Human, AI vs. synergy agency: how agency framing affects perceived uncertainty, controllability, and trust in AI in autonomous vehicles

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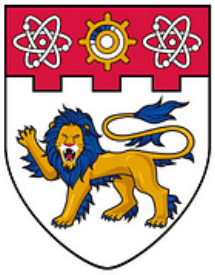

NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

HUMAN, AI, VS. SYNERGY AGENCY:

HOW AGENCY FRAMING AFFECTS PERCEIVED UNCERTAINTY, CONTROLLABILITY, AND TRUST IN AI IN AUTONOMOUS VEHICLES

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A thesis submitted to the Nanyang Technological University in partial fulfillment of the requirement for the degree of Master of Communication Studies

2024

Statement of Originality

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Liu Xinyi

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I have reviewed the content and presentation style of this thesis and declare it is free of plagiarism and of sufficient grammatical clarity to be examined. To the best of my knowledge, the research and writing are those of the candidate except as acknowledged in the Author Attribution Statement. I confirm that the investigations were conducted in accord with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

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Shirley S. Ho

Authorship Attribution Statement

This thesis contains material from 1 paper accepted at conferences in which I am listed as an author.

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The contributions of the co-authors are as follows:

- I completed the initial project conceptualization and edited the manuscript drafts. The manuscript was revised by Prof Shirley S. Ho.
- I designed the study with Prof Shirley S. Ho and collected all the data using Qualtrics. I also analysed the data.
- Prof Shirley S. Ho assisted in the conceptualization and guided the project, including data collection, manuscript proofreading, and the interpretation of the results.

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Table of Content

Abstract

Media often depicts artificial intelligence (AI) as autonomous entities that outperform human operators in the realm of automation. However, policymakers and industrial stakeholders are increasingly seeing AI as a form of assistance that can coexist with human involvement across a range of automation scenarios. How do the contrasting frames regarding AI, human agency, and synergy agency in automation affect public perception and trust toward these emerging technologies? This study examined agency framing in the communication of AI-automated technologies, delving into whether accentuating AI agency in replacing human drivers or highlighting human agency involvement in driving affects audience perception of technologies. The findings reveal that compared with synergy agency framing and human agency framing, AI agency framing significantly decrease perceived controllability and increase perceived uncertainty. When it comes to enhancing trust in AI and autonomous vehicles, synergy agency framing, which emphasizes collaborative interaction between human and AI, significantly increased trust through increased perceptions of controllability and reduced uncertainty, suggesting it is the most effective strategy for enhancing trust in AI systems and autonomous vehicles. These outcomes contribute to the discourse on how strategic communication can influence the acceptance of AI technologies, offering significant implications for media representation and policy-making in the era of advanced automation.

Keywords: agency framing, AI, perceived uncertainty, perceived controllability, trust, autonomous vehicles

Introduction

The implementation of Artificial Intelligence (AI) in various forms of automation has presented both opportunities and challenges for human interaction with automated systems. AI, as a software-driven system that can execute tasks dependently is liberating humans from various manual labors. However, it also raises concerns related to the loss of control and uncertainties, as it tends to distance human factors from the decision-making process (Endsley, 2017; Lim, 2018; Mittelstadt et al., 2016). From the communication perspective, further research is needed to examine how issues related to human and AI agency in automation should be presented to the public.

Media coverage frequently depicts AI-enabled automation, particularly in the context of autonomous vehicles, as independent entities, despite the current requirement for human operators to oversee the operations of automated systems (Land Transport Authority of Singapore, 2017; Ross, 2018). Media coverage surrounding AI demonstrates a tendency to portray AI-enabled technologies, such as autonomous vehicles and AI medical experts, as the end of human involvement in automation (Braun & Randell, 2020). A content analysis of AI-related news coverage within the healthcare industry has substantiated this observation (Bunz & Braghieri, 2022). The results of this analysis revealed a tendency among media platforms to depict AI as an independent entity and construct a future wherein AI outperforms and replaces human roles in various domains. However, industry players and regulators still acknowledge the indispensable role that human operators need to play in various forms of automation (Land Transport Authority of Singapore, 2017; Ross, 2018).

Media coverage surrounding autonomous vehicles often demonstrates a contradictory and biased narrative. Previous research has criticized the media's science and technology coverage for presenting superficial, biased, and inaccurate information while ignoring the technical and scientific details (Jelinski et al., 2021). A case in point is the portrayal found in

Singaporean media, which frequently shows a positive portrayal wherein AI systems replace human drivers entirely, positioning AI as the ultimate solution for addressing traffic accidents and congestion challenges (Ju-Len, 2020; Ku & Conejos, 2023). However, there are contrasting frames of autonomous vehicles that bring human efforts back into public view, pointing out that even in autonomous vehicles, humans are still able, or required, to act when it is urgent (Johnson, 2019). The contrasting frames of AI and humans in autonomous vehicles denote different facets of reality - they highlight either the AI agency with omnipotence and superior performance, the human agency with indispensable intervention in the autonomous driving process, or the synergy between human and AI agency with their interdependence. A deeper investigation into the effects of these three types of frames in media coverage on audience perception is necessary.

Research Gaps

The framing of messages influences audiences' perceptions by making certain information more salient. Previous studies have examined the role of framing in communicating emerging and controversial technologies to the public, including autonomous vehicles and AI (Bingaman et al., 2021; Ho, 2021; Ho, et al., 2020). For example, one study found that frames of benefits can induce more favorable attitudes toward autonomous vehicles in comparison with frames of risks (Ho, 2021). Another study on the framing of AI found that people exposed to the "AI as social progress" frame showed greater support for AI than those exposed to the "AI as potential threat" frame (Bingaman et al., 2021). These studies delved into the societal-level frames related to the adoption of AI and autonomous vehicles such as economy and safety. However, these investigations often overlook the frames of the technical aspects, such as the specific role that the relationship between AI and humans in autonomous vehicles (Jelinski et al., 2021).

Previous studies have examined the effects of human and AI agency issues on users. Studies in human-computer interaction (HCI) and human-machine communication (HMC) have investigated the effects of issues involving agency between humans and AI on people's perception of automation. A study found that individuals tend to perceive greater uncertainty and distrust toward computer performance when AI, rather than humans, dominates decision-making (Liu, 2021). Another study found that when people were told that humans are still in the decision loop, namely involved in the decision-making, they showed more initial trust in the systems (Aoki, 2021). Earlier studies also found that pilots showed less trust in advanced aircraft due to the unpredictability of accuracy and reliability in advanced automation systems (Wickens, 1998). However, no investigation has yet been implemented to examine the effects of the portrayal of agency issues in AI-based technologies, despite evidence substantiating that media coverage tends to favor AI agency frames in the news related to AI-based technologies (Bunz & Braghieri, 2022).

In addition, this study also wants to address the middle ground between human agency and AI agency, that is, the synergy agency (Di & Shi, 2021). In HCI research, although studies have found the beneficial impact of the involvement of human agency in promoting trust in autonomous technologies (Cornelio et al., 2022), few studies have examined the extent to which human agency can be incorporated --- should humans be allowed to dominate the functioning and assisted by systems, or should they collaborate with systems? From the perspective of the framing of agency, the synergy agency does not emphasize the agency of one party but focuses more on their interdependence.

Among the emerging technologies, AI has initiated a more rapid transition from human labor to intelligent automation, leading to increased tensions between human actors and AI. This shift has also triggered deeply rooted concerns about uncertainty and uncontrollability in automation. The evidence from content analysis, HCI, and HMC research

imply that the way agency issues in AI-automated technologies are conveyed to the public may influence public perceptions and acceptance of those technologies. However, the effect of agency framing on public attitudes toward AI and AI-based technology remains unexamined.

