could play a role in acceptability (see also Vlassenroot et al., 2010). If these concerns are prevalent, they could undermine the acceptability of a monitoring and feedback system.

The third and last level of potential rejection concerns the specific features of the system. The idea of assessment and data collection could be accepted, but if the end product is not attractive or easy to use, it could risk not being accepted: increasing the acceptability of any product can be done by assessing and taking into account the end-users' wants and needs (Alexandre et al., 2018; Epprecht et al., 2014). Fulfilling the needs of future users is one of the principles of user experience design (Kim et al., 2011) and is a necessary condition for acceptability.

Additionally, personal characteristics could influence acceptability and the different steps to attain it: the literature suggests, for example, that age can influence the acceptance of new technologies (Peek et al., 2014) as can gender (Venkatesh & Morris, 2000). The hypothesised process to achieve acceptability is depicted in Fig. 1.

This questionnaire study aims to provide insights into participants' acceptability level of a monitoring and feedback device and provide results that could contribute to the reflection around the introduction of such systems. Accordingly, this study's first aim is to *describe* attitudes towards monitoring and feedback devices in driving and to investigate potential predictors of personal characteristics.

To deepen the understanding of these results, this study includes three additional research questions. The first is whether drivers would perceive the idea of being assessed as useful: to address this, opinions about driving in general, about one's own driving skills, about the role of different contributors to traffic safety, and about whether an assessment would be possible and useful are investigated. The second question is whether data collection sensitivity, considered a personal characteristic, would be an obstacle to the implementation of such a system: online behaviour and the use of data-collecting applications are collected to determine one's sensitivity to data collection. As the monitoring and feedback system is still to be developed, the third and last question is *not* whether the system fits users' wishes and needs. Instead, the last question is about what practical features, system characteristics, or criteria would increase acceptability.

Finally, the predictive value of the first two steps of the model for acceptability is investigated. As mentioned above, it is not possible to investigate yet whether the system fits users' needs and thus, its predictive value on acceptability.

2. Method

2.1. Participants and recruitment

Participants were recruited by an external company, Dynata, through a diverse Dutch panel. Participants received a financial incentive for the completion of the study. In total, 809 participants were invited to participate in the study, of which 182 were excluded. Reasons for exclusion were: not consenting to participate ($n = 32$), not having a driving licence ($n = 28$), questionnaire not fully completed ($n = 99$), and responses being considered unreliable as the completion time was less than a third of the median duration (i.e., faster than 227 s) ($n = 23$). This resulted in a sample of 628 participants. The study was approved by the Ethics Committee of the Faculty of Behavioural and Social Sciences of the University of Groningen (research code: PSY-2021-S-0490).

2.2. Questionnaire content

The questionnaire was hosted on the website Qualtrics and was presented to participants in Dutch. It was structured into five sections: the first section asked for background information on the participants, including demographic information and driving behaviour. The next three sections were related to the three central questions of the study: sensitivity to data collection, perceived usefulness of being assessed, and opinions on specific features of the potential system. In the last section, participants could express their general opinion on the idea of a monitoring and feedback system and had the opportunity to leave comments to the researchers. The full questionnaire and the dataset are available in the Supplementary Material.

2.2.1. Demographics and driving behaviour

As stated earlier, personal characteristics can influence acceptability. Therefore, questions were asked regarding age, gender, type of residence environment, highest educational qualification, and employment status. Participants also indicated whether they were professional drivers and, if so, what their occupation was. Also, participants indicated the age at which they obtained their (first) driving licence, their frequency of use of different modes of transport, and their average annual mileage. Driving violations were investigated via seven violation-related items from the Driver Behaviour Questionnaire (De Winter & Dodou, 2016; based on Reason et al., 1990). Beliefs and opinions about driving were collected with three 7-point Likert items: "Driving should be fun", "I enjoy driving", and "I enjoy using ADAS (advanced driving assistance systems)", all ranging from 1, strongly disagree, to 7, strongly agree.

2.2.2. Sensitivity to data collection

The second questionnaire section aimed to assess the participants' sensitivity to data collection. This was done by investigating their online behaviour. Online behaviour can be an indicator of one's (mis)trust towards data collection and technology in general since behaviour and attitudes are linked (see, e.g., Ajzen, 1991). The points of interest were the frequency of use of six different types of applications and websites (e.g., social media, music application, travel application) and, in case participants indicated that they do not use one or more of the six items, whether the reason was privacy concerns. Two questions then aimed to investigate participants' knowledge of data collection. Participants were asked if they read the "terms and conditions" (ranging from 1, never, to 6, almost always) and if they know how much data are collected when they browse a website or application (ranging from 1, not at all, to 5, very much). Additionally, 15 types of data (e.g., name, age, number of children, online purchases, traffic violations, location history) were presented to the participants, and they were asked to rate how sensitive these types of data were according to them on a scale ranging from 1, not sensitive at all and acceptable to share, to 7 very sensitive and not acceptable to share.

For each participant, a *data collection sensitivity score* was constructed as follows: (the number of times "privacy concerns" was given as a reason to use a mobile app) $\times$ 3 + (score on reading the terms and conditions) + (score on knowing the quantity of data collected) + (sum of scores given to assess the sensitivity of certain types of data). Scores could range from 17 to 134, and the higher the score, the more sensitive the participant was to data collection.

