What Makes Futuristic Vehicles Risky? Preliminary Design Considerations Based on Automation Level and Driving versus Flying Modes

Hanna J. Neroj
Georgia Institute of Technology
hneroj3@gatech.edu

Bruce N. Walker
Georgia Institute of Technology
bruce.walker@psych.gatech.edu

ABSTRACT

When considering novel, futuristic vehicle designs, it is important to consider the technology's "adoption potential". Literature suggests that perceived risk is one of the key determinants of trust, which in turn affects adoption potential. Our research investigates how risky the general public perceives different design configurations for futuristic urban mobility vehicles, comparing highly futuristic flying cars to more traditional cars, while factoring in the issue of whether the vehicle is operated manually or autonomously. The initial results indicate that there is a combined effect of the level of autonomy and the driving mode of the vehicle on the way people perceive its riskiness. Further, the "exposure" component of perceived risk could be an important driver of people's judgments for future technologies. More research is required to establish the main drivers of futuristic, multimodal vehicles' risk perception.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **Empirical studies in HCI**;

KEYWORDS

perceived risk, autonomous vehicles, eVTOL, user interface, technology adoption

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1 INTRODUCTION

The first automobile patent was issued to Carl Benz in the year 1886. Soon after, in 1908, Ford Motor Company introduced a model T car that quickly became adopted by the masses in the US. Since that time, a broad range of shapes, styles, and designs for automobiles have been devised, leading to tremendous adoption of this transportation technology. Currently, over 90% of households in the US have at least one vehicle [1]. Despite the success of the automobile overall, there have been numerous car designs that never won over the market, failing to meet consumers' needs and expectations, and in many cases leading to the failure of the whole company. This fascinating history of commercial successes and failures brings us to our global research question: *what makes an automotive design an icon of its era?* More specifically, what factors lead to the success of a certain technology, and could we predict what influences technology adoption? The work in progress described in this paper aims to tackle those questions. We are interested specifically in the design of futuristic transportation technology, considering both evolutionary and revolutionary technology. We hope to improve existing theoretical knowledge of technology adoption and inform the designers and developers of the factors that affect their product design, depending on whether the intention is to revolutionize the field, or make a seamless transition, keeping familiarity with previous iterations of the product. Our intention is to address the gap in the general knowledge of the User Interface design of futuristic vehicles aimed for both driving and flying; currently, such research is frequently done separately within either automotive or aerospace engineering research contexts.

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2 BACKGROUND

The latest US transportation statistics indicate an increasing trend of people who travel, both using highways and air travel; this includes an increasing trend of air taxis and other small personal aircraft [2]. These alternative transportation means can be grouped under the umbrella term of Urban Air Mobility (UAM). It is a concept that focuses on the integration of traditional and highly automated systems into the everyday commute of people in metropolitan areas and cargo moving, aiming to reduce traffic congestion during peak times [3]. The industry is building solutions to face this increasing demand for alternative transportation means, one of them being the so-called eVTOL flying car or simply *flying car*, aiming to introduce them to the public shortly, by the year 2025 [4], [5], [6]. However, there is limited research on user-oriented issues, such as trust and technology adoption. Several studies have been conducted related to flying cars' social acceptance and perceptions regarding their safety [7], [8], [9], but not in the context of risk perception, trust, and technology adoption.

Another important aspect that we want to address is the introduction of vehicles with an increasing level of autonomy. Eker et al. describe flying cars as transportation means that have the potential to incorporate all elements of the future shared mobility and autonomous driving in spatially dual operations by incorporating capabilities of horizontal driving and vertical takeoff and landing [7]. Li et al. [10] argue that given the users are generally not familiar with the functionality of the future automated vehicles, the information they receive before interaction with the technology is essential in shaping their trust and reliance on automation; an essential part of it being the perceived risk during initial interaction. Literature suggests that successful technology implementation is highly reliant on targeted users' attitudes towards it, in particular trust. Trust is "a way that humans mitigate uncertainty" [10]. McKnight et al. [11] argue that trust in technology differs from trust in people and there are specific factors that will determine whether people will trust the technology, as well as continue using it, which are different from acquiring trust in a human-human context. The foundational theories of trust in a human-automation interaction context suggest that risk must be perceived in order for true trust to occur [12]. Moreover, risk measurements seem to be a critical issue for construct validity when studying the construct of trust, as opposed to a distinct construct of confidence [12]. This makes risk perception a sensible starting point for our investigations regarding trust and UI design of flying cars.