Research Aims

In sum, through an online experiment, this study aim to explore the effects of agency framing on audience uncertainty and controllability perceptions, as well as trust in AI and autonomous vehicles. This research acknowledges existing gaps in the literature regarding the framing of AI and autonomous vehicles, as well as HCI and HMC. As this study addresses the tensions between humans and AI agency in the context of intelligent automation by examining public perceptions of agency issues, the findings will contribute to the broader discussion on the psychological impact of the media coverage of AI applications. Additionally, the findings from this study could have practical implications for communication strategies related to AI-enabled automation. The media, industry, and policymakers can better deliver messages about AI-automated technologies by understanding how different framing strategies may affect public attitudes.

The literature review for this study will consist of four sections. The first section includes the background of the study, focusing on AI and autonomous vehicles. Agency issues in autonomous vehicles will be discussed to highlight the main concept of this research. The second section will delve into framing theory and previous literature on the framing of AI as well as autonomous vehicles. This section will also explore the concept of agency, how it can be integrated into framing strategies, and its implications for audience perception and attitude. The final section of the literature review will propose the study hypotheses on how AI agency framing and human agency framing affect the perception of uncertainty and controllability and how they can shape the public's attitude.

Literature Review

Artificial Intelligence and Autonomous Vehicles

In technical terms, *AI* is defined as a software-driven system that executes tasks and generates outcomes by adhering to specific algorithms and data guidelines (Lim, 2018). In a broader sense, AI is commonly viewed as the application of machine learning algorithms, marked by its capacity to autonomously create or revise decision-making rules (Mittelstadt et al., 2016). AI possesses human-like intelligence, which involves the capacity to "think" and act, enabling it to make decisions based on the analysis of its surrounding environment (Garnham, 2017; Jones-Jang & Park, 2022).

Autonomous vehicles are one application of AI. An autonomous vehicle is equipped with technological devices that sense surrounding environments, plan movements, and act according to pre-programmed plans. Various devices and AI carry out this sense-plan-act routine (Lim, 2018; Goh & Ho, 2024). For example, sensors within an autonomous vehicle are capable of detecting objects in motion and gathering relevant data about these objects (Lim, 2018). The AI system subsequently executes rules, such as applying the brakes to bring the vehicle to a stop. The implementation of AI systems in autonomous vehicles allows vehicles to decide routines and trajectories based on the data gathered from external and internal environments and eventually implement actions independently.

Although AI is expected to help autonomous vehicles gain full autonomy, the existing legislation and the reality within the automotive industry acknowledge the indispensable role that humans are likely to continue playing in their future development. The chapter aims to provide contextual information about these contrasting stances, focusing on the discrepancy between an idealized full-autonomy dream and the pragmatic need for human participation. In the following paragraphs, by providing these two stances, the rationale of this study will be stated.

On the Way to Gain Full Autonomy

The *Society of Automotive Engineers* (SAE, 2021) developed a classification of six levels of driving automation, ranging from level 0 to level 5. Each level represents an increasing degree of control and decision-making performed by automated systems. Level 1 involves a significant degree of human control, with the human operator being primarily responsible for vehicle operations. In levels 2 and 3, advanced driver assistance systems (ADAS) take on the role of managing various driving tasks, including both steering and acceleration. Nonetheless, the human driver retains the responsibility of monitoring the vehicle's functionality and must be prepared to assume manual control of the vehicle when necessary. Level 4 entails highly automated driving systems, where the need for human input is minimal. Level 5, characterized by full autonomy, is the ultimate goal for the engineering and automotive industries (Biondi et al., 2018; Society of Automotive Engineers, 2021). It is also the most extensively researched form of driving automation within the fields of psychology and sociology (Kassens-Noor et al., 2020, 2021). The SAE levels establish a developmental roadmap with the anticipation that autonomous vehicles will ultimately attain full autonomy.

This anticipation is also manifested in various message frames of autonomous vehicles. According to media coverage, reports, and research, one of the primary objectives of achieving fully autonomous vehicles is to minimize human errors from human-controlled driving. Traffic reports show that human errors play a substantial role in most road traffic accidents, contributing to over 90% of these accidents (National Highway Traffic Safety Administration, 2008; Singh, 2015). Scholars in the transportation field have suggested that roads will be considerably safer with the majority of human-driving vehicles being substituted by autonomous vehicles (Fagnant & Kockelman, 2015). In media coverage, AI systems are often depicted as having the potential to eliminate accidents caused by human

errors by outperforming human drivers and eventually replacing them (Joshi, 2022). However, this tendency to portray AI technologies as entities that outperform and potentially substitute humans has been largely criticized.

Technological Solutionism in Media Coverage

AI-related media coverage and research have faced criticism for their inclination toward technological solutionism. *Technological solutionism* is the belief that advanced technology alone can provide solutions to various challenges without considering the broader social, cultural, ethical, and individual context in which these challenges exist (Morozov, 2013). Such coverage and research often present AI and other automated technologies with positive envisions, such as the portrayal of those technologies as superior to humans and the solution to human errors. However, this "better than human" narrative leaves little room for discussions, concerns, or critical examination of the technologies themselves (Bunz & Braghieri, 2022).

Critics of technological solutionism argue that it oversimplifies complex problems and neglects the multifaceted nature of societal issues. In the case of autonomous vehicles, the elimination of deaths and injuries caused by human errors is a technologically deterministic construct, leading the public to overlook the pitfalls behind the "superiority" of technologies and researchers to ignore the challenges including power dynamics, human perceptions, and human behaviors (Braun & Randell, 2020).

Prior research found that the prevailing narrative concerning AI-enabled technologies demonstrates positivity and optimism toward the increased autonomy of automation. A content analysis showed that media coverage generally tends to display optimistic attitudes toward autonomous vehicles (Jelinski et al., 2021). In the context of AI-based automation in medicine, a content analysis study has found that media coverage often presents AI technology as an independent entity with the potential to surpass or replace human experts

and ignores aspects such as collaboration, assistance, information dissemination, and human support (Bunz & Braghieri, 2022). The authors also found a substantial volume of media coverage that presents AI as a replacement for human agency rather than highlighting its potential for collaboration, assistance, information provision, or support for humans. This narrow representation limits the examination of ethical, social, and practical considerations surrounding AI utilization (Bunz & Braghieri, 2022).

The portrayal of the autonomy of automation has a significant impact on public perceptions. In the case of autonomous vehicles, alternative terms are commonly used, such as "self-driving," "automated," and "driverless" cars. A study conducted by Kassens-Noor et al. (2021) examined participants' reactions to different terms used for autonomous vehicles and demonstrated that the term "self-driving" elicited heightened concern-related responses from the public, likely due to the implied higher level of autonomy associated with it. Even though it has been found that people can react differently to technical terms of autonomous vehicles that demonstrate different levels of autonomy, the effect of messages that highlight AI's autonomy on the public's perceptions of AI and autonomous vehicles has not been examined.

Media coverage often portrays AI technologies, such as AI doctors and autonomous vehicles, as independent entities capable of replacing humans and eradicating human errors, despite the fact that the actual state of these technologies is not as advanced as depicted. While the ultimate goal for autonomous vehicles is to achieve full autonomy, current research in fields like engineering, psychology, and public policy recognizes the importance of human involvement in the driving experience in promoting trust.

Human Control in Autonomous Vehicles

Currently, fully autonomous vehicles are not yet available for the mass market. The autonomous vehicles that are commercially implemented mostly fall under SAE levels 2 or 3,

far from reaching full automation. Singapore stands out as a country with comprehensive legislation supporting autonomous vehicles (Nunes et al., 2018). In Singapore, trials for autonomous vehicles ranging from level 3 to level 5 require specific authorization from the *Land Transport Authority of Singapore* (LTA). The LTA also imposes restrictions on the testing areas, as outlined in the *Road Traffic (Autonomous Motor Vehicles) Rules 2017*. The Rules also stipulated the need for humans in autonomous vehicles, specifying "a qualified safety driver or operator to be seated in an autonomous motor vehicle to monitor the operation of the vehicle and to take over operation of the vehicle if necessary" (Land Transport Authority of Singapore, 2017).