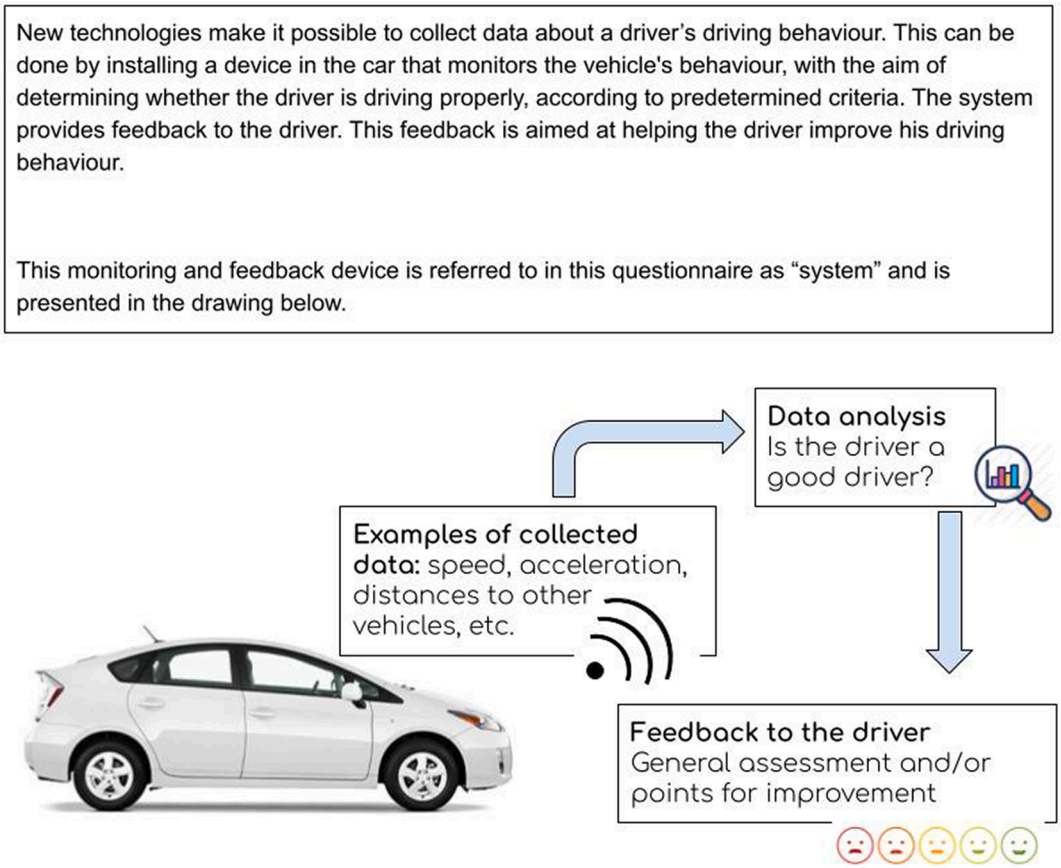

Fig. 2. Presentation of the Monitoring and Feedback System.

2.2.3. Perceived usefulness of being assessed

The participants had to indicate whether they think it is possible to determine if someone is a good driver, and unless they answered: "Absolutely not", they also had to indicate what makes a good driver. Options were "sporty driving", "driving safely", "being able to operate the car", "following the traffic rules", "being polite to other road users", "being aware of the traffic", "not getting into accidents", and "other". Participants could choose as many options as they wanted. These questions aimed to determine whether the system could achieve its objective (i.e., assessing drivers) according to the participants and what criteria should be used.

Participants' opinions on their own driving skills were assessed by creating a composite score based on three items: "I am a good driver", "The way I drive could be better", and "My driving behaviour could be improved", all ranging from 1, strongly disagree, to 7, strongly agree. The last two items were reversed, and scores of this new composite item ranged from 1, very low self-assessment, to 7, very high self-assessment. From now on, this score is referred to as the *self-assessment score*.

Additionally, participants rated the following two statements on a 7-point Likert scale ranging from 1, strongly disagree, to 7, strongly agree: "I would appreciate being assessed" and "I would appreciate receiving feedback".

Finally, the effect nine different stakeholders could have on road safety was also asked (themselves, other drivers, car manufacturers, government, police, insurance companies, research institutes and universities, driving schools, and the Dutch office of driving certification) on a slider scale ranging from 0, no effect, to 100, very strong effect.

2.2.4. Specific features of the system

The envisioned monitoring and feedback device was introduced through a brief text and corresponding picture to the participants (see Fig. 2). The illustration and description of the system were used to provide support for thought for participants but were general enough to obtain generalizable results. The information was presented to the participants in Dutch but is here translated into English.

This questionnaire section aimed to collect participants' opinions on the type of data collected by the device, the potential shareability of the data, and the form the feedback would take.

On the type of data, participants were presented with the argument that, in principle, the more data that would be collected, the more precise the feedback could be. They then had to indicate on a slider scale ranging from 0 to 100 whether they prefer as little data as possible, resulting in less precise information (0), or as much data as possible, resulting in more precise information (100). They also indicated on a 7-point Likert scale their agreement with the following two statements: "I would like to personally choose the type of data collected" and "I would like to personally choose the quantity of data collected" (ranging from 1, strongly disagree, to 7, strongly agree). Then, five data types were presented: speed, road-facing camera, driver-facing camera, GPS data, and g-forces (acceleration and deceleration). These examples were chosen because these are the data often collected in the case of driver monitoring (e.g., Driessen et al., 2021; Mase et al., 2020; McGehee et al., 2007) and are likely to be collected by the envisioned system. Participants had to provide two ratings on a scale from 0, very negative, to 100, very positive, for each type of data, contingent on the choice of sharing the data. The average of the two scores provided a general score for each data type.

On potential shareability, as mentioned above, the five examples (speed, road-facing camera, driver-facing camera, GPS data, and g-forces (acceleration and deceleration)) were presented twice. Participants had to indicate their rating on a scale that ranged from 0, very negative, to 100, very positive, once under the condition that they had the choice to share the data ("… assuming that the collected data are shared only with you and people that you choose to share the data with") and once where the choice was made for them ("… but are also shared with other stakeholders (e.g., government, insurance companies, police)").

The intention of using the monitoring and feedback device was also investigated for eight different conditions of data sharing or usage: "shared with no one", "shared with whom I choose (e.g., friends, colleagues), to be compared to and establish a ranking", "shared anonymously with researchers", "shared anonymously with authorities", "used to detect automatically if someone needs driving lessons", "used to tax drivers according to their driving behaviour (similarly to the pay-as-you-drive system)", "used to fine drivers who violate traffic rules", and for professional drivers only, "shared anonymously with my employer". The intention to use was measured with a 7-point Likert scale, ranging from 1, strongly disagree to use, to 7, strongly agree to use.

