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Driving towards sustainability: exploring risk perceptions of fossil fuels, e-fuels, and electric drives in individual transport

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The transportation sector is a significant contributor to CO_2 emissions, necessitating the adoption of alternative drive technologies to achieve decarbonization. This study investigates public perceptions of fossil fuels, e-fuels, and electric drives, with the aim of identifying factors influencing risk perceptions, perceived efficacy in combating climate change, and readiness to use or purchase cars with these technologies. Therefore, a quantitative study using a questionnaire (N = 141) was conducted. The results indicate that e-fuels and electric drives are perceived more positively than fossil fuels. E-fuels were found to have the lowest risk perceptions. Differences in cognitive and affective risk perceptions, as well as in financial, environmental, and health-related risks, were observed across drive types. Car affinity was found to correlate positively with risk perceptions of e-fuels and fossil fuels, but negatively with electric drives. The risk perception of global warming showed an inverse relationship. Regarding the prediction of readiness, differences were found between e-fuels and electric drives in terms of the influencing factors on readiness. The study contributes to the understanding of public perceptions by providing a comparison between different drive technologies and offers valuable insights for developing targeted communication strategies.

KEYWORDS

E-fuels, electric drives, fossil fuels, risk perceptions, sustainability, transport, empirical social research, quantitative survey

1 Introduction

The consequences of climate change are becoming increasingly apparent. In the future, large areas of the Earth will face progressively severe risks, for example, due to rising temperatures, rising sea levels, or more frequent extreme weather events (Lange et al., 2020; Parmesan et al., 2022). In order to limit global warming and its consequences, it is necessary to reduce CO_2 emissions significantly. The European Union (EU) has set a target of achieving zero carbon dioxide (CO_2) emissions by 2050 (Parmesan et al., 2022). In Germany, the government has set a goal of reducing CO_2 emissions by 49% compared to 1990 and achieving zero emissions by 2045 (UBA, 2023). According to the UBA (2023), the transportation sector is the third largest contributor to carbon dioxide emissions in Germany, accounting for 20% of the country's total emissions. While the government has already proposed various solutions, including increasing the appeal of public transport, implementing higher CO_2 pricing, and expanding the rail network, the number of cars in

Germany reached an all-time high in 2023, with 48.8 million registered vehicles (KBA, 2023).

One potential way of achieving more sustainable mobility is the development and implementation of alternative drives. In the context of this study, we categorize both electric drives and e-fuels under the term "alternative drives." In addition to electric drives, which are becoming increasingly popular, other drive types are being developed, including synthetic fuels such as e-fuels. Although e-fuels have not yet been widely utilized on the road, the European Union has established regulations that will permit the registration of internal combustion vehicles only if they are powered by e-fuels from 2035 onwards (European Parliament, 2022). Alternative drives, such as electric and e-fuels, are not isolated solutions but rather integral components of larger energy frameworks designed to reduce emissions (Azam et al., 2022; IPCC, 2022). Also from an economic standpoint, the transportation sector plays a pivotal role in a country's economic viability. Here, sustainable technological advancements have been demonstrated to increase a country's economic viability (e.g., for freight transport, Shafique et al., 2020).

However, the role of the public's perception, acceptance, and potential usage of new sustainable technologies is equally important to consider, as the most advanced technology is of little use if people are unwilling to use it. To successfully implement and communicate technologies, it is essential to understand the social risk perceptions of those involved (Huijts et al., 2012). Subjective risk perceptions, which represent an individual's personal judgments and feelings about the likelihood and severity of risks, are rarely aligned with the actual objective risk (Fischhoff et al., 1978). This discrepancy can lead to severe consequences, such as the underutilization of beneficial technologies due to an overestimation of risk or the misuse of high-risk technologies due to an underestimation of risk. It is therefore essential to understand these subjective perceptions of risk and their impact factors in the field of alternative drives.

While there are numerous studies examining the perception and acceptance of electric drives, there is a lack of studies investigating the perception of e-fuels, which are considered to be an important transitional technology for a defossilized mobility (Jones et al., 2022). In particular, research is needed in the context of individual transport, as most studies focus on other areas, such as e-fuels in aviation (e.g., Engelmann et al., 2020; Arning et al., 2023). The present study therefore focuses on the social risk perception of fossil fuels, e-fuels, and electric drives, as well as the related impact factors.

The innovation of our study therefore lies in the focus on individual transport and in the comparison between different drive technologies. In contrast to previous studies that have examined alternative drive technologies in isolation, our study provides a comparative analysis between the technologies. In particular, the inclusion of conventional fossil fuels in this comparison represents a significant innovation of our study. The ability to compare these technologies side-by-side not only enriches the discourse on sustainable transport solutions but also provides valuable insights for policymakers and stakeholders aiming to promote environmentally friendly technologies. Another innovation is the incorporation of the individual attitudinal factor car affinity as a potential influencing factor on perceptions of drive technologies. This factor was not addressed in previous studies, despite its potential value for investigations in the transport sector.

2 State of research

2.1 Alternative drive solutions: Electric drives and E-fuels

As a consequence of the effects of climate change, individual road transport, which accounts for 74% of CO_2 emissions in the transport sector (IEA, 2022), is undergoing a fundamental transformation towards climate-neutral mobility (Brynolf et al., 2022). Although the internal combustion engine (ICE) remains the predominant drive system, there is a notable increase in the number of newly registered vehicles with alternative power sources. In 2022, for the first time, nearly half of the newly registered vehicles were passenger cars equipped with alternative drive systems (KBA, 2022). This study examines public risk perceptions of two approaches within the sustainable mobility transformation in private transport: synthetic fuels (e-fuels) and electric drives.

Electric drives operate on stored electricity, eliminating the need for fossil fuels and reducing emissions. They offer potentially double the energy efficiency compared to traditional vehicles but require energy-intensive battery production, which impacts their net greenhouse gas balance over initial years (UBA, 2023).

E-fuels are synthetic fuels generated by combining hydrogen derived from electricity with carbon, typically carbon dioxide, or nitrogen to produce a range of fuels. They are compatible with existing vehicles, ships, and aircraft and can be used as "drop-in" fuels, seamlessly substituting conventional fuels (Brynolf et al., 2022). E-fuels have recently gained increasing interest in the transportation sector, particularly in the context of medium-to long-distance shipping, aviation, and heavy-duty road transportation. However, the potential and feasibility of e-fuels for individual passenger vehicles remain limited. Electric drives have so far proven to be more practical and viable for emission reduction due to significant advancements. E-fuels continue to face challenges, particularly in terms of energy conversion efficiency from electricity to vehicle energy and the associated high production costs (Brynolf et al., 2022). However, for a successful transition to a defossilized mobility, it is essential to understand how the public views and responds to the introduction of e-fuels and electric drives, as these perceptions significantly influence the adoption rates and overall success of sustainable transportation solutions.

2.2 Risk perception

Risk perception in the context of mobility and transportation has gained significant scientific interest in the last decade (Fyhri and Backer-Grøndahl, 2012; Linzenich et al., 2020). Analyzing risk perception is vital for effectively integrating alternative drive technologies into the mobility landscape. This section introduces and defines the concept of risk perception.

In contrast to the clearly defined concept of "risk", i.e., the probability distribution of an adverse event and the magnitude of its consequences (Renn and Benighaus, 2013), the concept of "risk perception" refers to the subjective assessment of risks. Risk perception is defined as the subjective assessment of the probability of a certain event occurring and the level of concern regarding its potential consequences (Sjöberg et al., 2004). Numerous factors influence risk perception, including specific characteristics of the risk, such as its dread properties or familiarity, as examined in the psychometric paradigm (Fishhoff et al., 1978). This approach was supplemented by research on individual factors like age, expertise, culture, or socio-demographic characteristics, which explain the variations in risk perception among different groups (Chauvin, 2018).