In addition to legal regulations, the significance of human involvement is also recognized by HCI research. HCI researchers have proposed the *automation conundrum*, describing a dilemma where human factors are increasingly excluded from advanced automation, despite the situational awareness and controllability of human actors when intervention is needed (Endsley, 2017). To address this conundrum, the HMC researchers proposed various methods to retain human operation in automation and help humans be prepared for emergent situations (Endsley, 2017). For instance, a burgeoning paradigm known as "human-AI shared control" in HCI promotes human oversight in autonomous systems, such as autonomous vehicles, where AI functions as an auxiliary component to enhance interaction accessibility, safety, precision, and reliability (Cimolino & Graham, 2022). Cimolino and Graham (2022) summarized the roles played by AI in autonomous vehicles and found that AI can be either supportive, cooptable, or delegated. The supportive role of AI is to assist humans while the human is primarily in control of the autonomous vehicles; the cooptable role allows humans to take over the control; the delegated role is to take over human tasks and perform on their behalf. This classification of AI's role in

autonomous vehicles further substantiates that even in autonomous vehicles, AI is not omnipotent and still needs human input.

While SAE levels of driving automation are widely accepted and referred to by regulators, the media, and the public, they have also faced criticism from automotive experts (Biondi et al., 2019; Inagaki & Sheridan, 2019; Templeton, 2015). The development of driving automation is expected to follow the path outlined by stakeholders and the public, as seen in the Singapore government's implementation of rules based on SAE levels (Templeton, 2015). However, the development of autonomous vehicles may not strictly adhere to a hierarchical or ordering classification system and may never achieve the full automation pictured by the SAE system due to the practical need for human involvement (Templeton, 2015). The SAE-level classification system has been criticized for overemphasizing vehicle automation while neglecting the varying levels of human supervision in the driving process (Biondi et al., 2019). Although the SAE levels present an idealized classification system that portrays a progression toward autonomy and freedom of humans from labor, the reality of legal frameworks and industry practices still retains human control in autonomous vehicles.

The aim of this study is to investigate the impact of agency framing in autonomous vehicles on audience perceptions and attitudes. This research is motivated by several factors. First, media coverage tends to frame AI technologies as autonomous entities, optimistically portraying a future where AI surpasses human experts in various domains. This portrayal might influence public perceptions and expectations of AI technologies. Second, the technological solutionism construct in media coverage surrounding autonomous vehicles excludes human factors and attributes high autonomy to autonomous vehicles. This narrative can trigger concerns among the public regarding the high autonomy implied in media coverage and the potential loss of control over technologies, especially for those who have

limited knowledge of AI and algorithms. Third, the prevailing industry standards, such as SEA levels, as well as the press, regulators, sociology and psychology researchers, and the public's notion of autonomous vehicles overlooked the potential long-term role that humans need to play in the game of driving. The disparity between the idealized vision of "AI achieving full autonomy" and the practical reality of "AI assisting humans" can introduce concerns and distrust within the public. Hence, this study will draw upon the framing theory to further explore how AI agency and human agency in the context of autonomous vehicles affect people's perceptions as well as trust toward technology.

Agency Framing of AI and Humans in Autonomous Vehicles

Framing is conceptualized as a "way to describe the power of a communicating text" (Entman, 1993, p. 51), involving the selection and salience of specific facets of reality in a message. Framing is about highlighting certain aspects of reality to make them more salient than others, eventually leading to different individual perceptions (Borah, 2011). Framing is a communication strategy that communicators adopt to disseminate information about a particular issue to the public. Communicators typically select particular facets of reality to emphasize while downplaying others. Message framing serves to underscore the core components of an issue (Gamson & Modigliani, 1989) and direct how individuals perceive and understand that issue (Chong & Druckman, 2007). Framing theory has been widely applied in the field of communication. Numerous studies have revealed that the framing of messages has different persuasive effects on the audience's perceptions, attitudes, and behaviors (e.g., Bingaman et al., 2021; Ho et al., 2020; Ho, 2021).

Messages play a significant role in shaping public perceptions and attitudes toward AI and autonomous vehicles, especially when the public has limited awareness of AI and limited access to autonomous vehicles. It is also reasonable to assume that the media is the predominant channel through which the public can learn about how AI functions in

autonomous vehicles, given that fully autonomous vehicles are not yet available in the mass market (Jelinski et al., 2021). As AI applications become increasingly prevalent in transportation and other sectors, the way information about those systems is presented to the general public is essential (Bunz & Braghieri, 2022). Given the complexity of AI and autonomous vehicle-related issues, a deeper investigation by drawing upon the framing theory can provide a further understanding of ways to effectively communicate emerging and controversial AI-enabled automation to the public.

Previous Framing Studies of AI and Autonomous Vehicles

Previous studies on framing AI and autonomous vehicles have predominantly focused on broader aspects of AI and autonomous vehicle use. For example, one study identified two types of AI frames – "social progress" frames and "potential threat" frames - and applied those frames in an online experiment (Bingaman et al., 2021). The results showed that participants exposed to the "social progress" framing demonstrated greater support for AI than those in the "social threat" condition (Bingaman et al., 2021). Another study focused on the effects of "complementary" and "competitive" frames of the impact of autonomous vehicles on public attitudes toward this technology (Ho, 2021). The frame emphasis of this study was on general topics such as safety and economy. The results indicated that providing congruent viewpoints on certain issues could polarize public opinions while providing contrasting viewpoints could neutralize them (Ho, 2021). So far, only a few studies have investigated the framing effects of AI and autonomous vehicles on public attitudes, and they predominantly focused on general social issues such as AI's and autonomous vehicles' impact on society, economics, and safety. Hence, the investigation on how to convey scientific and technical details of technologies to the public is imperative.

Media coverage of technology is essential for establishing a knowledge base for public discourse on science and technology. A recent approach known as *knowledge-based*

journalism advocates that news content of science and technology should require specialized and in-depth knowledge (Jelinski et al., 2021; Van Witsen & Takahashi, 2018). Therefore, the framing of technologies should not only focus on broader topics such as ethics and economics but also on effectively conveying scientific and technical knowledge. Building on previous content analysis findings, which suggest that technology-related media coverage tends to overlook or be inaccurate regarding the technical and scientific details of the technology itself (Jelinski et al., 2021), it is imperative to investigate how to effectively communicate scientific and technical details in science communication, such as agency issues regarding the collaboration between humans and AI, distribution of control, and shared autonomy in autonomous vehicles.

Past studies have examined the message framing of AI and autonomous vehicle-related content through content analyses. A content analysis of autonomous vehicle coverage found that this type of coverage often lacked technical details and tended to be optimistically biased (Jelinski et al., 2021). Another content analysis of AI-related news coverage in the health sector found that the media tends to emphasize AI's agency by presenting it as an entity that outperforms or replaces human experts rather than as a tool that can enhance human ability (Bunz & Braghieri, 2022). This empirical study substantiated the prevalence of agency framing in AI technology coverage. The authors also pointed out that the agency frame, which depicts technical innovations as "superior to humans," leaves little room for discussions, concerns, or critical examination (Bunz & Braghieri, 2022, p. 10).

Previous studies on framing AI-based technologies have provided insights into the impact of media coverage on public attitudes and opinions toward these emerging technologies. These studies have also identified the prevalence of agency framing in media content related to AI. Thus, informed by the content analysis from Bunz and Braghieri

(2022), this study further examines the effects of agency frames related to AI in autonomous vehicles on public perceptions and attitudes toward these technologies.