Regarding the form of feedback, two slider scales were presented, aimed at determining whether participants prefer feedback focusing on mistakes or feedback encouraging good behaviour and whether they prefer an overall score or specific items of data. Slider scales were used to emphasise the continuity aspect of these two items and allowed participants to provide a more nuanced answer. Participants were also asked to rank different forms of feedback in their order of preference: "email", "device in the car", "mobile phone application", "website", and "other". They also indicated their preferred frequency of feedback among eight options: "during the ride", "after each ride", "after a specific number of rides", "every week", "every month", "every three months", "never", and "other".

2.2.5. End of the questionnaire

The questionnaire ended with the question: "After completing this questionnaire, what is your general opinion about a monitoring and feedback system for your driving behaviour?", to which participants could answer on a 5-point Likert scale, ranging from 1, very negative, to 5, very positive. They were also given the possibility to leave comments or questions.

2.3. Data analysis

The general acceptability of a potential monitoring and feedback system was evaluated with four items: overall opinion (5-point Likert scale ranging from 1, very negative, to 5, very positive), opinion on being assessed, opinion on receiving feedback (both 7-point Likert scale ranging from 1, very negative, to 7, very positive), and intent to use (7-point Likert scale ranging from 1, strongly disagree to use, to 7, strongly agree to use). The intent-to-use score is a composite score constructed from the mean intent-to-use in the eight

sharing and usage conditions described earlier and is created to predict an intent to use regardless of the usage of the data collected. A composite score for the acceptability was also computed: to that effect, *z*-scores of the four items mentioned above were used to counteract the fact that different scales were used, and the mean was calculated for each participant. For both composite scores, reliability was assessed using Cronbach's alpha.

To investigate the predictors of acceptability, correlations between acceptability and demographic characteristics were computed. Correlation coefficients were interpreted according to Cohen's guidelines (2013), with a .10 coefficient considered as small, a .30 coefficient as moderate, and a .50 coefficient as a large effect. In addition, a regression analysis was conducted to identify predictors of acceptability.

The relationships between the first two constructs of the model presented in Fig. 1 were investigated through correlation analysis and regression analysis. For each section, relations between the acceptability composite score and the variables of interest presented earlier were investigated, as well as whether the variables of interest could be predictors of acceptability. For the first sub-theme, perceived usefulness of being assessed, the analyses were conducted between three variables (the self-assessment score, one's own effect on traffic safety and the possibility to determine a good driver) and the acceptability score. For the second sub-theme, accepting data collection, the analyses were conducted between the data collection sensitivity score and the acceptability score.

2.4. Sample description

Demographic information about the 628 respondents can be found below in Table 1. The mean age of the participants was 47.5 years ($SD = 19.6$ years), with a range of 18 to 90 years. Education levels and employment status were found to be quite similar to Dutch National statistics (Statistics Netherlands, 2018, 2022) indicating that the sample is representative of the Dutch population for these variables.

Participants' driving characteristics are listed in Table 2. The age at which they had obtained their driving licence was, on average, 20.5 years ($SD = 4.9$ years, range 16 to 72 years).

3. Results

3.1. General opinion towards a monitoring and feedback system

3.1.1. Acceptability

On a 5-point Likert scale ranging from 1, very negative, to 5, very positive, the average was 3.73 ($SD = 0.95$). Fifty-three of the 628 respondents indicated a very negative or negative opinion, representing 8.4% of the sample. The distribution of answers is shown in Fig. 3.

Participants were also asked their opinion on being assessed and on receiving feedback on 7-point Likert scales ranging from 1, very negative, to 7, very positive. These items received mean scores of 3.98 ($SD = 1.49$) and 4.00 ($SD = 1.55$), respectively.

The intention to use the system was assessed based on a composite score of eight items, each on a 7-point Likert scale ranging from 1, strongly disagree to use, to 7, strongly agree to use. The internal consistency of these eight items was found to be good, with a Cronbach's alpha of .87. The average for the composite intent-to-use score was 4.25 ($SD = 1.25$).

Using the standard scores for the four items presented in this section (i.e., general opinion, opinion on being assessed, opinion on receiving feedback, and intent to use), a composite score was also computed for each participant, corresponding to the mean of the four *z*-scores. The internal consistency of the four items was found to be acceptable, with a Cronbach's alpha of .79. The composite scores ranged from −2.36 to 1.88 (with $M = 0$, and $SD = 0.78$) and will be referred to from now on as the *acceptability score*.

3.1.2. Predictors of acceptability

The influence of predictors on acceptability was assessed using correlation analysis and multiple regression analysis. Correlations between the acceptability score and the dependent variables are shown in Table 3. For binary variables, the reported correlation is the so-called point-biserial correlation coefficient (Kornbrot, 2014).

Four variables appear to have the strongest and most significant correlations: higher acceptability is associated with higher

Table 1
Summary of Sociodemographic Characteristics of the Sample.

Variable	Category	*n*	%
Gender	Man	317	50.5
	Woman	310	49.4
	Non-binary	1	0.1
Age	18–25 years	150	23.9
	26–64 years	301	47.9
	65–90 years	177	28.2
Professional driver	Yes	68	10.8
	No	560	89.2
Place of residence	Urban	429	68.3
	Rural	199	31.7

Table 2
Summary of Driver Characteristics of the Sample.