Initially, cognitive models and heuristic approaches (e.g., Tversky and Kahneman, 1974) dominated the understanding of risk information processing and its influence on decisions and actions. These were expanded by dual-process theories, such as the Elaboration Likelihood Model (Petty and Cacioppo, 1986) or the "risk as feelings"-approach (Loewenstein et al., 2001), where cognitive aspects of risk evaluations, i.e., people's beliefs and knowledge of causes and negative consequences, are accompanied by affective responses like fear or anxiety. Finucane et al. (2000) presented the concept of the "affect heuristic", which posits that individuals rely on their basic emotional reactions (such as liking or disliking) towards a risk object to simplify complex decision-making processes, thus conserving cognitive and temporal resources. Studies have consistently identified that the perception of risks plays a crucial role in shaping attitudes toward a particular technology (Alhakami and Slovic, 1994; L'Orange Seigo et al., 2014). Furthermore, contemporary frameworks on the adoption of sustainable technologies emphasize the significance of individual perceptions in forming acceptance of sustainable technology innovations (Huijts et al., 2012). Recognizing the critical impact risk perceptions might have, this research specifically focuses on the perception of risks associated with low-carbon technologies such as alternative fuels.

2.3 Current state of research on risk perception and acceptance of alternative fuels

In recent years, there has been a significant focus on the perceived risk of alternative drive technologies, particularly electric drives and vehicles. The overall risk perception of CO_2-based fuels tends to be relatively low, and there is a high level of acceptance for this drive technology (Arning et al., 2017; Linzenich et al., 2022). Moreover, the potential toxicity of CO_2-based fuels was perceived to be lower compared to conventional fuels (Engelmann et al., 2020). Nevertheless, it is crucial to understand the risk perceptions of alternative drive technologies, as increased risk perceptions are associated with a reduced usage and purchase intentions (Dk and Samarasinghe, 2019). As the aim of the study is to gain a comprehensive understanding of the risk perceptions associated with alternative drive types and the factors that influence these perceptions, the following section will present an overview of the current state of research on this topic.

Socio-demographic factors: Younger individuals tend to exhibit a more positive attitude towards sustainable technologies such as biofuels or hydrogen fuels (Ziegler, 2010; Bertsch et al., 2016), whereas older individuals tend to report higher risk perceptions towards sustainable technologies (Zaunbrecher et al., 2014). Additionally, a higher educational level is associated with a higher risk perception of alternative technologies (Ren et al., 2016; Arning et al., 2023). Furthermore, higher education and a high income have a positive effect on the use and readiness of battery electric vehicles (BEVs) (Plötz et al., 2014; Nayum et al., 2016). Regarding gender, it was found that women perceive higher risks concerning health and the environment for CO_2-based products, while men have a higher acceptance and interest in these technologies (Perdan et al., 2017; Linzenich et al., 2019). Regarding the adoption of BEVs, one study indicated that in Germany, middle-aged men with technical occupations from rural and suburban multi-person households exhibit a higher willingness to purchase BEVs (Plötz et al., 2014).

Environmental attitude and awareness have also been found to influence the acceptance and adoption of sustainable innovations (Linzenich et al., 2019; Todaro et al., 2023). An increased environmental awareness was found to positively correlate with a high readiness for CO_2-based fuels (Arning et al., 2023). This is equally applicable to the adoption of BEVs (Priessner et al., 2018; Chen et al., 2020) and the purchasing intention for hydrogen vehicles (Tarigan et al., 2012). Additionally, individuals with stronger environmental attitudes demonstrate greater interest in plug-in vehicles (Carley et al., 2013). Furthermore, the importance of driving an environmentally friendly car is positively associated with high affinity towards BEVs (Plötz et al., 2014). However, there is a lack of comprehensive research that has explored the specific influence of environmental awareness on cognitive and affective risk perceptions related to different drive technologies. As this study concentrates on drive technologies in the context of sustainable mobility transition and risk perceptions, it will investigate environmental attitudes in the form of risk perception of global warming.

Car affinity is a further factor that is specifically investigated in the context of the mobility transition (Steg, 2005). Although the role of the car as a status symbol is slowly crumbling, driving by car remains the most popular mode of transportation in Germany (Destatis, 2023). Car owners assign significant value to car ownership, with the majority of this value being rooted in non-use aspects such as freedom, autonomy, or status (Haustein, 2021). This indicates that car owners have personal and emotional connections to their automobiles, which could affect their acceptance of sustainable transport alternatives. It is therefore crucial to determine whether an affinity towards cars affects the perceptions of alternative fuels and drive types.

In this study, in addition to electric drives and e-fuels, we also investigate the perception of fossil fuels as a baseline, emphasizing the importance of conducting specific comparisons between fossil and alternative fuels or drive types. As Engelmann et al. (2020) have observed, individuals' perceptions of e-fuels may be influenced by their familiarity with fossil fuels, with existing characteristics being transferred to e-fuels. Similarly, Chen et al. (2020) observed that individuals apply their knowledge of conventional vehicles to assess BEVs, influencing their overall perception. This indicates that the perception of e-fuels and electric drives is strongly influenced by

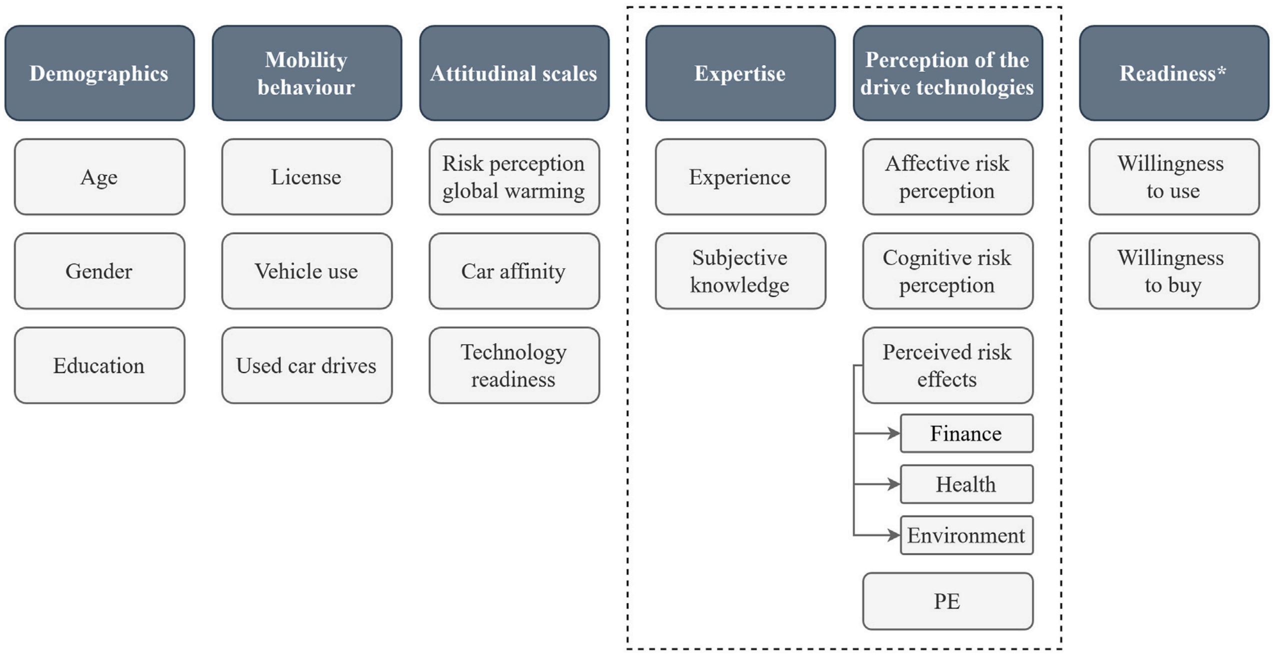

FIGURE 1
Structure of the conducted questionnaire. Factors within the dotted line were surveyed once for each drive type. PE = Perceived efficacy of each drive type for mobility transition. *Readiness was surveyed only for e-fuels and electric drives.

existing patterns of knowledge and experience associated with fossil fuels.