2.1 Perceived risk

Risk can be defined as a combination of the probability of harm and the magnitude of its consequences. For example, to assess the objective risk of air travel, one may look at the statistical analysis of air accidents by US carriers over 10 years to determine likelihood; and then factor in the consequences of a crash. Statisticians thereby calculate that it is safe to engage in air travel. However, such a calculation is challenging for laypeople. Literature suggests that perceived risk always includes a large component of judgment, despite an appearance of objectivity [13] and is prone to multiple biases in human judgment, such as the availability heuristic [14]. Thus, perceived risk is often not aligned with objective risk, and is inherently subjective [15], [16]. Raue and Lermer argue that "risk means different things to different people," [16] thus it will be subject to individual differences (e.g., in reliance on intuition, affect, or feelings). Wilson and colleagues' research suggests that perceived risk should be captured in measurements as a multidimensional construct that includes affect elicited by the hazard, as well as subjective feelings of severity of the outcomes of a hazard [17]. In a follow up study, Walpole and Wilson extended their risk perception measurement scale to include the susceptibility dimension, which examines subjective perception of the likelihood of suffering consequences, given exposure to a hazard [18]. The final risk scale utilized in our present study was adopted from [18] and consisted of the following dimensions: *affect* (five questions investigating feelings of fear, anxiety, and worry when thinking of the technology in question); *exposure* (three questions investigating the subjective perceived likelihood of using a particular technology in the near future); *severity* (three questions investigating how severe the impact of using the technology would have on oneself); and *susceptibility* (five questions investigating the subjective perception of the likelihood of suffering the consequences from using the technology on oneself, family, and property).

2.2 The characteristics of the flying car

The literature describes flying cars as a transportation mode that has the potential to incorporate all elements of the future shared mobility and autonomous driving in spatially dual operations [7]. The currently available design of a flying car is a 2-seater, four-wheel sedan car with extendable symmetrical rotors for the flight phase (see Figure 1).

Figure 1: 2021 XPENG 6th Generation Flying Car. Visualization by XPENG AEROTH. [Public domain], via YouTube. (https://www.youtube.com/watch?v=6gpRCw2Y4-8&t=1s).

2.3 Research Questions

In this project, then, we seek to evaluate how risky the general public perceives different design configurations for futuristic urban mobility vehicles, comparing highly futuristic flying cars to more traditional cars, while factoring in the issue of whether the vehicle is operated manually or autonomously.

3 METHOD

3.1 Participants

This Approval for the study was obtained from the university's Institutional Review Board (IRB). Participants were recruited through online means, by sharing a link to the survey on online forums (LinkedIn, Facebook, SurveySwap). The 185 participants were located primarily in the USA (58.9%) and Poland (19.5%); the remaining 21.6% of the participants were located in the UK (5.4%), Germany (4.3%), Austria, Canada, France, India, Italy, Malta, the Netherlands, Singapore, and Sweden (approx. 0.5-1% per each country). There were 118 females (aged M=35.5, SD=13.4), 65 males (aged M=33.3, SD=12.4), one non-binary individual aged 35, and one participant, aged 18, who did not wish to identify their gender. A total of 86.5% of participants had a valid driver's license.

3.2 Materials and procedure

Data were collected through an online questionnaire delivered via the Qualtrics platform. After giving informed consent, participants completed demographics questions, including whether they hold a valid driver's license. During the experimental portion of the study, participants viewed pictures of one specific type of vehicle, which were accompanied by a brief description of the technology and its intended use. The experimental task consisted of answering questions related to how participants perceived the risk of the vehicle they were presented. The risk assessment consisted of 16 survey questions in the form of statements, with responses on 5-point Likert agreement scales (adopted from [18]). This risk assessment scale is comprised of four separate subscales covering perceived risk components related to "affect" or emotional reaction; "severity" of potential negative outcomes; "susceptibility" to the danger; and "exposure" to the technology. The vehicles differed on two dimensions: (1) mode, specifically whether the vehicle was driven on the road or flown in the air; and (2) autonomy, specifically whether the vehicle was operated by the occupant or operated autonomously via a software control system. Thus, there were four separate vehicles: manually-driven car; autonomous car; manually-flown flying car; and autonomously-flown flying car. Each participant saw and rated only one type of vehicle, leading to four between-subjects groups in the study. There were, therefore, two independent variables (mode and autonomy), and four dependent variables (4 risk components), in a between-subjects multivariate design. We conducted a multivariate analysis of variance (MANOVA) followed by simple effects analysis to investigate the nature of any statistically significant interactions.