Variable	Category	*n*	%
Main mode of transport	Walking	58	9.2
	Cycling	138	22.0
	Public transports	52	8.3
	Private vehicle (car)	343	54.6
	Private vehicle (e.g., motorcycle, scooter)	17	2.7
	Other	20	3.2
Frequency of driving a motorised vehicle	Everyday	108	17.2
	4 to 6 days a week	195	31.0
	1 to 3 days a week	208	33.1
	Between once a month and once a week	66	10.5
	Less than once a month	28	4.5
	Never	23	3.7
Annual average mileage	0 km	19	3.0
	1–1000 km	77	12.3
	1001–5000 km	120	19.1
	5001–10 000 km	169	27.0
	10 001–20 000 km	142	22.6
	20 001–30 000 km	58	9.2
	30 001–50 000 km	35	5.6
	50 001–100 000 km	4	0.6
	More than 100 000 km	4	0.6

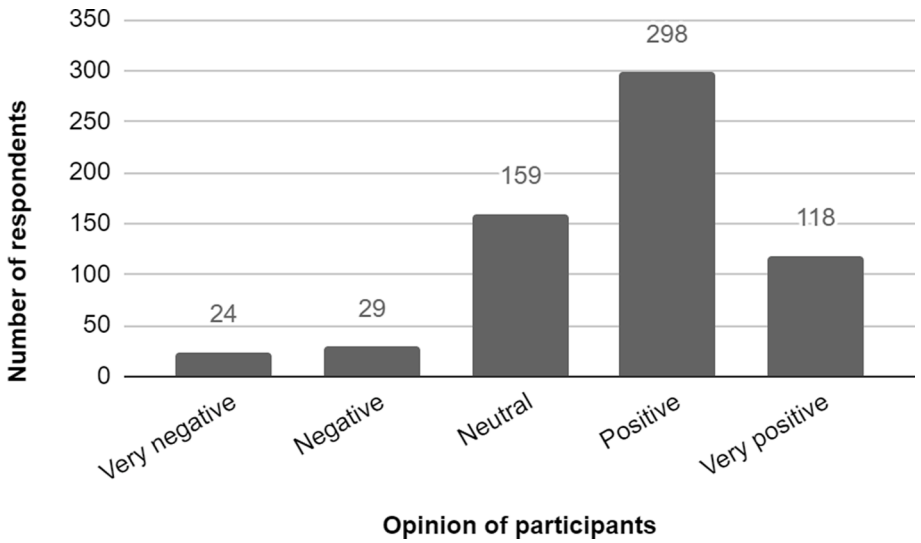

Fig. 3. General Opinion on a Monitoring and Feedback System.

Table 3
Correlation Coefficients Between Acceptability Score and Predictor Variables.

Variables	Mean	*SD*	1.
1. Acceptability score	0	0.78	
2. Age (18 to 90)	47.5	19.6	.10**
3. Gender (0 = Male, 1 = Female)	0.50	0.50	−.08*
4. Professional driver (0 = No, 1 = Yes)	0.11	0.31	.27***
5. Place of residence (0 = Urban, 1 = Rural)	0.32	0.47	−.08
6. Driving violations (1 to 5)	1.50	0.60	−.03
7. Frequency driving (1 to 6)	4.35	1.22	.09*
8. Average annual mileage (1 to 9)[a]	4.11	1.52	.14**
9. Belief that driving should be fun (1 to 7)	5.16	1.36	.21***
10. Enjoyment of driving (1 to 7)	5.27	1.52	.21***
11. Enjoyment of using ADAS (1 to 7)	4.26	1.74	.28***

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$.
[a] For this variable, the Spearman-rank order correlation is depicted.

enjoyment of driving, the belief that driving should be fun, enjoyment of using ADAS (Advanced Driver Assistance Systems), and being a professional driver. A significant difference is found between professionals ($M = 0.60$, $SD = 0.70$) and non-professionals ($M = -0.07$, $SD = 0.76$), $t(626) = -6.99$, $p < .001$. Table 3 further shows weaker correlations: statistically significant and positive relations can be observed between the acceptability score and age, average annual mileage, and frequency of driving. A significant negative relation can also be observed between acceptability and gender: male participants ($M = 0.06$, $SD = 0.81$) show higher acceptability than female participants ($M = -0.06$, $SD = 0.75$), $t(625) = 2.04$, $p = .042$. The place of residence and driving violations are not significantly correlated with the acceptability score.

A multiple regression analysis was performed to identify whether the 10 dependent variables investigated above are predictors of the acceptability score. The analysis used the Enter method, and the linearity, homoscedasticity, independence of observations, normal distribution of residuals, and multicollinearity assumptions were checked and met. The obtained model includes 10 predictors and explains 20.1% of the variance (adj. $R^2 = .20$, $F(10, 617) = 16.8$, $p < .001$). The predictors and their respective standardised coefficients are shown in Table 4.

Considering the number of variables included in the model, 20.1% of the variance explained is low, and these 10 variables do not predict the acceptability of a monitoring and feedback system well.

3.2. Underlying factors influencing acceptability

3.2.1. Perceived usefulness of being assessed

Whether participants were interested in being assessed and receiving feedback was evaluated using a 7-point Likert scale ranging from 1, strongly disagree, to 7, strongly agree, and received, respectively, average scores of 3.98 ($SD = 1.49$) and 4.00 ($SD = 1.55$).

Additionally, beliefs on what makes someone a good driver and self-ratings were recorded. Of the total sample, 10.5% believed it is "absolutely not" or "probably not" possible to determine if someone is a good driver. Multiple options were suggested to describe what a good driver is: the most popular were "driving safely" and "being aware of the traffic", which were selected, respectively, by 79.0% and 78.3% of the participants. "Being able to operate the car" followed (70.1%), accompanied by "following traffic rules" (69.1%). The least popular options were "being polite to other road users" (45.7%), "not getting into accidents" (36.3%), "sporty driving" (10.0%), and "others" (1.9%).

On the belief that participants were good drivers, ranging from 1, strongly disagree, to 7, strongly agree, the mean score was 5.29 ($SD = 1.14$), with only 5.3% of the respondents answering with one of the three disagreeing options. On whether they think their driving behaviour could be improved and whether they could drive better, the mean scores were 4.14 ($SD = 1.36$) and 4.10 ($SD = 1.37$), on a scale ranging from 1, strongly disagree, to 7, strongly agree. On both of these items, about a third of the respondents answered with a 4 (the neutral option), about 40% answered with one of the agreeing options, and about 27% with one of the disagreeing options.