Agency

In traditional philosophy and sociology, *agency* is defined as the ability to act intentionally (Dennett, 1988; Schlosser, 2015). This definition implies that agency is a property unique to humans and not accessible to machines that can supposedly only perform pre-programmed actions. The *Chinese Room argument* further supports this claim, arguing that AI can have human cognition such as memory, thinking process, and understanding in the same literal sense; however, it lacks intentionality to think and cannot be considered an intentional agent (Searle, 1980). In HCI studies, the term *apparent agency* is used when attributing agency to computers and machines. This concept refers to the seemingly present thinking and acting capabilities of these devices, which they do not actually possess (Takayama, 2015). From the perspective of humans, in the interaction with technologies, users or audiences can perceive different levels of agency. Cornelio et al. (2022) identified that in the interaction between humans and technologies, different levels of agency can be summarized as "human agency – mixed agency – technology agency" (p. 19), characterized by varying levels of senses on the ability to influence the outcomes.

Unlike conventional computers that operate based on pre-programmed rules and commands, modern AI systems employ machine-learning techniques. Mittelstadt et al. (2016) describe machine learning as the capability of a computer system to independently define or adjust its decision-making rules. This method endows AI systems with a level of autonomy, decreasing their dependence on human input compared to fully programmed machines. The move towards automated learning opposes the conventional view of machines as mere tools created by humans (e.g., Dennett, 1988) for two primary reasons. Firstly, machine-learning AI does not rely entirely on human-defined rules. Secondly, the insights gained by machine-

learning algorithms from data are often opaque, even to their programmers (Mittelstadt et al., 2016). The use of AI in autonomous vehicles provides vehicles with the ability to adapt and make decisions based on complex situations and data, potentially outperforming or replacing human drivers (Ma et al., 2020). Internally, the decision-making processes of autonomous vehicles do not rely solely on pre-programmed rules or human-generated commands. Instead, these vehicles can learn from their surroundings, adapt to novel situations, and formulate decisions accordingly (Lim, 2018), potentially outperforming human drivers. Externally, in an ideal scenario, autonomous vehicles should be able to perform driving-related tasks without human intervention, thereby completely replacing human drivers.

Agency Locus and Agency Framing

The idea of agency locus is derived from Rotter's (1966) concept of locus of control, which describes how individuals perceive the extent to which outcomes are influenced by their own actions versus external factors. Recently, this concept has been applied in HCI research (Liu, 2021). The researcher designed an experiment where the locus of the system's apparent agency is AI (internal locus) or human (external locus). When the locus of a system's apparent agency is internal, the functioning of the machine relies on machine-learning AI systems. Conversely, when the agency locus is external, the functioning primarily relies on pre-programmed human rules (Liu, 2021). By creating and presenting an imaginary computer system that is based on either AI-generated rules or human-generated rules, this study found that, compared to the human agency system, the AI agency system elicited higher uncertainty perception and lower trust in the system (Liu, 2021). Drawing upon this definition, in this study, *AI agency framing* refers to a message frame that depicts the locus of an autonomous vehicle's agency on AI systems, with emphasis on the ability of AI to outperform and replace humans and carry out driving tasks. On the other hand, *human agency framing* refers to a message frame that attributes the locus of an autonomous vehicle's agency

to human operators, with emphasis on the ability of humans to outperform and take over the driving tasks. Synergy agency framing refers to a message that depicts the locus of agency in autonomous vehicles as jointly attributed to both humans and AI, with emphasis on the interdependence and collaboration between humans and AI. Consequently, agency framing for autonomous vehicles can emphasize either full reliance on AI or the partial involvement of humans. In AI agency framing, all human factors are excluded from the functioning of autonomous vehicles. Concerning the incorporation of human involvement, human agency framing underscores the indispensable role of humans, while synergy agency framing emphasizes the interdependence between humans and AI.

The discourse on AI frequently emphasizes the framing of AI agency, which demonstrates a tendency toward technological solutionism and conceptualizes the ideal AI as a separate, autonomous entity (Morozov, 2013). In the healthcare sector, AI-related news frequently utilizes frames centered on AI agency, highlighting its potential to replace or outperform human doctors rather than focusing on its role in assisting and informing them (Bunz & Braghieri, 2022). A similar framing approach is also evident in coverage related to autonomous vehicles (Ju-Len, 2020; Ku & Conejos, 2023), necessitating further investigation into their effects. Since agency frames bring attention to the locus of agency of either AI or humans, audiences may perceive different levels of uncertainty and controllability, depending on the subject of emphasis.

Perceived Uncertainty, Controllability, and Trust in AI and Autonomous Vehicles

People experience uncertainty and a lack of control when interacting with autonomous technologies. Previous empirical studies have found that, when people operate or interact with aircraft systems, AI-enabled fact-checking systems, AI-enabled decision-making systems, and autonomous vehicles, they perceive uncertainty or a lack of controllability over these technologies (e.g., Ha et al., 2020; Liu, 2021; Wickens, 1997; Rödel et al., 2014).

Autonomous vehicles, like other highly autonomous technologies, face inherent risks due to uncertainty and a lack of control arising from their decision-making and movement based on integrated algorithms and environmental input. Due to the complexity of algorithms and the opacity of decision-making, it is challenging for humans in autonomous vehicles to understand what is going on within the systems and how humans can contribute to the functioning of autonomous vehicles (Liu, 2021). In addition to this inherent uncertainty and uncontrollability manifested by the technology per se, the exclusion of human factors from the portrayal of autonomous vehicles by the media may also have a significant impact on people's perceptions of the controllability and uncertainty of the technology's adoption. This, subsequently, can influence the level of trust placed in this technology.

Perceived Uncertainty and Trust in AI and Autonomous Vehicles

The concept of *uncertainty* refers to an individual's inability to predict or explain the behavior of their interaction partner or the events in their environment (Berger, 1987; Pfeffer & Salancik, 1978). The *uncertainty reduction theory* (URT), originally developed to understand human-human interaction, has recently been applied to explain how people perceive their interactions with emerging and sophisticated technologies (Liu, 2021). Uncertainty Reduction Theory (URT) posits that in the early phases of human interaction, individuals have minimal information about each other's attitudes, beliefs, and characteristics, making it challenging to foresee or understand each other's actions (Berger & Calabrese, 1975).

Similar to human-human interaction, individuals interacting with sophisticated technologies such as AI systems may have limited knowledge about the mechanisms behind algorithms or limited experience of interaction with AI-based technologies (Liu, 2021). The algorithmic logic of AI systems that drive automation may be fundamentally different from human logic, thus introducing uncertainty in people's perceptions of AI-enabled automation

(Liu, 2021; Wickens, 1998). For instance, one study identified the opacity and uncertainty of algorithms as psychological barriers to the adoption of autonomous vehicles (Shariff et al., 2017).

Due to the novelty of autonomous vehicles and their AI applications, the majority of the public accesses related information through mass media and has little experience with relevant technologies. This can lead to a heightened perception of uncertainty among the public. In addition, according to URT, people are intrinsically driven to reduce uncertainty by acquiring the ability to predict and explain the behavior of others (Berger & Calabrese, 1975). In the context of framing, individuals are more inclined to seek information that aligns with their existing beliefs to alleviate their perception of uncertainty. As the operational mechanism of AI is often different from human logic, people tend to feel more certain about adopting autonomous vehicles when human factors are fully or partially involved in their operation. Conversely, they are likely to experience greater uncertainty when human factors are fully or partially excluded.

In autonomous vehicles, the role of AI can be supportive, cooptable, or delegated, demonstrating an increased involvement of AI agency in autonomous vehicles and a decreased involvement of human agency (Cimolino & Graham, 2022). Hence, it is reasonable to assume that people may experience less uncertainty when the portrayal of autonomous vehicles includes more human involvement and more uncertainty if autonomous vehicles are depicted as operated by AI systems, or shared agency between humans and AI. In the experiment of this study, participants who read the message depicting AI as an omnipotent actor capable of surpassing and replacing humans in autonomous vehicles may perceive a higher level of uncertainty than those who read the message reintroducing human involvement in the operation of autonomous vehicles.