3.3 Hypotheses

In this paper, we will evaluate how risky the general public perceives different design configurations of the futuristic urban mobility vehicles, comparing highly futuristic flying cars to traditional cars, differentiating on the level of autonomy of these vehicles. We hypothesize that because of the novelty of the flying cars, they may induce feelings of being highly risky to the public; so risky, that it may prevent people from using them. The aim of this study is to see whether two key design aspects impact risk perception of such vehicles. Specifically, we hypothesize that: Fully autonomous flying cars will be perceived as less risky than the flying cars that are human-operated (*Hypothesis 1*); Flying cars will yield higher perceived risk scores than the traditional cars in for both autonomy levels (*Hypothesis 2*); There will be a statistically significant interaction effect between autonomy level and driving mode (*Hypothesis 3*).

4 RESULTS

The global MANOVA yielded statistically significant interaction effect between the mode of driving and the automation level of the vehicle, F(4, 178)=19.381, p<.001, Pillai's τ =.303, partial η^2 = .303. There was homogeneity of covariance matrices, as assessed by Box's M test (p = .007). Given the significant interaction effect, we proceeded with univariate two-way ANOVAs to determine whether there are any statistically significant interaction effects for each perceived risk dimension. There was a significant interaction between driving mode and the automation level for affect, F(1, 181) = 24.547, p<.001, partial η^2 = .119; for exposure, F(1,181) = 56.960, p<.001, partial η^2 = .239; for severity, F(1,181) = 10.471, p=.001, partial η^2 = .055; and for susceptibility, F(1,181) = 16.623, p<.001, partial η^2 = .084. Given these significant results, we proceeded to analyze simple main effects for each independent variable. Figure 2 presents these results, as described below. For the simple main effect of autonomy, there was a significant difference between "driving only" vehicles and "driving + flying" vehicles for the no-autonomy case (ie., human-driven vehicles) on the affect score, F(1, 181) =40.632, p<.001, partial η^2 = .183, but not for the fully autonomous vehicles, F(1, 181) = 0.507, p = .477, partial η^2 = .003. A similar effect was observed across all other perceived risk dimensions: for exposure, there was a significant difference between "driving only" and "driving + flying" vehicles for the human-driven vehicles, F(1, 181) =121.331, p<.001, partial η^2 = .401, but not for the fully autonomous vehicles, F(1, 181) = 0.034, p = .854, partial η^2 = .000; for severity, there was a significant difference between "driving only" and "driving + flying" vehicles for the human-driven vehicles, F(1, 181) =24.348, p<.001, partial η^2 = .119, but not for the fully autonomous vehicles, F(1, 181) = 0.081, p = .776, partial η^2 = .000; and for susceptibility, there was a significant difference between "driving only" and "driving + flying" vehicles for the human-driven vehicles, F(1, 181) =24.249, p<.001, partial η^2 = .118, but not for the fully autonomous vehicles, F(1, 181) = 0.807, p = .370, partial η^2 = .004. The level of autonomy had a significant effect on the affect score for "driving only" vehicle types, F(1,181)=63.509, p<.001, partial η^2 = .260, but not for vehicles with dual driving capabilities ("flying + driving" mode), F(1,181)=0.703, p=.403, partial η^2 = .004; and that effect remained true for each of the perceived risk dimensions. Specifically, the level of autonomy had a significant effect on the exposure score for "driving only" vehicle types, F(1,181)=123.125, p<.001, partial η^2 = .405, but not for vehicles with dual driving capabilities, F(1,181)=0.069, p=.793, partial η^2 = .000; for severity score, the level of autonomy had a significant effect for "driving only" vehicle types, F(1,181)=22.433, p<.001, partial η^2 = .110, but not for vehicles with dual driving capabilities, F(1,181)=0.008, p=.927, partial η^2 = .000; and for susceptibility, the level of autonomy had a significant effect for "driving only" vehicle types, F(1,181)=56.871, p<.001, partial η^2 = .239, but not for vehicles with dual driving capabilities, F(1,181)=2.711, p=.101, partial η^2 = .015.