A composite self-assessment score was calculated, as described in the Methods section. The Cronbach's alpha for the three items was .63, which is categorised as questionable but could be explained by the low number of items. The self-assessment score had an average of 4.35 ($SD = 0.98$), suggesting a slightly above-neutral self-assessment.

The last item in this questionnaire section concerned the potential impact one can have on traffic safety. Participants had to indicate how much the given example could have an impact on safety, with 0 being no impact at all and 100 a very large impact. Among all examples, the mean was 65.2 ($SD = 13.2$), and results per factor indicate that the most effective actors of safety on the roads would be the participants themselves ($M = 74.7$, $SD = 21.2$) and driving schools ($M = 74.1$, $SD = 18.5$). In comparison, "other drivers" received an average score of 68.8 ($SD = 20.8$).

3.2.2. Accepting data collection

The 628 participants indicated the frequency of use of six types of applications and websites, resulting in a total of 3768 frequency responses. Among those, the option "never or almost never" was selected 1267 times, and the reasons were then investigated. "Privacy concerns" was selected by 9% of the respondents on one or more of the six types of applications and websites; as a comparison, "I do not see the point" was selected by 49% of the respondents across all types of applications ($n = 1267$).

Table 4
Coefficients of Multiple Regression Analysis for the Dependent Variable Acceptability Score ($n = 628$).

Variables	Standardised coefficient β	t	p value
Professional driver	0.28	7.29	< .001***
Enjoyment of using ADAS	0.24	6.58	< .001***
Age	0.13	3.21	.001**
Belief that driving should be fun	0.13	3.11	.002**
Enjoyment of driving	0.10	2.33	.020*
Driving violations	-0.08	−2.07	.039*
Place of residence	-0.08	−2.06	.040*
Frequency driving	0.01	0.30	.766
Average annual mileage	0.01	0.18	.855
Gender	0.01	0.14	.888

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$.

Sixty-three per cent of the respondents never or almost never read the terms and conditions before using a website or an application. Fifty-two per cent declared not knowing at all or knowing only a little about how much data are collected when they use a website or an application.

On a scale ranging from 1, not sensitive at all and acceptable to share, to 7, very sensitive and not acceptable to share, the average score given to the fifteen data types was 4.45 ($SD = 1.70$). Average per-item scores ranged from 3.66 ($SD = 1.57$) for the item "age" to 5.64 ($SD = 1.48$) for the item "medical data". The most relevant types of data in the context of driving monitoring were "Travel and location history" ($M = 4.69$, $SD = 1.54$), "Traffic violations" ($M = 4.48$, $SD = 1.57$), and "Vehicle driven" ($M = 3.81$, $SD = 1.55$).

As described in the Methods section, a data collection sensitivity score has been created for each participant. The observed scores ranged from 18 to 120, with an average of 73.3 ($SD = 16.6$).

3.2.3. Relations between underlying factors and items of general acceptability

As described in the Methods section, relationships between acceptability and self-assessment and between acceptability and data collection sensitivity were investigated through correlation analysis and regression analysis.

The correlations between the acceptability score and the three variables of interest in the *Perceived Usefulness of Being Assessed* section are shown in Table 5.

A multiple regression analysis was conducted to test whether the three variables included in Table 5 are predictors of acceptability. The results indicate that the three predictors explain 4.2% of the variance ($R^2 = .04$, $F(3, 624) = 9.14$, $p < .001$). Self-assessment ($\beta = -0.09$, $p = .02$), own effect of safety ($\beta = 0.11$, $p < .001$), and the possibility to determine a good driver ($\beta = 0.13$, $p < .001$) are all significant predictors of acceptability, although the explained variance is small.

The correlation analysis between the acceptability score and the data collection sensitivity score was found to be not significant: $r(626) = .07$, $p = .07$. The regression analysis also found no significant results, with the model including the data collection sensitivity score as a predictor explaining only 0.5% of the variance ($R^2 = .005$, $F(1, 626) = 3.25$, $p = .07$).

3.3. Preferred features of the device

Specific features of the data were investigated through three different aspects: the type of data collected by the device, the potential shareability of the data, and the form the feedback would take.

3.3.1. Type of data

The precision and quantity of data that participants are willing to accept were investigated: on a scale ranging from 0 to 100, with 0 being as little data as possible, resulting in less precise information, and 100 being as much data as possible, resulting in more precise information, participants provided a mean rating of 62.4 ($SD = 23.4$). A Likert scale ranging from 1, strongly disagree, to 7, strongly agree, was used to ask whether participants would like to personally choose the type of data and the quantity of data being collected. These questions yielded scores of 5.3 ($SD = 1.4$) and 5.4 ($SD = 1.3$), respectively, indicating positive opinions towards the option of personalisation.

Five data types were then presented to participants (under two sharing conditions), with the instruction to indicate their opinion on the collection of each data type, on a scale ranging from 0, very negative, to 100, very positive. The average of the two scores were as follows: "speed" received the highest score with a mean of 59.6 ($SD = 28.8$), followed by "road facing camera" ($M = 55.3$, $SD = 28.7$), "g forces" ($M = 52.7$, $SD = 28.4$), "GPS data" ($M = 48.2$, $SD = 29.7$), and "driver-facing camera" ($M = 41.5$, $SD = 31.5$).

3.3.2. Shareability of data

As mentioned above, the five data types were presented to participants twice: once with the choice of whom to share the data with and once without the choice of whom to share the data with. The collection of the different data types was rated significantly higher, i.e., more positively, when participants were offered the choice to share them ($M = 51.5$, $SD = 22.5$) than when they did not have such a choice ($M = 46.1$, $SD = 27.1$), $t(627) = 13.4$, $p < .001$. The order of preference of the type of data did not vary as a function of the condition of sharing, i.e., whether one would have control over with whom the data are shared does not seem to affect the participants' ranking.