2.4 Research aims

Given that research on the risk of sustainable drive technologies has primarily focused on electric vehicles, there is a notable research gap concerning the risk perception of e-fuels in individual transport. Additionally, there is no direct comparison between the risk perceptions associated with the current *status quo* of fossil fuels and alternative drive solutions, such as e-fuels and electric drives. This comparative analysis has the potential to reveal relative differences and similarities in the perception of different technologies, thereby offering valuable insights that can be used to promote sustainable mobility. This study advances the understanding of e-fuels' risk perception and how it can be directly compared to other drive technologies, thereby laying the groundwork for future research in this field. Accordingly, the following research aims were pursued in the study:

1. Comparative evaluation of risk perception of different drive types, which involves analyzing how risk perceptions vary across different drive technologies, including e-fuels, electric drives, and fossil fuels.
2. Impact of individual factors influencing risk perception and an evaluation of drive types, which refers to the analysis of how personal characteristics, such as environmental awareness and car affinity, shape individuals' perceptions and evaluations of different drive technologies.
3. Prediction of the readiness for electric drives and e-fuels based on different dimensions of risk perception, as well as car affinity and environmental awareness as individual factors.

3 Methods

3.1 Questionnaire design

To empirically analyze the research questions, a quantitative study was conducted. The developed questionnaire was modular in structure and contained five blocks (see Figure 1). The complete list of questionnaire items is available in the Supplementary Material.

The first section of the questionnaire collected *demographic data* of the participants, including their age, gender, and level of education. Furthermore, the mobility behavior was surveyed, including ownership of a driver's license, vehicle use, and currently used car drive technologies.

Furthermore, *risk perception of global warming* (RGW) ($\alpha = .93$) was measured with nine items by using the risk perception index of Leiserowitz (2006). Additionally, *technology readiness* was assessed by a 12-item scale that measures three distinct facets: technology acceptance, technology competence, and technology control beliefs (Neyer et al., 2016). Participants' *affinity towards cars* ($\alpha = .85$) was measured using an adapted version of a scale by Steg (2005). While the original scale measures car affinity in three dimensions (instrumental, symbolic, and affective), with five items each, we retained only the two items with the highest factor loadings for each dimension, resulting in a total of six items.

The fourth section of the questionnaire addressed *personal experience* and *subjective knowledge* related to the three examined drive technologies. The level of knowledge was assessed on a scale from 1 to 6, with 1 representing the highest level of subjective knowledge and 6 representing the lowest. The scale included 8 items to measure subjective knowledge on multiple dimensions, e.g., general knowledge, knowledge concerning sustainability or efficiency. The experience of the participants was measured using a single item, which inquired as to whether they had previously driven a vehicle with the specified drive type.

The main section of the survey focused on the perceptions of the three drive technologies. The order in which the drive technologies were assessed was randomized. Prior to the assessment of perceptions, a brief informational text was provided for each drive technology. To measure risk perception across multiple dimensions, a semantic differential with six levels and eleven dimensions was employed. The *perceived efficacy of the drive types for a sustainable mobility transition (PE)* was measured using a single item on a six-point Likert scale (1 = "not efficacious at all," 6 = "very efficacious"). *Affective risk perception* (fossil: α = .92; electric, e-fuels: α = .93) includes the affect subscale of Walpole and Wilson (2021), which was measured on a six-point Likert scale (1 = "very strong," 6 = "very light"), as well as affective items of a semantic differential (boring - fascinating, negative - positive, scary - harmless). *Cognitive risk perception* (e-fuels: α = .92, fossil, electric: α = .91) includes both PE and cognitive items of the differential (harmful to health - harmless to health, environmentally harmful - sustainable, unnecessary - necessary, inflexible - flexible, complex - simple, expensive - cheap, risky - safe, dirty - clean). Also, the *perceived risk effects* of the respective drive types on finances, health, and the environment were measured. Two facets were included: the perceived probability that the use of the drives would have an impact on the three areas and the perceived severity of the potential impact. The Cronbach's α values for the dimensions and drive types ranged from .66 to .91. Although the scales for financial risks associated with fossil fuels and health risks associated with electric drives were below the .70 threshold, we proceeded with their inclusion in the analysis, assuming that the internal consistency of the scales would be satisfactory given the limited sample size.

Finally, we evaluated the participants' *readiness* for electric drives (α = .89) and e-fuels (α = .94) with two items for each drive, measuring the willingness to use and buy the respective drive on a six-point Likert scale.

To construct the between-group-factors, the sample was divided into two groups based on their responses, respectively: respondents (n = 84) with a mean car affinity score <3.5 were assigned to the "low car affinity"-group, while those with a score >3.5 (n = 55) were assigned to the group of "high car affinity." Those with a mean RGW <3.5 were assigned to the "low RGW"-group (n = 40), while those with a score >3.5 (n = 95) were assigned to the group of "high RGW".

3.2 Sample

The study was conducted via an online questionnaire and data collection occurred in June and July 2023 in Germany. To participate in the study, individuals were required to be at least 18 years of age. All participants were asked to complete the survey voluntarily and did not receive any reward for their engagement. Prior to responding to the questionnaire, participants were informed about the objective of the study and that their opinions were of interest. It was emphasized that there were no incorrect or wrong answers. Additionally, participants were informed that no prior knowledge was required, and that high privacy protection is guaranteed in handling their data.

A total of 227 datasets were collected using a convenience sampling method, primarily via social networks and social media, with Facebook groups being the primary recruitment channel. The survey was distributed to localized groups, as well as groups with a special interest in electromobility or e-fuels. After conducting data cleaning, a sample of 141 datasets remained.

The sample consisted of 38% female, 60% male, and 2% non-binary participants aged between 18 and 79 years, with an average age of 45 years (SD = 15.67). The educational level was relatively high, with 25% of the respondents holding a high school diploma and 54% having obtained an academic degree. Most participants (93%) possess a driver's license and use a car at least several times a year. Three-quarters of the sample (76%) drive cars with combustion engines, and 12% use BEVs. The majority of participants had previous experience with fossil fuels (85%), followed by electric drives (61%), and e-fuels (6%).

The mean perceived risk of global warming was found to be relatively high (M = 4.09, SD = 1.05). The sample exhibited a slightly negative affinity towards cars (M = 3.31, SD = 1.15). Subjective knowledge was slightly higher for electric drives (M = 4.03, SD = 1.29) than for e-fuels (M = 3.58, SD = 1.67).

3.3 Data cleaning and data analysis

The data cleaning and analysis was conducted using R and SPSS software. For data cleaning, pretests, incomplete datasets, speeders, and datasets with longstrings were filtered out. The speeder limit was set at half the median of the processing time. The limit for longstrings was set to 14 consecutive items answered with the same response option by considering the layout of our questionnaire and analyzing our dataset.

For statistical data analysis, Pearson's r correlations, linear regression analyses, and analyses of variance (ANOVAs) were calculated. The data were tested for normal distribution, and corrected values were used in cases of deviations. Following the ANOVA, *post hoc* tests were conducted to statistically assess differences between individual factor levels (see information on T-tests for individual comparisons in the Supplementary Material). Bonferroni-Corrections were used to avoid the increased risk of a type I error. In linear regression analyses, we used the forward selection method (Döring and Bortz, 2016), entering predictors into the model in order of their standardized estimates, from largest to smallest with each new predictor forming a new model. This approach allows us to quickly identify the best predictive model.