Figure 2 provides a detailed breakdown of perceived risk scores per sub-dimension and allows one to clearly see the trend in the data for both driving modes. The dotted line represents "driving + flying" mode and the solid line represents the "driving only" mode. Notably, the perceived risk scores tend to increase with the introduction of autonomy for the "driving only" mode for affect (Figure 2a), severity (Figure 2b), and susceptibility (Figure 2c), whereas for exposure there is a decline of perceived risk score with the increase of automation (Figure 2d). For the "driving + flying" mode, all four of the perceived risk scores remain relatively stable across levels of autonomy. The mean perceived risk scores on the affect dimension were 1.54 (*SD*=0.68) for human-driven traditional car, 3.15 (*SD*=0.99) for fully autonomous traditional car, whereas for the flying car they were 2.83 (*SD*=1.19) for human-driven and 3.0 (*SD*=1.0) for fully autonomous flying car. The mean perceived risk scores on the severity dimension were 1.65 (*SD*=0.83) for human-driven traditional car, 2.56 (*SD*=0.86) for fully autonomous traditional car; for the flying car they were 2.60 (*SD*=1.02) for human-driven and 2.62 (*SD*=1.03) for fully autonomous flying car. The mean perceived risk scores on the susceptibility dimension were 1.45 (*SD*=0.63) for human-driven traditional car, 2.88 (*SD*=0.95) for fully autonomous traditional car, whereas for the flying car they were 2.38 (*SD*=1.02) for human-driven and 2.7 (*SD*=1.04) for fully autonomous flying car. The mean perceived risk scores on the exposure dimension were 3.51 (*SD*=0.53) for human-driven traditional car, 2.38 (*SD*=0.37) for fully autonomous traditional car, whereas for the flying car they were 2.38 (*SD*=0.47) for human-driven and 2.36 (*SD*=0.61) for fully autonomous flying car.

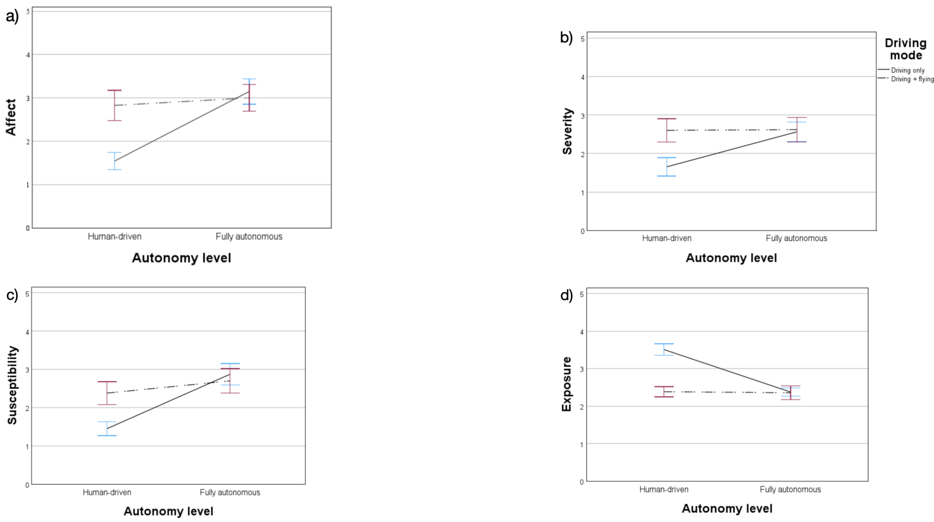

Figure 2: Risk perception by autonomy level and driving mode, split by four perceived risk dimensions: a) affect b) severity c) susceptibility d) exposure.