The intention to use the monitoring and feedback device was investigated on a scale ranging from 1, strongly disagree, to 7, strongly agree. This question was asked several times, contingent on whom the data would be shared with. The results are presented in Fig. 4. Professional drivers were asked an additional question: the intent to use the device if the data would be shared with their employer. They gave an average score of 4.79 ($SD = 1.93$).

Table 5
Correlation Coefficients Between Acceptability and Perceived Usefulness of Being Assessed items.

Variables	Mean	*SD*	1.
1. Acceptability score	0	0.78	
2. Self-assessment (1 to 7)	4.53	0.98	−.10*
3. Own effect on traffic safety (0 to 100)	74.69	21.23	.14***
4. Possibility to determine a good driver (1 to 5)	3.58	0.91	.14***

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$.

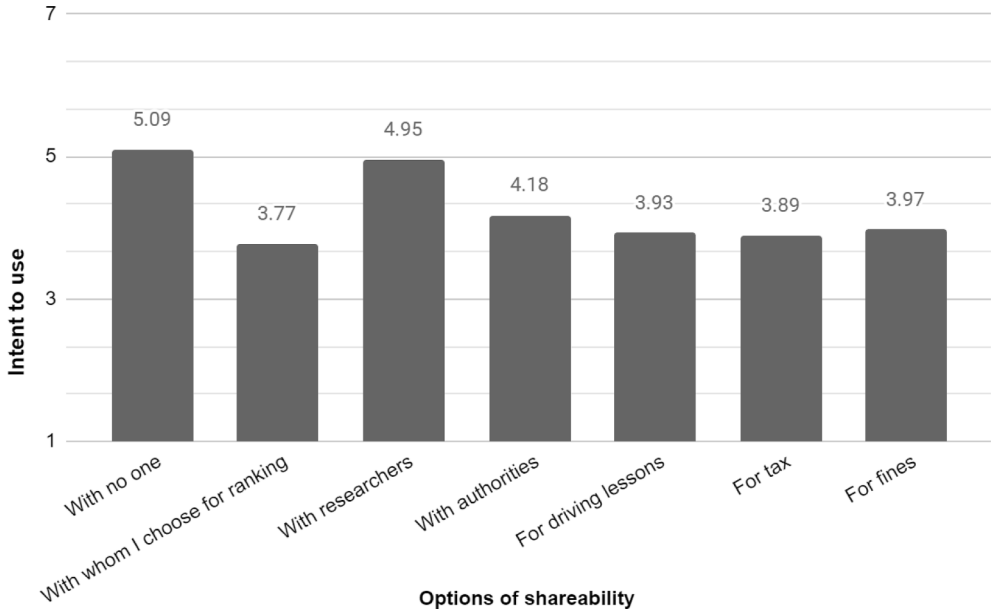

Fig. 4. Intent to Use the Device as a Function of Shareability of the Data.

3.3.3. Form of feedback

Scores from two slider scales, ranging from 0 to 100, were used to indicate whether participants prefer feedback focusing on mistakes or encouraging good behaviour and whether they prefer an overall score or specific items of data. The first result indicates a preference for feedback that encourages good behaviour, suggested by an average score of 63.5 ($SD = 22.3$). The second score was an average of 60.8 ($SD = 22.6$), indicating a slight preference for more specific information rather than an overall score.

The most preferred forms of feedback were email (average ranking of 2.43/5, $SD = 1.2$) and through a device in the car (average ranking of 2.45/5, $SD = 1.3$). They were followed closely by feedback on a mobile application (average ranking of 2.63/5, $SD = 1.2$)

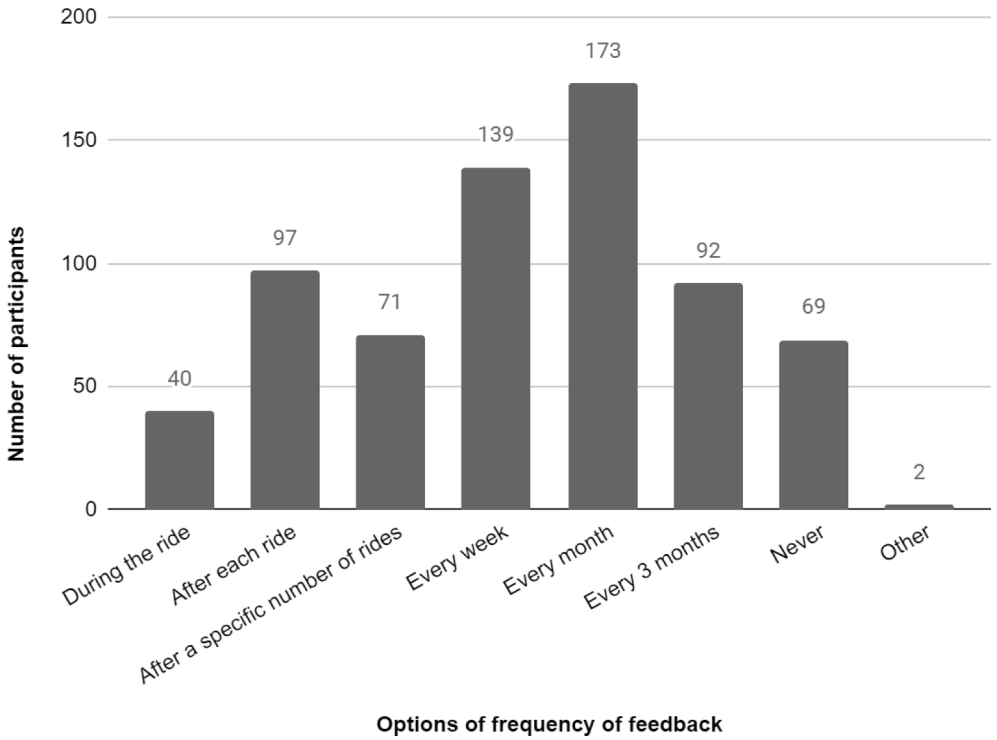

Fig. 5. Desired Frequency of Feedback of the Participants.

and on a website (average ranking of 3.07/5, $SD = 1.2$). The option "other" (with the possibility of specifying in a textbox) was ranked 4.42/5 on average ($SD = 1.2$).