H1: Compared with participants in the (a) human agency frame and (b) synergy agency condition, participants in the AI agency frame condition will perceive higher levels of uncertainty.

H2: Compared with participants in the human agency frame condition, participants in the synergy agency frame condition will perceive higher levels of uncertainty.

Trust is an important construct in the investigation of public opinion and autonomous vehicles due to its close alignment with the adoption of automation (Alvarez et al., 2024; Ho & Cheung, 2024). Lee and See (2004) defined trust as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (p.51). An earlier study in HMC found that the adoption of automation highly correlated with trust in automation. It also found that people rejected to use of distrusted automation, and they preferred to control the task manually, exerting their own agency (Muir & Moray, 1996). This suggests that the agency of automation and human actors is related to trust in automation. Compared with other forms of automated systems, the shared autonomy between humans and AI in autonomous vehicles requires more investigation into trust issues as it involves a transition of control from human to AI systems (Ha et al., 2020). As for the factors of trust in autonomous vehicles, previous research found that risk perception, benefit perception, knowledge, and trust can further influence the public's acceptance, willingness, and intention to adopt autonomous vehicles (Buckley et al., 2018; Ho et al., 2020; Ward et al., 2017).

Perceived uncertainty is closely associated with trust. Empirical studies on traditional automation technologies, such as aircraft, indicate that pilots have lower trust levels toward advanced automation aircraft than less advanced ones due to perceptions of uncertainty about automation's reliability and accuracy (Wickens, 1997). Another study examined the effects of AI-generated deepfake news videos on audiences' perceptions and found that the

involvement of AI increased participants' uncertainty perception, while the AI-made news video through increased perceived uncertainty leads to a lower level of trust in the social media news (Vaccari & Chadwick, 2020).

Previous research in HCI has explored ways to augment public trust in autonomous vehicles, including sharing goals and information with human operators and providing detailed explanations. For example, one study found that by sharing goals and information from autonomous driving systems with humans, people perceived higher trustworthiness in autonomous vehicles and subsequently enhanced trust in autonomous vehicles (Verberne et al., 2012). In this study, the system's behavior of sharing goals and information with human operators can be seen as a form of shared autonomy by reattributing human agency, while trustworthiness increases when information and goals are shared with human operators (Verberne et al., 2012). It is also reasonable to assume that the shared information and goals can reduce uncertainty, and eventually increase trust in AI and autonomous vehicles (Verberne et al., 2012). This study suggested that even sharing autonomy through information and goal sharing can have positive impacts on user's perception of systems. Another study found that sharing uncertainty information regarding the vehicle's autonomous driving ability, such as the status of the driving system, can decrease people's trust in autonomous driving systems (Helldin et al., 2013). This suggests trust in autonomous vehicles or driving systems can be affected by uncertainty perception.

Based on the current literature, this study hypothesizes that perceived uncertainty may act as a mediator between the experimental condition and trust in AI systems in autonomous vehicles, portraying increased human involvement in autonomous vehicles might increase the audience's trust in both AI and autonomous vehicles, via uncertainty perception:

H3: Perceived uncertainty mediates the positive effects of synergy agency framing and (vs. AI agency framing) on trust in (a) AI systems and (b) autonomous vehicles.

H4: Perceived uncertainty mediates the positive effects of human agency framing and (vs. synergy agency framing) on trust in (a) AI systems and (b) autonomous vehicles.

Perceived Controllability and Trust in AI and Autonomous Vehicles

The advancement of AI technologies has brought about significant changes, particularly in terms of autonomy. The media often depict AI-driven autonomy as a positive development, representing social progress, liberation from labor, and technological advancement (Bingaman et al., 2021; Bunz & Braghieri, 2022). However, when it comes to autonomous vehicles, which directly impact people's lives and property, the autonomy of AI presents a complex situation. According to the *SAE Levels of Driving Automation*, full autonomy, where no human intervention is required, is the ultimate goal for autonomous vehicles (Society of Automotive Engineers, 2021; Templeton, 2015). However, in current industrial practice, academic research, and legal regulations, AI is expected to be supervised by humans (Land Transport Authority of Singapore, 2017; Nunes et al., 2018; Templeton, 2015). The convergence and transition between human control and self-control in autonomous vehicles are subjects of intense research in engineering, mechanics, and psychology (Cunningham & Regan, 2015; Naujoks et al., 2018). Previous researchers recognized that in the design and implementation of autonomous vehicles, it is crucial to prioritize the goals of human users, including factors like speed, route selection, destination, and driving maneuvers, which are expected to be achieved automatically by the vehicles themselves under human supervision (Cunningham & Regan, 2015). Regulations also impose specific requirements for human operators to control or drive autonomous vehicles (Land Transport Authority of Singapore, 2017).

From the perspective of human drivers and operators, the perception of controllability plays a crucial role in shaping trust in these technologies. *Controllability* is defined as "the extent to which the user can bring about or prevent particular actions or states of the system if

she has the goal of doing so" (Jameson, 2007). *Perceived controllability*, based on this definition, refers to individuals' perception of their capability to affect the outcomes of their actions according to their goals. Perceived controllability has primarily been studied in the context of HCI, particularly in topics related to the personalization of digital media and self-service technologies (Sundar, 2008; van Velsen et al., 2015). For instance, a survey study found that perceived controllability is the most important antecedent of intention to adopt the personalization of digital media (van Velsen et al., 2015). However, it has not been extensively explored in other forms of automation, such as autonomous vehicles, and has not been explored in framing studies.

Perceived controllability, as a concept, has not been extensively explored in the field of framing research for two main reasons. Firstly, controllability is a construct that is specific to automation technologies and the effects of framing of automation technologies have not been widely examined. Secondly, studies focusing on how autonomous technologies should be communicated to the public often tend to address broader societal issues such as safety, economics, and security (Ho, 2021), or explore perspectives related to social progress (Bingaman et al., 2021). These studies typically do not delve into the technical aspects of AI in autonomous vehicles. This study takes a technological perspective, aiming to find how the technical aspects of AI in autonomous vehicles should be communicated.

Users' sense of agency can indeed influence their perception of controllability. In autonomous vehicles, a study found that people's perceived controllability continuously decreases as the autonomy of autonomous vehicles increases, and higher perceived controllability leads to more favorable attitudes toward autonomous vehicles (Rödel et al., 2014). In other words, people perceived higher controllability with semi-autonomous vehicles that are mainly operated by humans, perceived relatively lower controllability for those jointly operated by AI and humans, and perceived lower controllability with fully

autonomous vehicles that are mainly operated by AI systems (Rödel et al., 2014). Other research found that when users can adjust a system using their agency, they tend to perceive a higher level of controllability (Burton et al., 2020). Their ability to exert their agency by adjusting the system can also reduce their aversion toward the system (Dietvorst et al., 2018). Another study found that users perceive AI agents, compared to human agents, to have less control over the functioning of decision-making systems (Jones-Jang & Park, 2022).

In this study, the different framing of the agency is expected to influence participants' perception of controllability in autonomous vehicles, and the perception of controllability will increase as the message portrays more human involvement.

H5: Compared with participants in the AI agency frame condition, participants in the (a) synergy agency frame and (b)human agency frame condition will perceive higher levels of controllability.

H6: Compared with participants in the synergy agency frame condition, participants in the human agency frame condition will perceive higher levels of controllability.

Previous studies showed inconsistent findings regarding the effects of perceived controllability on trust. One study found that perceived controllability plays a crucial role in the acceptance of AI-related health services (Park et al., 2022). When users feel they have higher control over AI health monitoring systems, their anxiety decreases, and they express greater acceptance of AI monitoring in healthcare services (Park et al., 2022). Similarly, controllability has been identified as a significant factor influencing public trust in autonomous vehicles (Sela & Amichai-Hamburger, 2023). While the importance of controllability may vary among individuals with different personality types, overall, perceiving a higher level of controllability is associated with greater acceptance of autonomous vehicles (Sela & Amichai-Hamburger, 2023). However, another study did not find supporting evidence for the effects of perceived controllability on users' trust in

autonomous vehicles. However, it found that increased controllability and observability can lead to a decrease in users' confidence and trust in autonomous vehicle systems (Cummings et al., 2021).