5 DISCUSSION

The results of our initial study indicate that there is a combined effect of autonomy level and driving mode on the risk perception of futuristic vehicles. Further, simple effect analyses suggest that for the vehicles with only driving capability, the level of autonomy affects people's risk perception of those vehicles such that the vehicles with more autonomy seem to be perceived as riskier. This seems to be true for all sub-dimensions of the perceived risk as described in [18]. However, for multimodal vehicles (i.e., driving and flying capabilities) the level of autonomy does not seem to significantly influence perceived risk. Autonomous vehicles seem to induce significantly higher feelings of fear, anxiety and worry (M=1.54, *SD*=0.68) than those with no autonomy (M=3.15, *SD*=0.99) (affect dimension). This effect is not surprising and has been shown by a large body of research within the autonomous vehicles (AV) literature on human-automation trust; for instance, [19] argued that expectancy based upon predictable behavior of the vehicle saves on drivers' cognitive effort such that they do not have to "worry" about vehicle functioning and can begin to depend on it. Muir [20] argued that trust depends on how generalizable past dependability is for future scenarios. In that sense, our results seem to align with prior research, and we could infer that due to the experience with traditional cars, people generally would rely on human-driven cars more and generally depend on them more than on the less familiar self-driving cars. Yet, the increasing familiarity with self-driving cars might allow people to make better judgments on the likelihood of "something bad" happening, even though they still seem to not expect to be exposed to using them in the near future (exposure M=2.38, *SD*=0.37 on a 5-point scale for autonomous "driving only" vehicles). However, the noteworthy result is that this seems not to be the case for more futuristic vehicles, such as flying cars. Our data showed no significant difference in perceived risk scores for the "driving + flying" mode across two autonomy levels, raising the question of why people seem not to fear autonomous flying cars much more than human-piloted flying cars, since the effect of autonomy for traditional cars is so prevalent. The simple effects results and the visual inspection of the graphs seem to suggest that - contradictory to our assumptions - it is possible that people may not perceive autonomous flying cars as more fearful, worrisome, or anxiety-inducing. Interestingly, people seem to be slightly more fearful, anxious, and worried about self-driving cars than self-flying cars. Looking at the mean perceived risk score plots (Figure 2), even though people seem to feel that they will not be exposed to fully autonomous "traditional" cars, their risk perception was still influenced by the autonomy level and the perceived risk scores were different across perceived risk dimensions. People felt that it is almost equally unlikely to be exposed to multimodal vehicles that are human-driven or fully autonomous in the near future. This indicates that exposure might be a risk dimension that somehow overweighs the importance of other dimensions. Specifically, perhaps the multimodal vehicles represent technological advancement so distant for people, that the remaining dimensions of perceived risk do not seem to be of equal importance? To answer those questions, we have begun to deploy more nuanced multivariate statistical analyses that may unravel the loadings of particular factors that may be driving risk perception more than others in the context of futuristic vehicles. Our initial investigations utilizing canonical correlation methods suggest that the exposure dimension may be driving the direction of the interaction effect of autonomy level and driving mode within the four-dimensional perceived risk space. Our plan is to continue those considerations as this work progresses. What may be specifically of interest to the Automotive UI community is that these data could inform the discussion on the UI design of flying cars, depending on whether those new multimodal vehicles are intended to be introduced as evolutionary vehicles (somewhat familiar, like a car, but flying), or whether the aim is to revolutionize the transportation industry by deploying a unique, futuristic vehicle. Our data, though preliminary, suggests that in the latter case the level of automation may not be a particularly relevant factor associated with risk perception and as such might not be a reliable predictor for technology adoption. However, should the technology be introduced as the next evolution of a familiar car, the level of automation seems to remain an important factor to be considered when trying to meet customer needs. Again, we highlight that more research is required to confirm this thesis. Finally, our preliminary results indicate that there is a need to further investigate the exposure dimension of perceived risk, as it may be dominating the direction of the perceived risk in the four-dimensional space. This indicates that perceived risk (in the context of futuristic transportation) could be predominantly shaped by the (more real) potential of being exposed to this technology in the near future. It seemed that the more distant the deployment of a technology is, the less specific functionalities may matter, such as whether it is operated by a human driver, or being fully autonomous. This is consistent with the decision theory literature, in that the high ambiguity largely impacts decision-making process [21].

5.1 Limitations

It must be noted that this is a work in progress and as such, the conclusions should be treated with care. The preliminary results suggest that it is possible that this scale may not be fully efficient in capturing perceived risk in the futuristic technology context such as flying cars, as the scores may be influenced by the exposure dimension. Additionally, we investigated only two extreme cases of the level of automation; future studies could differentiate between different automation levels. Nevertheless, we see the value in those preliminary results as they can shape the direction of future studies of risk perception of futuristic, innovative technology.

6 CONCLUSIONS AND FUTURE DIRECTIONS

This work in progress raises an important question with regards to some of the factors determining technology adoption – does the autonomy level matter in the context of futuristic technology? It seems like an important matter in the context of technology adoption and trust regarding self-driving cars versus traditional cars operated by real persons. For instance, the affective responses were higher for fully autonomous car (ie., feeling fearful, anxious, and worried). The non-significant simple effect of the mode across perceived risk dimensions suggest that this may not be the case for futuristic technology like flying cars. Specifically, it seems not to matter whether the flying car is fully autonomous or operated by real persons, keeping the perceived risk scores relatively stable across these two dimensions. Overall, our primary conclusions are as follows:

- There is a combined effect of the level of autonomy and the driving mode of the vehicle on the way people perceive its riskiness. This initial finding could support UI designers in the future to help them consider user perspective and the potential for technology adoption.
- Exposure could be an important perceived risk driver. For futuristic, revolutionary technology adoption, exposure seems to be an important factor. Further analysis is required to establish the influence of this dimension on the overall risk perception. Additionally, a new scale, or a refinement of the current scale, may be more appropriate to capture the perception of the risk in the context of futuristic, innovative technology.
- Autonomous cars seem to be perceived as more risky than traditional human-operated cars. It seems that for technology that is familiar to people, the more autonomy is introduced, the higher the perceived risk.
- However, autonomous flying cars seem not to be perceived as more risky than human-piloted flying cars. For technology that is novel and futuristic, the level of automation may not be the key contributor to perceived risk; however, more research is required to confirm this thesis.

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