Participants also indicated how often they would like to receive feedback. The corresponding results are presented in Fig. 5.

4. Discussion

In this study, the acceptability of the introduction of monitoring and feedback systems in driving was investigated, as well as the hypothesised underlying factors of acceptability, i.e., the perceived usefulness of being assessed and the acceptability of data collection, as illustrated in Fig. 1. By highlighting specific features of the system, ways to improve acceptability were also investigated. Opinions from a Dutch panel of a wide age range and diverse educational backgrounds were collected to allow for generalizable results. The discussion will follow the order of presentation of the results, starting with the description of opinions of acceptability, followed by the results on the perceived usefulness of being assessed, acceptability of data collection, and lastly, the specific features of the system.

The main result concerns acceptability: opinions were slightly positive while not diverging much from the neutral option. The responses on the general opinion and the intention to use tended towards the positive side, and the opinions on being assessed and receiving feedback were, on average, neutral. These findings suggest a lack of clear interest, or opinion, in what the monitoring and feedback system could offer (i.e., assessment and feedback), yet a slight enthusiasm regarding the system in general. This can imply that future potential users still need to be convinced of the usefulness of the system but suggests favourable prospects for acceptability.

To understand better the determinants of acceptability, different demographic variables were investigated as possible predictors through correlation and regression analyses. Most correlation coefficients were found to be small, which highlights the magnitude of individual variability and rejects the idea that certain classes of drivers would show higher acceptability than others. Supporting the same interpretation, the regression model explained only a small proportion of the variance, suggesting that the 10 identified variables are not good predictors of acceptability. Three variables still yielded noteworthy results: professional drivers were found to have a more positive attitude than other drivers, respondents who indicated enjoying using ADAS indicated more positive opinions on the system, and acceptability tended to increase with age. This last point is striking when taking into consideration that older people tend to accept new technologies less easily than younger people (De Winter & Nordhoff, 2022; Hancock & Parasuraman, 1992), especially before they can experience said technology (De Waard et al., 1999).

The first sub-theme identified in Fig. 1 is the perceived usefulness of being assessed. This relates to whether drivers believe they can improve their driving and whether this improvement can have a positive effect on road safety and benefit the drivers themselves. On average, drivers rated themselves as good drivers and only a third of the respondents indicated that they could improve their driving. Another third indicated a neutral attitude towards possible improvement, and the last third showed no belief that they could improve. Participants had, on average, a slightly above neutral self-assessment, which can be linked to a tendency to overestimate one's own driving skills (e.g., DeJoy, 1989; Sundström, 2008). Although drivers thought they were already good drivers, they still recognised that improved driving would have a positive effect on road safety: among the nine examples of stakeholders who can impact traffic safety, the item "you [themselves]" was rated, narrowly, as having the strongest impact. Thus, drivers acknowledge their own responsibility for safety and do not let other drivers or other stakeholders bear the entire responsibility. When interpreting these results through the causal attribution theory (Kelley, 1973), it appears that the causal attribution made is rather stable (only a third of the respondents believe they can improve, and the vast majority consider themselves good drivers) but not necessarily external (all stakeholders can have an effect on safety, themselves as much as others). Behaviour change is particularly difficult when a stable attribution is made. Therefore, shifting the attribution to an unstable cause (i.e., helping drivers realise they can improve their driving behaviour as it is neither fixed nor optimal) would be the advised first step towards a behaviour change. Additionally, for drivers to accept being assessed, they would have to agree with the assessment criteria. The results showed that being a "good driver" is defined more by their awareness of traffic and staying safe than obeying traffic rules, indicating that if the system only relies on traffic rules, it might be judged as irrelevant by future users.

The second sub-theme identified in Fig. 1 is the data collection component of the monitoring and feedback system. The participants' online behaviours showed that they seemed accepting of their data being collected: high-collecting applications such as social media were still among the most used, and privacy concerns were usually not the reason why someone would not use them. Furthermore, participants showed little anxiety, as it appeared common to not read the terms and conditions or to be unaware of how much data are collected when using a mobile app or browsing a website. The apparent little concern about data collection could be explained by a trade-off between privacy and utility (e.g., Alfnes & Wasenden, 2022), i.e., the (perceived) costs (i.e., sharing personal data) are balanced or even outbalanced by the benefits (i.e., accessing a social media network with all its social implications). It could be argued that people are simply used to having their data collected, and this no longer constitutes an issue for them. However, it is also possible that the participants of this study were unaware of the privacy-related costs, as it was not explained how intruding a monitoring and feedback system could potentially become. While providing participants with little information on data collection could lead to higher acceptance, it would be an ethically questionable means to obtain higher acceptance.

The relations between these two sub-themes and acceptability were investigated, as it was hypothesised that they were key determinants of acceptability. The items of perceived usefulness of being assessed and acceptability of a monitoring and feedback system showed significant but weak relations. In the same vein, the regression analysis led to a statistically significant model, but which explained only a small proportion of variance. These results indicate that the acceptability of a monitoring and feedback system is not determined by the perceived usefulness of being assessed, and the weak relations found could also be explained by an optimism bias or social desirability of the respondents. The data collection sensitivity was also investigated as a predictor of acceptability and yielded no significant result: participants who were less likely to accept sharing their data were *not* less likely to accept the monitoring and

feedback system. This lack of significant relations between the two sub-themes and the acceptability likely refutes the model hypothesised in Fig. 1, but could also be explained by the little information participants were given. Indeed, the goal was not to "sell" the product nor to inform on its risks but only to collect current attitudes. Therefore, the usefulness of the system and the data collection were not highlighted, which could have led to more neutral opinions than what can be expected when future users have all the information to make an informed judgement.