4 Results

4.1 Risk perception of drive types

The analysis of the perception of drive types begins with an analysis of perceptual judgments regarding fossil fuels, e-fuels, and

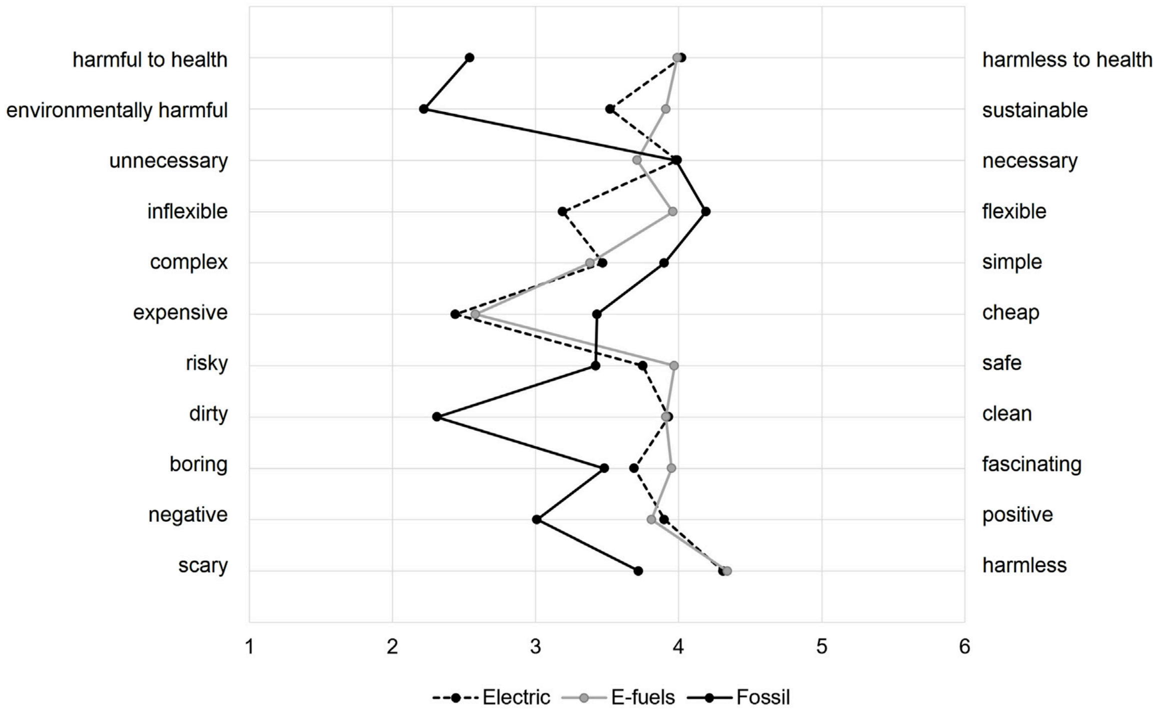

FIGURE 2
Semantic differential for evaluating perceptions of fossil fuels, e-fuels, and electric drives.

electric drives on the semantic differential. This is followed by ANOVAs to investigate main effects and interactions in the risk perception of the drive types.

The analysis of drive type perception ratings on the semantic differential revealed that electric drives and e-fuels were rated similarly (n.s.) but differed significantly from the ratings of fossil fuels. Figure 2 visualizes the results for the ratings on the semantic differential. In total, alternative drives were perceived more positively than conventional fossil fuels. Regarding health and environmental impact, electric drives were perceived as the least harmful to health and environment, indicated by their positioning closer to the 'harmless to health' and 'sustainable' end of the scale. In contrast, fossil fuels were positioned at the opposite end, reflecting a perception of being harmful to health and environmentally damaging. Regarding cost, electric drives and e-fuels were perceived as significantly more expensive compared to fossil fuels. Electric drives were rated more positive in terms of safety and cleanliness, whereas fossil fuels scored significantly lowest on these attributes. The biggest difference between electric drives and e-fuels referred to flexibility. Electric drives were seen as less necessary and less flexible compared to other types, which may reflect current market penetration and infrastructure limitations. Conversely, fossil fuels were still perceived as more necessary and flexible, indicating conventional usage patterns. Regarding affective responses, electric drives scored higher on positive emotional attributes such as fascinating and positive, indicating a more favorable overall sentiment. E-fuels were less positively perceived than electric drives but more positively than fossil fuels. Fossil fuels were consistently associated with negative attributes such as boring, negative, and scary. The results of all t-tests for mean differences are available in the Supplementary Material.

A two factorial ANOVA with repeated measurement was calculated with the within-factors "drive type" (three levels: fossil fuel, e-fuel, electric drive) and "risk perception dimension" (two levels: cognitive and affective risk perception) on cognitive and affective risk perception ratings as dependent variables. The highly significant main effect "drive type" [$F(2,137) = 24.59$, $p < 0.001$, $\eta = .26$]. Figure 3 showed that e-fuels elicited the lowest and lowered risk perception ($M = 2.9$, $SD = 1.3$), followed by moderately pronounced risk perceptions for electric drives ($M = 3.4$, $SD = 1.2$) and slightly elevated risk perceptions for fossil fuels ($M = 3.6$, $SD = 1.2$). Cognitive and affective risk perception ratings also differed highly significantly [$F\ (1,137) = 12.81$, $p < 0.001$, $\eta = .16$]. Cognitive risk perceptions ($M = 3.5$, $SD = 0.6$), which did not deviate from the midpoint of the scale, were significantly higher than affective risk perceptions ($M = 3.1$, $SD = 0.7$). A significant interaction between drive type and evaluation [$F\ (1,137) = 12.8$, $p < 0.001$, $\eta = .16$] indicated that the affective risk perception for e-fuels ($M = 2.6$, $SD = 1.4$) was significantly lower compared to cognitive risk perception of e-fuels ($M = 3.2$, $SD = 1.3$). The same applied for the risk perception of electric drives, with lower affective risk perceptions ($M = 3.2$, $SD = 1.4$) compared to cognitive risk perceptions ($M = 3.6$, $SD = 1.2$).

In a next step, risk perceptions regarding perceived negative effects for individual health, financial situation or the environment were analyzed for the three drive types. A two-factorial ANOVA with repeated measurement with the two within-factors "drive type" (three levels: fossil fuel, e-fuel, electric drive) and "perceived risk effect" (three levels: health, environment, finance) was run on risk

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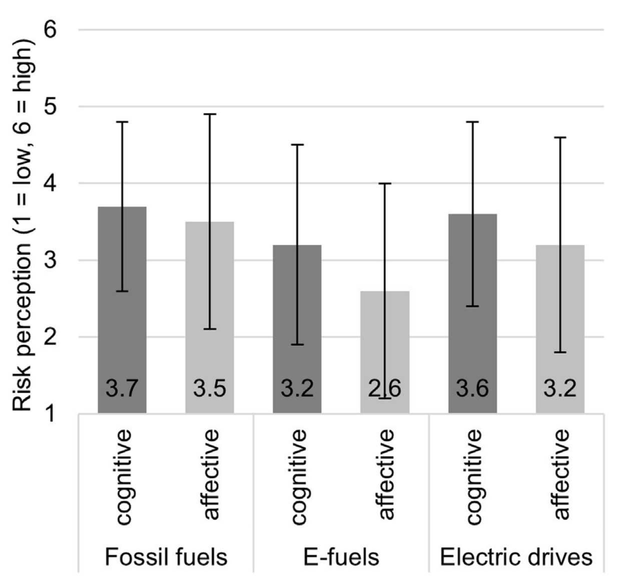

FIGURE 3
Cognitive and affective risk perception ratings for fossil fuels, e-fuels, and electric drives. Error bars indicate standard deviations.