Despite the inconsistent findings, this study proposes that the increase in perceived controllability may act as a mediator between the experimental condition and trust in AI systems in autonomous vehicles; portraying increased human involvement in autonomous vehicles might increase the audience's trust in both AI and autonomous vehicles, via controllability perception:

H7: Perceived controllability mediates the positive effects of synergy agency framing and (vs. AI agency framing) on trust in (a) AI systems and (b) autonomous vehicles.

H8: Perceived controllability mediates the positive effects of human agency framing and (vs. synergy agency framing) on trust in (a) AI systems and (b) autonomous vehicles.

A lack of perceived controllability is thought to be related to uncertainty perception. Earlier research in psychology found that people who perceive less control over the outcomes of events will also perceive higher levels of uncertainty regarding the causes of those events (Edwards & Weary, 1998). Another study investigated the relationship between control and uncertainty from behavioral psychology and found that people will seek more sense of control to cope with uncertainty perception (Sankaran et al., 2023). This suggests a sense of being able to affect the outcomes can alleviate their perception of the uncertainty of the current situation. Another study in the medical and psychology field found that perceived controllability over cognitive, physical, and social functioning is directly associated with perceived uncertainty of type 1 diabetes (Hoff et al., 2002).

In AI agency framing, autonomous vehicles operate without human intervention, minimizing the risk of human errors in control. However, users may experience uncertainty because they are excluded from the driving process and perceive they are unable to control or

respond to potential accidents with their own initiatives (Ha et al., 2020). For instance, the study of uncertainty perception on trust in autonomous vehicles found that when people are exposed to uncertainty information during the driving simulation, they are more eager to take control of the vehicles and become more attentive to the environment (Helldin et al., 2013). Based on the URT, people are intrinsically motivated to decrease uncertainty by gaining the ability to predict and explain others' behavior (Berger & Calabrese, 1975). It is reasonable to assume that controllability can be an antecedent of uncertainty reduction in the context of interacting with complex systems or AI-enabled automation. In the study by Helldin et al. (2013), having control over operations in autonomous vehicles is a form of retaining perceived controllability, to alleviate uncertainty perception.

In the context of autonomous vehicles, it is reasonable to assume that the perception that one cannot control the driving outcomes of autonomous vehicles, brought about by the message that humans will be outperformed and replaced by AI, or humans need to collaborate with AI, leads to uncertainty perceptions.

H9: Perceived controllability mediates the negative effects of AI agency framing (vs. synergy agency framing) on perceived uncertainty.

H10: Perceived controllability mediates the positive effects of human agency framing (vs. synergy agency framing) on perceived uncertainty.

Consequently, serial mediation relationships can be found in the relationship between experimental conditions and dependent variables.

H11: Perceived controllability and perceived uncertainty serially mediate the negative effects of AI agency framing (vs. synergy agency framing) on (a) trust in AI, and (b) trust in autonomous vehicles.

H12: Perceived controllability and perceived uncertainty serially mediate the positive effects of human agency framing (vs. synergy agency framing) on (a) trust in AI, and (b) trust in autonomous vehicles.

Methodology

Research Method

This study employed a between-subjects design with three conditions: AI agency, human agency, and synergy agency, using an online experiment to examine the effect of agency framing on trust toward AI systems and autonomous vehicles. After answering a series of questions regarding participants' knowledge, prior attitudes toward AI, automation bias, and desirability to control, participants were randomly assigned to one of the three conditions and read a message regarding the role of AI and humans in autonomous vehicles. Participants then answered another set of questions about their perception, and trust in AI systems and autonomous vehicles. Demographic information was collected at the end of the questionnaire. Based on the suggestion of sample size from *G*Power* (Faul et al., 2007), the experiment aimed to have at least 84 participants in each group (3 groups, $N = 252$) to detect an effect size of $f = 0.25$ with 95% power in one-way ANOVA (3 groups, $alpha = 0.05$).

A total of 271 Singaporeans were recruited from a *Telegram* community in March 2024. The participants engaged in this study via *Qualtrics*. All participants were either citizens or permanent residents of Singapore, aged 21 years or older. Participants who either did not complete the study or failed the attention check question were excluded from the analysis. The final sample comprised 160 females and 111 males. The majority of participants identified as Chinese (91.9%). The median age of the participants was 26 years. The median income bracket was SGD 7,000–7,900. Additionally, the median educational attainment was a bachelor's degree or equivalent.

Stimuli

The experiment stimuli for this study are included in Appendix I. The messages were designed based on three dimensions: (a) delineating the roles of AI or humans; (b) explicating the functionalities exhibited by AI or humans; and (c) emphasizing that the autonomous

vehicle's operation was predominantly performed by AI or humans. Then, the message briefly presents the participants with advantages and potential drawbacks pertaining to (a) errors, (b) sensing capabilities, and (c) decision-making that arise when AI or humans are engaged in the driving and decision-making processes. The potential drawbacks and advantages will be stated to ensure a balanced tone across the two conditions. Furthermore, the word counts of the messages are similar across both conditions. This is to ensure that the manipulations are structurally parallel, the descriptions are symmetric, and the tones are neutral. In addition, manipulation checks on argument strength and agency locus were included in the questionnaire.

AI agency, human agency, and synergy agency conditions were experimentally manipulated through the presentation of textual messages. The AI agency frame communicates the notion that "AI will outperform and replace human drivers"; the human agency frame conveys the perspective that "human drivers will not be outperformed or replaced by AI"; and the synergy agency frame conveys "AI and humans are interdependent and need to collaborate." Additional explanations were provided, for example, by specifying that in the context of autonomous vehicles, these entities are endowed with "advanced sensors and cutting-edge algorithms" (or, in the case of human drivers, "a deep understanding of road dynamics"), which enable AI or humans to seamlessly assess their environment, anticipate potential challenges, and make split-second decisions. Subsequently, a brief discussion of advantages and disadvantages was presented regarding the outcomes of the presence (or absence) of human intervention.

Pilot Tests

The formal experiment was informed by pilot tests conducted in August and July 2023. The first pilot test was conducted to refine the experimental stimuli. The second pilot test focused on the relationship between the proposed variables and measurements. For the

second pilot test, the manipulation check was successful, and the argument strength of the two conditions was balanced. After controlling the demographic variables, the pilot test results suggested that agency framing had significant effects on participants' uncertainty and controllability perceptions, as well as trust in AI and autonomous vehicles. The reliability test of measurements showed good results with all Cronbach's $\alpha > 0.80$.

Manipulation Checks

Argument strength was checked using a one-way ANOVA to compare the effectiveness of argument strength across three different agency conditions. Participants rated the strength of the arguments on a scale from 1 (very weak) to 5 (very strong). There was not a statistically significant difference in the strength ratings for the three conditions: F (2, 268) = 1.253, p =.287, η^2 =.009. The mean strength rating for the AI agency (M = 3.64, SD =.727) was not significantly different from the human agency (M = 3.77, SD =.694) or the synergy agency (M = 3.63, SD =.646). These findings suggest that the manipulation of argument strength was consistent across conditions.

Agency locus was checked using a one-way ANOVA to evaluate the perceived locus of agency in the operation of autonomous vehicles based on the messages read by participants. Responses were scored on a scale from 1 (completely self-operate) to 5 (completely human-operate). There was a statistically significant difference in agency locus scores for the three conditions: F(2, 268) = 45.396, p <.001, η^2=.253. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the AI agency (M = 2.45, SD = 1.098) was significantly lower than that for the human agency (M = 3.71, SD =.815; p <.001) and the synergy agency (M = 3.33, SD =.795; p <.001). Additionally, the synergy agency was perceived as having less human agency than the human agency (p =.013). These findings suggest that the manipulation of the messages regarding the locus of agency was successful.