The third and last sub-theme identified in Fig. 1 concerned the opinions of participants on specific features. While average preferences can determine which features would allow for a better acceptance in a population, possibilities for tailoring have a better chance of being accepted. This point was indicated by the participants themselves: they would, on average, prefer to be able to choose the type and quantity of data collected by the system. Letting users select their specific preferences would also allow them to better understand the system, which could help increase acceptability. At the same time, the system must remain easy enough to use, as the perceived ease of use is a direct factor of acceptability (Davis, 1989). In terms of specific features, the participants indicated that they preferred data on speed and video fragments of the road being collected, both being less intrusive than driver-facing video footage. The preference for speed recording is interesting as it is information drivers already have access to and could indicate a desire to see averages and obtain better self-knowledge. Moreover, speed is unambiguous and relevant, as it is a determinant of traffic safety (Elvik, 2005). Participants also indicated that they would prefer not to share their data with anyone, but in the case that it would be shared, it should be shared anonymously with researchers, authorities, or employers (for professional drivers only) rather than with people they know for comparison purposes or to automatically lead to traffic violation fines. To be better accepted, the feedback should stimulate positive behaviour rather than discourage negative behaviour, and include specific information rather than an overall score. This result is in line with practices adopted for providing feedback in education, especially on the dimensions of encouragement (i.e., positive feedback) and fairness (i.e., transparency) (Lizzio & Wilson, 2008). On top of that, feedback must be easy to access (whether it is on a device in the car, on a mobile application, or on a website) and recurring, yet not too frequent (preferably every month or every week). This preference can be explained by a wish to reduce the "costs" of using the system: easily accessible, which relates to the perceived ease of use and not disturbing drivers too often in their daily rides.

As a general discussion, it seems that acceptance depends on a trade-off between costs and benefits, or between utility and privacy. Although trading privacy seems common nowadays, the utility has to become more obvious to prospective users to ensure actual use. The utility of the driver monitoring and feedback system presented in the questionnaire, and arguably the main objective of such a system, was to improve traffic safety. However, it can be seen as non-relevant to most drivers, as most of them will never experience a crash in their lifetime: according to De Winter et al. (2015), road accidents are rare from an individual point of view, leading notably to a low correlation between reported traffic law violations and accidents. While it could be enough to rely on empathy and a sense of duty or conscience for drivers to take it upon themselves to improve their driving behaviour, it might be necessary to find other ways to emphasise the benefits of the system. An idea could be to add a monetary incentive, either by decreasing taxes or insurance costs for users of the system or by highlighting the reduced costs of fuel in case of economical driving and lower speed. Although monetary rewards are sometimes preferred by participants, such rewards do not always lead to the best performance (Jeffrey, 2009). Another approach could be to rely on more personal values of future users, such as the preservation of the environment, by emphasising how one can reduce CO_2 emissions. Another way to possibly increase acceptability would be to allow for "self-tracking", which would constitute a "bottom-up" approach. Individuals would voluntarily and autonomously collect their own data, as is commonly done for health trackers such as weight, sleep schedule, exercise routine, or even moods (Fox & Duggan, 2013; Lupton, 2014). Allowing drivers to access their data and track their behaviour themselves would encourage them to take responsibility for the data analysis and assessment according to their own criteria. Ownership reduces the risk of rejecting the external party, such as an algorithm, which might be considered incompetent to judge the driving skills based on data alone. This last part relates to the importance of keeping a human as the main assessor of driving skills, which has been deemed necessary by driving examiners to allow for an overall assessment of competencies (Driessen et al., 2021) and is reflected in the results obtained in this study, with participants indicating they would prefer receiving more data to allow for more precise feedback.

5. Limitations

As this study relies on a questionnaire, it is subject to common limitations in questionnaires, such as the tendency to select neutral responses when an odd number of options is available (Choi & Pak, 2005), while social desirability may have incited participants to respond towards more positive opinions. Moreover, most questions of the questionnaire were self-developed, as they were tailored to the specific aims of the study and could have failed to measure the intended attitudes or opinions. Another limitation is that participants did not test the system and, therefore, might have had difficulty imagining themselves in a future where driving monitoring and feedback would be available. Lastly, the questionnaire was conducted online, meaning that the respondents had already accepted some data collection and were familiar with technology, which could indicate a slightly biased sample (Andrade, 2020). Taking into account its limitations, this study does not intend to predict acceptability objectively nor to provide an absolute truth regarding the best system features, but rather to provide insights on factors that matter and, by that, provide a basis for future research on acceptability.

6. Conclusion

To conclude, this research has shown potential for the implementation of driving monitoring and feedback systems by observing a slight tendency towards positive opinions. Since data collection may not be a major constraint, future research should focus on incentives and encouragement to use monitoring and feedback systems, while also taking into account possible behavioural adaptation.

Specific investigation can be conducted on the goals of future users (e.g., through the goal-framing theory; Lindenberg & Steg, 2007) and on what reasons could motivate people to change specific behaviours. Even without necessarily understanding drivers' goals and motivation, monitoring and feedback systems can adopt specific features that are judged on average to be more attractive, such as giving indications about speed or allowing drivers to personalise the system in terms of data collected or even frequency of feedback. In that sense, increasing the acceptability of a monitoring and feedback system can be achieved through two strategies: by matching the underlying goals of drivers and therefore making the system address specific needs and/or by adopting features deemed interesting or enjoyable by future users; a combination of both approaches could prove most effective.

CRediT authorship contribution statement

Angèle Picco: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Arjan Stuiver:** Conceptualization, Supervision, Writing – review & editing. **Joost de Winter:** Conceptualization, Supervision, Writing – review & editing, Funding acquisition. **Dick de Waard:** Conceptualization, Supervision, Writing – review & editing, Funding acquisition, Project administration.

Declaration of Competing Interest

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

Data availability

The file "dataset questionnaire" which includes the data used for this manuscript can be found at Supplementary Material.

Acknowledgements

This research is funded by Transitions and Behaviour grant 403.19.243 ("Towards Safe Mobility for All: A Data-Driven Approach"), provided by the Netherlands Organisation for Scientific Research (NWO). We would like to thank Dimitra Dodou for her help in creating the questionnaire and Dynata for their help in the data collection.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2022.10.021.

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