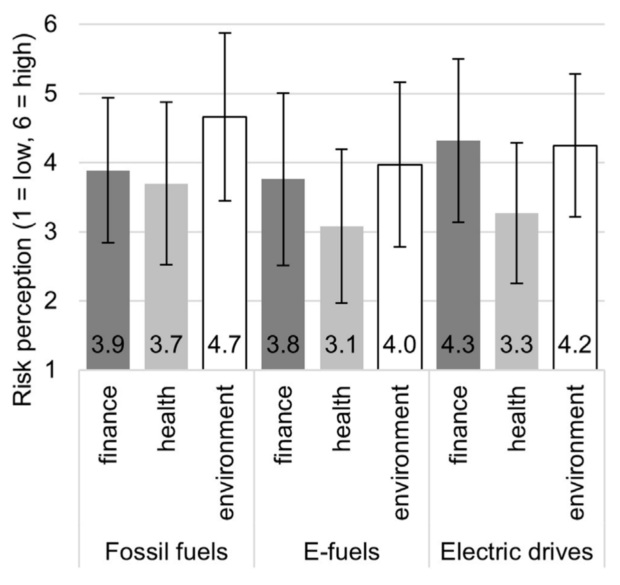

FIGURE 4
Perceived risk effect ratings (finance, health, environment) for fossil fuels, e-fuels, and electric drives. Error bars indicate standard deviations.

perception ratings of effects for the respective drive types as dependent variables. The results (Figure 4) indicated significant differences in perceived risks for both: the drive type (F (2,137) = 15.52, $p < 0.001$, η = .18) and the perceived risk effects [F(2,137) = 109.6, $p < 0.001$, η = .61], as well as a significant interaction between these two factors [F(4,137) = 12.8, $p < 0.001$, η = .27]. Looking at the main effect "drive type," effect risk perception was the highest for fossil fuels (M = 4.1, SD = 0.9), followed by effect risk perception for electric drives (M = 3.9, SD = 0.8) and the lowest for e-fuels (M = 3.6, SD = 0.9). Regarding the type of perceived risk effects, concerns were the highest regarding negative effects for the environment (M = 4.3, SD = 0.8), followed by financial risks (M = 4.0, SD = 0.9). The lowest risk perception was reported for negative effects on health (M = 3.3, SD = 0.9). The significant interaction indicates that the effect risk perception was different for the respective drive types. As visualized in Figure 4, fossil fuels were rated significantly higher for negative environmental effects compared to e-fuels and electric drives. Conversely, e-fuels and electric drives were associated with significantly lower perceptions of health risks, underlining the distinction in public perception between traditional and alternative fuel sources. After analyzing the effect of drive types on affective and cognitive risk perception as well as on different effect types, individual factors were included into the analysis.

4.2 Impact of individual factors on drive type perceptions

In a first step, the influence of individual factors (RGW/perceived risk of global warming and car affinity) on risk perception was investigated based on correlation and regression analyses.

Significant correlations were found for perceived risk of global warming and car affinity and the risk perception ratings for different fuels (see Table 1). Specifically, there was a significant negative correlation between RGW and risk perceptions for e-fuels ($r = -0.40$, $p < .01$) and fossil fuels ($r = -0.63$, $p < .01$), indicating that individuals with higher concerns about global warming perceive these fuels as riskier. In turn, higher concerns about global warming were associated with lower risk perception of electric drives ($r = -.39$, $p < .01$).

Additionally, car affinity showed a negative correlation with the risk perception of fossil fuels ($r = -0.41$, $p < .01$) and e-fuels ($r = -0.37$, $p < .01$), suggesting that individuals with a higher affinity towards cars perceive less risk associated with these fuel types. In contrast, a higher car affinity was related to a higher risk perception of electric drives ($r = 0.24$, $p < .01$). Interestingly, higher levels of car affinity were associated with reduced perceived risks of global warming ($r = -0.42$, $p < .01$).

To analyze the respective influence of the two attitudinal factors, car affinity and perceived risk of global warming (RGW) on risk perceptions, repeated measures ANOVAs were calculated in the next step.

First, a two factorial ANOVA with repeated measurement with the between-factor *car affinity* (two levels: low and high car affinity) and the within-factors "drive type" (three levels: fossil fuel, e-fuel, electric drives) and "risk perception dimension" (two levels: cognitive and affective risk perception) on cognitive and affective risk perception ratings as dependent variable was run. As the results on the within-subject factors have already been presented in section 4.1, only the between-subject effects and their interactions are reported here.

In the ANOVA, a highly significant effect of the between-subject factor car affinity [F(1,137) = 21.56, $p < 0.001$, η = .14] as well as a two-way interaction between the between-subject factor car affinity and the within-subject factor drive type [F (2,137) = 19.8, $p < 0.001$,

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TABLE 1 Bivariate correlations between risk perceptions (RP) of each drive type and the individual factors perceived risk of global warming (RGW) and car affinity.

	RP fossil	RP E-fuels	RP electric
RGW	.63**	.40**	−.39**
Car affinity	−.41**	−.37**	.24**

η = .13], and a three-way interaction between the between-subject factor car affinity and the within-subject factors drive type and risk perception dimension [F (2,137) = 3.7, $p < 0.05$, η = 0.03] were identified.

Respondents with a higher car affinity reported a lower risk perception (M = 3.0, SD = 0.5) than those with a lower car affinity (M = 3.4, SD = 0.5). Regarding the two-way interaction between the car affinity and drive type, individuals with a low car affinity reported higher risk perceptions for fossil fuels (M = 4.0, SD = 1.0) compared to those with a high affinity for cars (M = 3.0, SD = 1.2), which reported significantly lower (and lowered) risk perceptions. For e-fuels, those with low car affinity also reported higher risk perceptions (M = 3.3, SD = 1.2) than individuals with high car affinity (M = 2.3, SD = 1.3). Interestingly, the risk perception of e-fuels was the lowest in the group of individuals with high car affinity. In contrast, the risk perception for electric drives among individuals with high car affinity (M = 3.8, SD = 1.3) was higher than those with low car affinity (M = 3.1, SD = 1.1). These findings indicate a clear divergence in risk perception based on car affinity, with high-affinity individuals perceiving lower risks for traditional and e-fuels, but higher risks for electric drives, compared to those with low car affinity.

The analysis of the three-way interaction enabled a further, more in-depth understanding of the differentiated risk perceptions (see Figure 5). For fossil fuels, cognitive risk perception is lower for high (M = 3.1, SD = 1.1) compared to low (M = 4.0, SD = 0.9) car-affine individuals. The same pattern applies for affective risk perceptions for fossil fuels, which are even lower in high car affine people (M = 2.8, SD = 1.3) compared to low (M = 4.0, SD = 1.2) car-affine individuals. For e-fuels, individuals with high car affinity report significantly lower affective risk perceptions (M = 2.1, SD = 1.3) compared to those with low car affinity (M = 3.0, SD = 1.3). This suggests that those with a strong car affinity emotionally perceive e-fuels as less risky. On the cognitive risk perception side, the difference is also prevalent, with high car affinity individuals reporting lower risk perceptions (M = 2.6, SD = 1.3) than low car affine respondents (M = 3.5, SD = 1.1). In contrast, for battery-electric vehicles, those with high car affinity report a higher cognitive risk perception (M = 4.0, SD = 1.2) compared to those with low car affinity (M = 3.3, SD = 1.1). Affectively, individuals with high car affinity report a mean risk perception (M = 3.6, SD = 1.4), which is higher than for those with low car affinity (M = 2.9, SD = 1.3). This indicates that individuals with high car affinity recognize the risks associated with electric drives more and also feel more emotionally affected by them.

Overall, the results indicate that car affinity significantly influences individuals' risk perceptions towards different types of drives. Specifically, individuals with a high affinity for cars tend to view both fossil fuels and e-fuels as less risky, while assigning greater risk to electric drives. Conversely, those with lower car affinity perceive alternative fuels and drive types, such as e-fuels and electric drives, as less risky compared to traditional fossil fuels. For both fossil fuels and e-fuels, cognitive risk perceptions exceed affective ones among individuals, regardless of car affinity. However, this trend reverses in the context of electric drives: individuals with high car affinity exhibit higher affective risk perceptions compared to their cognitive assessments. These findings suggest that car affinity plays a critical role in shaping public perceptions towards the adoption of new automotive technologies.