Measures

The proposed variable measurements are provided in Table 1. The individual items were summed and averaged to formulate a composite scale. For a comprehensive list of specific items and the questionnaire, see Appendix II.

Table 1

Sample items for measures of variables

Measured Variables	N	Sample Items
Agency Framing Manipulation Check (Liu, 2021)	1	Based on the message you just read; the operation of autonomous vehicles is completely self-operate / completely human-operate
Argument Strength Check (Ho, 2021)	1	From very weak to very strong, how strong do you think the arguments are in the message you just read?
Perceived Controllability (Jones-Jang & Park, 2023)	4	How much do you perceive that AI will have control over the driving process in autonomous vehicles?
Perceived Uncertainty (Pavlou et al. 2007)	6	1. How much do you feel that you are aware of the driving process in autonomous vehicles? 2. How much do you feel that you can explain the decision-making in autonomous vehicles?
Trust in AI (Uggirala et al., 2004)	5	1. To what extent do you think the AI in autonomous vehicles performs the driving tasks effectively? 2. To what extent can you anticipate the performance of AI in autonomous vehicles with some degree of confidence?
Trust in Autonomous Vehicles (Gefen et al.,2003; Pavlou, 2003)	5	1. To what extent do you think the autonomous vehicle is dependable? 2. To what extent do you think the autonomous vehicle is reliable?
Prior Belief of AI (Waddell, 2018)	4	1. If AI does a job, then the task is done objectively. 2. If AI does a job, then the work is error-free.
AI Awareness (Liu, 2021)	8	How likely is it that the following technologies/applications/services are using AI? - Self-driving cars

Autonomous Vehicles Acceptance (Vu & Lim, 2022)	5	In your opinion, from completely unacceptable to completely acceptable, - Having autonomous vehicles for public transport - Having an autonomous vehicle perform driving tasks for individuals
AI Threat (Liu, 2021)	7	1. I am concerned that AI might cause job losses. 2. I am concerned that AI might abuse users' data.
Use Intention (Lee et al., 2019)	4	Assuming I have access to an autonomous vehicle, I would intend to use it.

Note: All variables were measured on 5-point scales.

Results

A one-way ANOVA was conducted to investigate the effect of agency framing on perceived uncertainty. There was a significant effect of agency framing on perceived uncertainty, $F(2, 268) = 10.59$, $p < .001$, $\eta^2 = .07$. The Tukey HSD post hoc test indicated significant differences between the AI agency condition ($M = 3.12$, $SD = 0.83$) and the synergy agency condition ($M = 2.61$, $SD = 0.97$), and between the AI agency condition and the human agency condition ($M = 2.57$, $SD = 0.88$). No significant difference was found between the synergy agency condition and the human agency condition. *H1* was supported, but *H2* was not supported.

Similarly, a one-way ANOVA was conducted to examine the effect of agency framing on perceived controllability among AI, synergy, and human agency groups. Results indicated a significant effect of agency framing on perceived controllability: $F(2, 268) = 17.087$, $p < .001$, $\eta^2 = .113$. Post hoc comparisons using the Tukey HSD test revealed significant differences between the AI agency condition ($M = 2.17$, $SD = 1.08$) and synergy agency condition ($M = 2.76$, $SD = 0.82$), and between the AI agency condition and human agency condition ($M = 2.96$, $SD = 0.92$). However, no significant difference was found between the synergy agency condition and the human agency condition (Table 2). *H5* was supported, but *H6* was not supported.

Table 2

Post Hoc Comparisons for Perceived Uncertainty and Perceived Controllability Among Experimental Groups

Dependent Variable	AI agency	Synergy agency	Human agency	*F*	η^2
Perceived Controllability	2.17_a (1.08)	2.76_b (0.82)	2.96_b (0.92)	17.077***	.113
Perceived Uncertainty	3.12_b (0.83)	2.61_a (0.97)	2.57_a (0.88)	10.590***	.073

Note. Values are based on post hoc comparisons using the Tukey HSD test. Standard deviations appear in parentheses beside the means. The mean difference is significant at the $p < .05$ level. Significance levels are indicated as follows: *$p < .05$, **$p < .01$, ***$p < .001$. F and η^2 values are reported from one-way ANOVA.

Trust in AI

A multicategorical mediation analysis was conducted using the PROCESS macro for SPSS (Version 4.1; Hayes, 2022) Model 4 with 5,000 bootstrap resamples and 95% percentile bootstrap confidence intervals (CIs) to explore the indirect effects of agency framing on trust in AI through perceived controllability and perceived uncertainty. Age, gender, and driving experience were controlled throughout the analysis. To test *H3*, *H4*, *H7*, and *H8*, the categorical independent variable, agency framing, was coded with synergy agency as the reference group as 0, AI agency as 1, and human agency as 2.

The regression models for both mediators indicated significant effects. The model predicting perceived controllability from agency framing, age, gender, and driving experience accounted for 12.11% of the variance: $R^2 = .12$, $F(5,265) = 7.31$, $p < .001$. AI agency significantly decreased perceived controllability compared to synergy agency ($\beta = -2.51$, $SE = .59$, $p < .001$, 95% CI [-3.67, -1.35]), whereas human agency did not significantly alter perceived controllability ($\beta = .82$, $SE = .58$, $p = .16$, 95% CI [-0.33, 1.96]). The model for perceived uncertainty was also significant: $R^2 = .09$, $F(5,265) = 5.2797$, $p < .001$, showing that compared with the synergy agency, AI agency increased perceived uncertainty ($\beta = 1.32$, $SE = .35$, $p < .001$, 95% CI [0.63, 2.01]), while human agency showed no significant effect ($\beta = -.18$, $SE = .35$, $p = .612$, 95% CI [-0.86, 0.51]).

In terms of trust in AI, the overall model was significant: $R^2 = .11$, $F(7,263) = 4.87$, $p < .001$. Neither AI agency nor human agency showed significant direct effects on trust in AI compared to the synergy agency, with $\beta = -.03$, $p = .446$ and $\beta = -.01$, $p = .878$, respectively. However, the indirect effects were significant; AI agency significantly decreased trust in AI

through both perceived controllability (β = −.03, BootSE = 0.01, 95% CI [-0.06, -0.01]) and perceived uncertainty (β = −.02, BootSE = 0.01, 95% CI [-0.05, -0.01]). The human agency showed non-significant indirect effects on trust through these pathways. The total effect models of independent variables on dependent variables also reflected these relationships. AI agency showed a significant negative total effect on trust in AI (β = −.08, *SE* =.04, *p* =.040, 95% CI [-0.16, -0.01]), whereas human agency had no significant total effect (β =.01, *SE* = 04, *p* =.878, 95% CI [-0.07, 0.08]). These findings suggest that the type of agency, particularly AI agency, can significantly alter trust in AI systems through changes in perceived controllability and uncertainty. While AI agency diminished trust compared to synergy agency, human agency did not significantly differ from synergy agency in its effect on trust. *H3(a), H7(a)* were supported; *H4(a)* and *H8(a)* were not.

Trust in Autonomous Vehicles

Another mediation analysis was conducted to examine the mediation path from agency framing to trust in autonomous vehicles from two meditators. The overall regression model examining trust in autonomous vehicles was significant: R^2 =.12, $F(7, 263) = 5.05$, p <.001. The direct effects of agency framing on trust in autonomous vehicles were not significant for either AI or human agency, suggesting that the impact of agency type on trust might operate through the mediators. Specifically, when synergy agency was the reference group in the analysis, AI agency was associated with a non-significant decrease in trust (β = -.10, *p* =.353), and human agency also showed a non-significant effect (β = -.03, *p* =.799). Gender emerged as a significant predictor of trust in autonomous vehicles (β =.28, *SE* =.09, *p* =.002, 95% CI [0.10, 0.46]), suggesting that gender differences may play a role in trust dynamics.