In a next step, the between-subject factor "perceived risk of global warming" was included into the analysis. A two factorial ANOVA with repeated measurement was calculated with the between-factor perceived risk of global warming (RGW, two levels: low and high) and the within-factors "drive type" (three levels: fossil fuel, e-fuel, electric drive) and "risk perception dimension" (two levels: cognitive and affective risk perception) on cognitive and affective risk perception ratings as dependent variable. As before, since the results on the within-subject factors have already been presented in section 4.1, only the between-subject effects and their interactions are reported here.

In the ANOVA, a highly significant effect of the between-subject factor RGW [F (1,132) = 33.2, $p < 0.001$, η = .2] as well as a two-way interaction between the between-subject factor RGW and the within-subject factor drive type [F (2,132) = 37.5, $p < 0.001$, η = .22], were identified.

Respondents with a higher RGW (M_{high} = 3.4, SD = 0.5) reported higher risk perceptions for the drive types (M_{low} = 2.9, SD = 0.5). Interpreting the two-way interaction, Figure 6 visualizes that the risk perception patterns of individuals with high and low RGW-scores were different for electric drives compared to fossil fuels and e-fuels. For electric drives, individuals with a low level of RGW perceive a higher risk (M = 4.1, SD = 1.2) compared to those with a high level of RGW, who perceive a lower risk (M = 3.0, SD = 1.1). This pattern is the reverse for fossil fuels and e-fuels, where a high level of RGW corresponds with a higher risk perception (fossil fuels: M = 4.1, SD = 0.9; e-fuels: M = 3.2, SD = 1.2) compared to a low level of RGW (fossil fuels: M = 2.6, SD = 0.9; e-fuels: M = 2.1, SD = 1.2). This interaction suggests that individuals who are more concerned about global warming see electric drives as less risky compared to those less concerned about global warming. In contrast, individuals with high RGW perceive higher risks associated with traditional fossil fuels and e-fuels.

In a last step, the relationship between the two individual factors was analyzed. An ANOVA with the between-subject factors car affinity and risk perception of global warming as well as the within-subject factor drive type revealed no interaction between the between-subject factors.

4.3 Prediction of the readiness to use alternative drive types

To predict the readiness for e-fuels and electric drives, linear regressions were calculated. As fossil fuels represent the conventional type of propulsion, the readiness to use was not

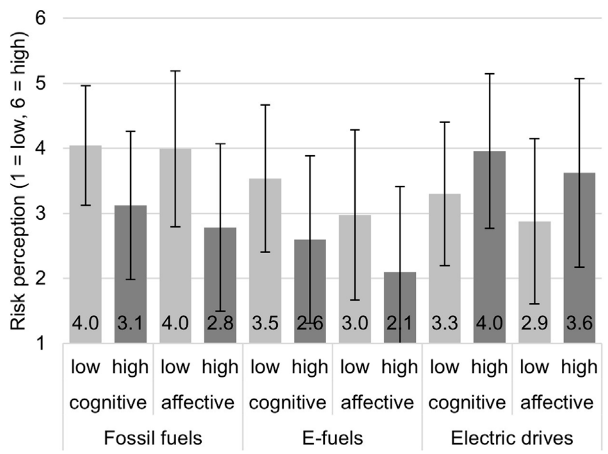

FIGURE 5
Cognitive and affective risk perception ratings for individuals with low and high car affinity for fossil fuels, e-fuels, and electric drives. Error bars indicate standard deviations.

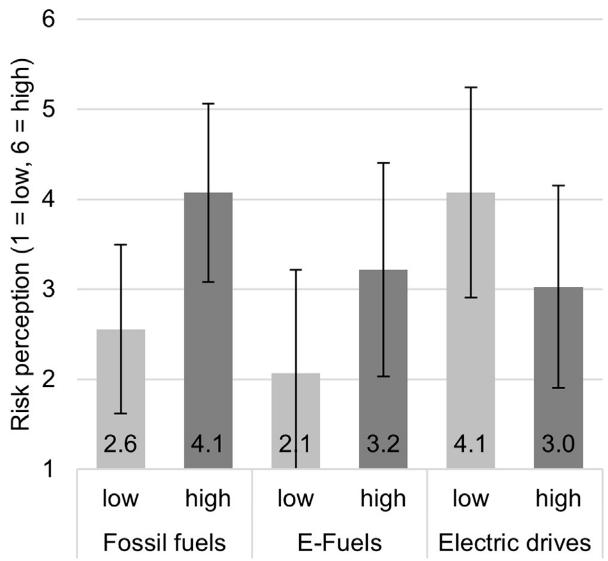

FIGURE 6
Risk perception ratings for individuals with low and high levels of perceived risk of global warming (RGW) for fossil fuels, e-fuels, and electric drives. Error bars indicate standard deviations.

measured in this context. As predictors, affective and cognitive risk perception, perceived risk effects, car affinity, and RGW were entered into regression models. The predictors were entered sequentially based on their standard estimate, following the stepwise forward approach. A significant model was found for e-fuels, as follows:

e-fuel = 5.77 + −0.72 · cognitive risk perception + −0.3 · affective risk perception +0.29 · car affinity

The model explained 64% of variance, adjusted R^2 = .644, F (3, 137) = 84.2, p < .001. The effects of the predictors in this model are operating in a manner that is contrary to one another. While cognitive risk perception (β = −0.51, t (140) = −4.65, p < .001) and affective risk perception (β = −0.23, t (140) = −2.21, p < .01) have a negative influence on the readiness for e-fuels, car affinity [β = 0.19, t (140) = 3.35, p = .01] has a positive influence on the readiness for e-fuels (see Table 2). The remaining variables were not found to be significant predictors of readiness for e-fuels. The variance inflation factor (VIF) analysis indicated that the predictor variables exhibited an acceptable level of multicollinearity, with all VIF values below the commonly used threshold level of 10 (cognitive risk perception = 4.34, car affinity = 1.19, affective risk perception = 4.08).

A model was also developed for electric drives, which demonstrated a high level of explanatory power:

electric drives = 7,64 · −0.64 x affective risk perception · −0.47 x cognitive risk perception · −0.13 x financial risk

The model explained 72% of variance, adjusted R^2 = .718, F(3, 137) = 119.9, p < .001. The predictor variables exhibit a complex interplay in this model. In a manner analogous to that observed with e-fuels, affective risk perception [β = −0.54, t (140) = −5.64, p < .001] and cognitive risk perception [β = −0.34, t (140) = −3.53, p < .001] exert a negative influence on the readiness for electric drives. Perceived financial risk [β = −0.09, t (140) = 2.04, p < .05] also has a negative effect on readiness for electric drives (see Table 3).

The VIF analysis revealed that the predictor variables exhibited acceptable levels of multicollinearity, with all VIF values below the threshold level of 10 (affective risk perception = 4.58, cognitive risk perception = 4.52, perceived financial risk = 1.04). The remaining variables were not found to be significant predictors of readiness for electric drives.

5 Discussion

Considering the urgent need to reduce CO_2 emissions in the transport sector, this study investigated the public's risk perceptions associated with alternative drive technologies—focusing on fossil fuels, e-fuels, and electric drives. By examining both cognitive and affective dimensions of risk perception and considering the impacts on health, financial aspects, and the environment, we aimed to uncover the underlying factors influencing public risk perception. Furthermore, the study explored the roles of car affinity and global warming risk perception and conducted a predictive analysis of consumer readiness for e-fuels and electric drives.

5.1 Risk perception of different drive types

While most comparative analyses of drive types are either techno-economic analyses (e.g., Ravi et al., 2023) or investigate perceptions of innovative drive types separately, our study conducted a comparative analysis of two alternative drive types and included conventional fossil fuels as a baseline in the analysis. The perception of fossil fuels as the highest risk factor suggests that the sample is aware of the potential risks associated with fossil fuels (e.g., Engelmann et al., 2020). This may reflect the extensive public and political debates on the topic that have taken place in recent years. Conversely, e-fuels were perceived as having a lower risk, possibly due to a lack of widespread familiarity and their current early stage of development.

Moreover, the study demonstrated that affective risk perceptions were significantly lower than cognitive risk perceptions across all drive types. This indicates that respondents are less emotionally sensitive to the risks associated with the drive technologies, while simultaneously demonstrating a rational awareness of the potential dangers. This may be attributed to the ongoing discussions surrounding drive technologies, which may enhance cognitive assessments by providing well-reasoned arguments. Furthermore, we assume that respondents do not feel highly vulnerable or exposed to the risks which could account for the reduced affective risk perception. This result is contrary to what might be expected, given that individuals tend to rely more on affective resources when making judgments, e.g., to conserve time and resources (Finucane et al., 2000).

In terms of distinct evaluative aspects, e-fuels and electric drives were rated similarly. In comparison to fossil fuels, these alternative technologies are deemed less detrimental to health, more ecologically sustainable, generally more favorable, cleaner in operation. Conversely, they were also rated as more expensive and more complex, aligning with previous research on public perception of alternative fuel solutions (e.g., Linzenich et al., 2023). This indicates that both e-fuels and electric drives are perceived as viable and advantageous alternatives to fossil fuels.

Further insightful differences were found in how participants rated the risk impact of different drive technologies on health, finances, and the environment. Environmental risks associated with drive types received the highest concern, whereas health-related risks were perceived as least concerning. This discrepancy may be attributed to the fact that drive types are mostly discussed in an environmental or sustainable mobility context. Based on the availability heuristic (Tversky and Kahneman, 1974), respondents may rate environmental risks as higher due to the greater availability of information on this topic. Furthermore, this study noted that participants attributed lower health risks to e-fuels and electric drives compared to fossil fuels, likely reflecting an awareness of the negative health impacts of fossil fuel emissions. These findings align with previous studies who found that the perceived toxicity of e-fuels is lower than for conventional fuels (Engelmann et al., 2020). Apart from health risks for e-fuels and electric drives, none of the risk effects was rejected, i.e., for all other drive types and risk dimensions the risk perceptions were at least slightly increased. Interestingly, the health risks related to e-fuels and electric drives were evaluated as relatively minor. We assume that this may be due to the lower CO_2 emissions associated with these technologies, leading to an expectation of diminished health risks (Boudet, 2019). Contrary to this, environmental risks were rated higher, which presents a paradox. The discrepancy suggests that there may be other environmental concerns related to e-fuels and electric drives beyond CO_2 emissions that have yet to be fully explored or communicated. However, this paradox could also reflect a lack of knowledge regarding alternative drive types, as this factor was previously identified as an influencing factor in the context of alternative drives. For example, it was found that limited consumer knowledge reduces the chance of the adoption of alternative fuel vehicles (Kowalska-Pyzalska et al., 2021). Knowledge about the respective drive types should therefore be investigated in further studies.

TABLE 2 Results of multiple linear regression analysis to predict readiness to use or buy vehicles that use e-fuels. RP, Risk perception.

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept	5.77	0.46	12.51	<.001	
Cognitive RP	−0.72	0.15	−4.65	<.001	−0.51
Car Affinity	0.29	0.09	3.35	<.01	0.19
Affective RP	−0.3	0.13	−2.21	<.01	−0.23

TABLE 3 Results of multiple linear regression analysis to predict readiness to use or buy vehicles that use electric drives. RP, Risk perception.

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept	5.77	0.46	12.51	<.001	
Cognitive RP	−0.72	0.15	−4.65	<.001	−0.51
Car Affinity	0.29	0.09	3.35	<.01	0.19
Affective RP	−0.3	0.13	−2.21	<.01	−0.23

5.2 Impact of individual factors

5.2.1 Risk perception of global warming

Regarding the impact of the individual factor “risk of global warming” (RGW) on risk perception, we identified a robust link between the affective risk perception for fossil fuels and RGW. This suggests a clear awareness among individuals of the contribution of fossil fuels to climate risk. In the case of e-fuels, although the correlation was moderate, the association might reflect a developing recognition of their potential climate impacts or an associative transfer from well-established perceptions of fossil fuels (Engelmann et al., 2020).

In contrast, the inverse correlation between risk perception of electric drives and RGW suggests a more nuanced understanding. Climate-conscious individuals appear to differentiate EVs from other technologies by recognizing their lower environmental impact. This is consistent with research showing high environmental awareness among electric vehicle adopters, suggesting an alignment between pro-environmental attitudes and the adoption of greener technologies (Plötz et al., 2014; Priessner et al., 2018; Chen et al., 2020).

However, the reluctance to adopt electric drives in the lower RGW segment may be due to a reluctance to change mobility patterns and drive technologies, a phenomenon underpinned by loss aversion theory (Kahneman and Tversky, 1979). This highlights a potential barrier to the transition to sustainable mobility solutions for those less concerned about climate change.

Effective risk communication strategies should therefore be multifaceted, addressing the affective components of risk perception and the cognitive biases that may hinder the adoption of electric vehicles. By extending previous research, our study highlights the importance of understanding the affective dimensions of risk perception in promoting a shift towards more climate-friendly transport options.

5.2.2 Car affinity

The influence of car affinity on perceptions of drive technologies emerged as a critical factor in our study. Individuals with high car affinity reported lower risk perceptions for fossil fuels and e-fuels than individuals with low car affinity, possibly reflecting car enthusiasts' desire to maintain their preferred driving style. Consequently, the utilization of e-fuels would represent an opportunity to simultaneously achieve the preservation of the preferred drive technology and sustainability. This is consistent with the findings of Fischhoff et al. (1978), who found that familiarity with a technology tends to reduce perceived risk, i.e., individuals might be more familiar with fossil fuels than electric drives. Moreover, individuals with a high car affinity may be inclined to consume information that presents a positive view of cars, including fossil fuels, because they confirm their preexisting assumptions and beliefs (Wason, 1960; Hart et al., 2009). Furthermore, biased assimilation may occur when consuming information. This phenomenon refers to the process by which new information is interpreted in a way that aligns with preexisting assumptions and expectations (Lord and Taylor, 2009). This may result in a positive bias towards fuels, while simultaneously increasing risk perceptions of EVs. A high affinity for cars negatively affects the perception of EV, suggesting a fear of losing the features valued in traditional vehicles (Kahneman and Tversky, 1979).

In contrast, individuals with low car affinity perceive fossil fuels and e-fuels as riskier, but have lower risk perceptions for EVs, which may be due to heightened pro-environmental attitudes and perceived risk of global warming (Plötz et al., 2014; Priessner et al., 2018; Chen et al., 2020), as well as a view of cars as functional objects rather than status symbols. Individuals with low car affinity may not perceive cars as status symbols, may not identify with (their) car(s) and their drive technologies and might attach more importance on a car's environmental impact or see it more as a functional object. Although the car remains to be a prominent status symbol (Pojani et al., 2018), another stream of research posits that sustainable mobility itself is becoming a status symbol, reflecting a societal shift towards valuing ecological awareness (de las Heras-Rosas and Herrera, 2019). The emphasis on a vehicle's environmental footprint over prestige may also be in line with broader trends of increased environmental awareness and a desire for sustainable living (Boudet, 2019). Therefore, promoting sustainable mobility options may benefit from framing them not only as environmentally responsible choices, but also as contemporary status symbols that resonate with evolving societal values. However, given the lack of research on the influencing factor of car affinity, future studies should investigate the relationships between environmental attitudes and other individual characteristics.

5.3 Public readiness for sustainable drive and fuel solutions

The public readiness to adopt e-fuels or electric vehicles is a complex and multifaceted phenomenon, influenced by both cognitive and affective factors. The importance of cognitive risk perception in determining the acceptance of e-fuels underscores the necessity for a rational evaluation process among potential consumers. Car affinity emerged as another influential factor. Enthusiasts who value car culture are inclined towards e-fuels, appreciate their sustainability potential, and align with a preference for familiar technologies. Conversely, individuals with a lower affinity for cars demonstrated a lower willingness to adopt e-fuels, potentially due to concerns about toxic emissions, which contribute to their perception of e-fuels as less environmentally friendly, and a lack of attachment to conventional fuel vehicles. Affective risk perception was the least significant predictor, indicating that high affective risk perceptions correspond to low readiness and *vice versa*.

Conversely, affective risk perceptions are relevant drivers of EV adoption, suggesting that the decision to invest in this technology is significantly influenced by affective factors (He et al., 2022). Concerns such as range anxiety and the environmental impact of battery production (e.g., Featherman et al., 2021) may be of secondary importance to the emotional resonance of electric vehicles. Financial concerns, while present, play a minimal role in our findings, suggesting that the perceived economic risks associated with electric vehicles do not critically deter potential adopters. However, the cost trajectory of EVs, namely, the comparably higher price of EVs and the perceived uncertainty of future costs due to recharging and maintenance might impact risk perception (e.g., Egbue and Long, 2012).

These findings underscore the complexity of risk perception in the adoption of sustainable propulsion systems and fuels and call for further research to disentangle the differential influences of cognitive and affective risk perceptions on public willingness to adopt different propulsion technologies.

5.4 Methodological considerations and next steps

Although this study provides valuable insights into cognitive and affective risk perceptions of sustainable drive solutions, it is limited by several factors. Regarding sampling issues, the sample exhibited a gender imbalance, with a majority of males and a small minority of individuals without a driver's license. The inclusion of younger and unlicensed individuals may be beneficial, as they may represent a future cohort of drivers. Their perspectives may be more open-minded, providing a unique opportunity to investigate the risk perception of future generations' sustainable driving practices.

The study employed a convenience sample, primarily recruited via social media platforms, specifically Facebook groups, to gather data on public perceptions of fossil fuels, e-fuels, and electric drives. While this approach proved effective in reaching a broad audience quickly, it also introduced potential biases. Notably, there is a potential self-selection bias, whereby participants who are more engaged with topics related to mobility and alternative fuels might have been more likely to participate, potentially skewing the sample towards individuals with heightened interest or existing knowledge in these areas. Future research should therefore aim to recruit more diverse and representative samples, potentially utilizing stratified sampling techniques to ensure balanced representation across key demographic variables such as age, gender, and educational background. Furthermore, the utilization of multiple recruitment channels beyond social media, including offline methods, could serve to mitigate the biases associated with self-selection and social media algorithms. Even though the sample provided valuable initial insights, the study should be regarded as a case study with conclusions of exploratory nature. Further studies utilizing larger, more representative samples are required to validate these findings and enhance their generalizability to the general population.

In addition, the influence of socio-demographic factors on risk perception was not addressed in our analysis, although many studies suggest that they play an important role in risk perception, e.g., age (Ziegler, 2010; Zaunbrecher et al., 2014; Bertsch et al., 2016), education (Ren et al., 2016; Arning et al., 2023) and gender (Perdan et al., 2017; Linzenich et al., 2019). Further research should take these aspects into consideration to extend our findings.

Although we did collect data on the willingness to use or buy cars powered by e-fuels or electric drives, we did not collect data on the general willingness to use or buy a car. These data could be useful to explain our findings on the readiness for e-fuels and electric drives and should therefore be considered in future studies. Further, we collected data on the perceived environmental, financial, and health risks. These categories were not analyzed in detail; therefore, we have limited insights into what factors determine these categories for our participants. Future research should therefore investigate these categories in detail.

The concept of car affinity, particularly as it strongly relates to risk perception and acceptance, warrants a more detailed investigation. The utilization of an existing scale (Steg, 2005) may not fully encompass the contemporary dimensions of car affinity, particularly in light of the evolving landscape of internal combustion and electric vehicles. Consequently, the development of a more contemporary measurement tool is essential, e.g., for future communication strategies supporting the mobility transition. In addition to conceptualizing car affinity and investigating its influence on the perception of certain drive technologies, future studies should investigate the relationship between car affinity and the perceived risk of global warming as this is important for future risk communication strategies. Moreover, the relationship between car affinity and the risk perception of the depicted drive technologies should be investigated. Given the lack of knowledge about the role of car affinity in the perception of drive technologies, both qualitative and quantitative studies are necessary to gain a more profound understanding of the role of car affinity in the risk perception of alternative drive technologies.

Despite these limitations, the study's insights into the risk perception of alternative drive and fuel technologies represent a valuable contribution to the limited body of literature on e-fuels and car affinity. Another strength of our approach is the consistent comparative empirical framework employed across drive technologies. Nevertheless, further research is essential to extend and validate these preliminary findings.

6 Conclusion

To facilitate the transition to more sustainable mobility solutions and to effectively combat climate change, it is important to gain an understanding of the public's perceptions of fossil fuels, e-fuels, and electric drives. Therefore, this study investigated public perceptions of fossil fuels, e-fuels, and electric drives. The aim was to identify factors influencing risk perceptions regarding different drive types, their perceived efficacy in combating climate change, and public readiness to use or purchase cars with these technologies. A quantitative study using a questionnaire was conducted.

When investigating overall risk perceptions, it was observed that e-fuels were perceived to have the lowest risk, followed by electric drives and then fossil fuels, which were perceived to have a slightly elevated risk. Furthermore, cognitive risk perceptions were overall higher than affective ones. Regarding the risk impacts on different dimensions, perceived risks were found to be highest for environmental impacts, followed by financial and then health impacts.

Our findings indicate that car affinity plays an important role in influencing perceptions of different drive types. Individuals with a higher affinity towards cars tend to perceive lower risks associated with e-fuels and fossil fuels but show a higher perception of risk for electric drives. Examining the risk perception of global warming (RGW), respondents with high RGW exhibited a lower perception of risk associated with electric drives and a higher perception of risk for fossil fuels and e-fuels. It is essential to develop measures that specifically address the influence of car affinity to effectively promote the adoption of sustainable drive technologies.

In terms of readiness to use, higher risk perceptions for e-fuels were related to a lower willingness to adopt them. Among these risks, cognitive risk perception was found to be more influential than affective risk perceptions. Conversely, a higher car affinity is positively related to a higher readiness to adopt e-fuels. For electric drives, affective risk perception emerged as the most significant predictor. Again, higher risk perception (both affective and cognitive) correlated with lower readiness. A third significant factor was financial risk, though its influence was relatively small.

From our results, several implications for policymakers can be derived. The implementation of tailored communication strategies that resonate with car enthusiasts and emphasize the benefits of e-fuels and electric drives can assist in reducing perceived risks and increasing acceptance. In particular, for individuals with a high RGW, it would be beneficial to emphasize the environmental advantages of alternative drives. Given that individuals with low RGW tend to be averse to the use of electric drives, it is recommended that policymakers prioritize the promotion of environmental awareness and the creation of incentives that extend beyond the environmental aspects of the drives. Additionally, as the familiarity with combustion engines appears to reduce the perceived risks of e-fuels among car enthusiasts, policymakers should also prioritize enhancing familiarity with electric drives among the general public. Ultimately, the promotion of sustainable drive technologies will necessitate the implementation of targeted interventions that address both cognitive and affective concerns, with the objective of enhancing familiarity and reducing the perceived risks associated with e-fuels and electric drives. This comprehensive approach is essential for the successful transition to sustainable mobility.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of the "Empirical Human Sciences" department of the Faculty of Humanities at RWTH Aachen University (ETHICS APPROVAL NUMBER: 2022_010_FB7_RWTH AACHEN). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ER: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing–original draft, Writing–review and editing. TS: Conceptualization, Data curation, Investigation, Methodology, Writing–original draft, Writing–review and editing. UK: Conceptualization, Data curation, Methodology, Writing–original draft, Writing–review and editing. KA: Funding acquisition, Investigation, Methodology, Supervision, Writing–original draft, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenrg.2024.1415430/full#supplementary-material

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