Indirect effects analyses showed significant results. AI agency decreased trust in autonomous vehicles through both decreased perceived controllability (β = -.06, BootSE =

0.03, 95% CI [−0.13, −0.01]) and increased perceived uncertainty (β = -.07, BootSE = 0.03, 95% CI [−0.15, −0.02]), while human agency showed non-significant indirect effects through both pathways. The total effect of AI agency on trust in autonomous vehicles was significant (β = -.24, *SE* =.11, *p* =.029, 95% CI [−0.45, −0.02]), indicating an overall negative impact on trust in autonomous vehicles compared to synergy agency. Human agency had a non-significant total effect on trust in autonomous vehicles. These results illustrate that agency framing significantly affects trust in autonomous vehicles through changes in perceived controllability and uncertainty, with AI agency notably decreasing trust compared to synergy agency. Thus, *H3(b), H7(b)* are supported, and *H4(b)* and *H8(b)* are not supported.

Serial Mediation

A serial mediation analysis was conducted using the PROCESS macro for SPSS Model 6 (Version 4.1; Hayes, 2022) with 5,000 bootstrap resamples and 95% percentile bootstrap confidence intervals (CIs) to explore the indirect effects of agency framing on trust in AI through perceived controllability and then perceived uncertainty. When trust in AI was the dependent variable, the serial mediation model revealed that the agency type indirectly influenced trust in AI through a pathway from perceived controllability to perceived uncertainty. Specifically, for AI agency (coded as 1 compared to synergy agency coded as 0), the serial indirect effect was significant: β = −.02, BootSE =.01, 95% CI = [-.012, -.01]. This pathway showed that AI agency decreased perceived controllability, which in turn increased perceived uncertainty, culminating in a decrease in trust in AI systems. For human agency (coded as 2 compared to synergy agency coded as 0), the serial indirect effect was not significant. β =..0014, BootSE =.0014, 95% CI = [-.0004,.0049].

Similarly, in the context of trust in autonomous vehicles, the serial mediation model highlighted the role of perceived controllability and uncertainty. For AI Agency, there was a significant negative serial indirect effect on trust in autonomous vehicles, quantified at β =

−.0133, BootSE =.0086, 95% CI = [-.0346, -.0014]. This effect underscores how AI agency is associated with decreased perceived controllability and increased perceived uncertainty, which subsequently reduces trust in autonomous vehicles. For human agency, the serial indirect effect β =..0043, BootSE =.0039, 95% CI = [-.0010,.0139], which was not statistically significant. This suggests that, compared with synergy agency, the changes in perceived controllability and subsequent uncertainty induced by human agency do not significantly impact trust in autonomous vehicles. Thus, *H9* and *H11* were supported, while *H10* and *H12* were not supported.

Discussion

The findings of this study indicate that message frames highlighting AI autonomy while neglecting human involvement in the communication of AI-enabled automation may impede the development of trust towards AI and related technologies among the public. This research compared three distinct types of message frames: those focusing on human agency, AI agency, and their synergy in autonomous vehicles. The results showed variations in perceptions of controllability and uncertainty, as well as trust, when audiences were exposed to different portrayals of the roles of AI and humans. A significant discovery is that, unlike frames that exclusively emphasize the decision-making and dominant roles of either AI or humans, frames that simultaneously accentuate both AI and human agency through a lens of collaborative coexistence are more likely to foster favorable attitudes by enhancing perceived controllability and reducing perceived uncertainty.

Agency Framing and Perceptions

Drawing on framing theory, which highlights how communication shapes perception by emphasizing specific aspects over others (Entman, 1993; Chong & Druckman, 2007), this research examines the impact of different framings on perceived controllability and uncertainty. The study reveals that participants experience a heightened sense of controllability in scenarios where human agency is emphasized over, or in conjunction with, AI agency. The findings suggest that individuals feel more confident and in control when they perceive that humans are actively overseeing or directly involved in the operation of autonomous technologies. This increased perception of controllability likely stems from the reassurance provided by the potential for human intervention and a deeper understanding of the system's operations. This observation aligns with the research of Rödel et al. (2014), which investigated how user acceptance varies with the degree of system autonomy in autonomous vehicles. They found that perceived control and enjoyment decrease as

autonomy increases, with the highest levels of acceptance occurring at lower levels of autonomy that incorporate human control. These findings underscore the importance of human presence in the communication of sophisticated AI-enabled automation, emphasizing that such presence is vital for enhancing user acceptance of these technologies.

AI agency framing leads to higher perceived uncertainty compared to human and synergy agency framings. This aligns with the existing literature suggesting that when AI is perceived as the dominant decision-maker, as in systems like fact-checking, it can induce a sense of uncertainty among users (Liu, 2021; Wickens, 1998). This effect may stem from the "black box" nature of AI systems, where the decision-making process remains opaque and difficult for users to comprehend (Shariff et al., 2017). Given the fundamentally different logic underpinning AI systems from human reasoning, and the general unfamiliarity of users with AI decision-making mechanisms, there is a lack of predictability and understanding of how AI makes decisions. This can lead to heightened uncertainty.

In contexts such as autonomous vehicles, the decision-making process of AI is inherently less predictable and comprehensible compared to human drivers (Liu, 2021). Audiences seek a sense of controllability and certainty in messages that involve human factors in technologies, viewing humans as indispensable actors in the automation process. The results also suggest that AI, as an agent processing information and making decisions in ways that cannot be fully comprehended and interpreted by the audience, inevitably introduces uncertainty when it functions as the central component of autonomous vehicles.

Synergy agency framing, emphasizing collaborative interaction between humans and AI, serves as a balanced middle ground. This framing type fosters more balanced perceptions of controllability and uncertainty, suggesting it could be the most effective method for enhancing trust in AI systems and autonomous vehicles. By integrating both human capabilities and AI, this approach offers a sense of security and predictability that can reduce

the perceived risks associated with full autonomy. This synthesis of human oversight and AI innovation provides a dual assurance that can assuage public apprehensions about over-reliance on technology, thereby facilitating greater controllability and lesser uncertainty in these advanced systems.

Although the effects of human agency framing on perceived controllability and uncertainty are not significantly different from synergy agency, human agency framing significantly influences perceptions of controllability and reduces uncertainty among users. The emphasis on human agency helps mitigate these fears by suggesting that the technology is not entirely self-governing but instead operates under human supervision. This perceived increase in controllability implies that users have the potential to intervene or alter outcomes. It also significantly lessens the uncertainty associated with autonomous operations.

The analysis of the effects of agency framing on audience perceptions indicates that by integrating human factors into the portrayal of AI-enabled automation, such as illustrating how humans can coexist and collaborate with AI systems during accidents and system failures and how they can complement AI's sensing abilities and decision-making, this approach may mitigate the formation of uncertainty by enhancing perceptions of controllability and, subsequently, trust in AI-enabled automation.

Perceived Controllability, Perceived Uncertainty, and Trust Dynamics

As noted in a content analysis by Bunz and Braghieri (2022), there is a prevailing tendency in media coverage to frame AI technology predominantly as an independent entity capable of outperforming or replacing humans, often overlooking the potential for collaboration and human support. This study extends the focus of agency framing beyond the typical AI agency to include synergy and human agency frames and empirically examines the hypothesis that an overemphasis on AI agency, to the exclusion of human agency, may

impede the formation of positive attitudes and can potentially affect public discourse around AI technologies.

The mediation analysis results for agency framing in relation to trust in AI and autonomous vehicles show similar patterns. The models revealed significant effects, underscoring that the type of agency framing significantly impacts trust in AI systems and autonomous vehicles. Specifically, in scenarios where AI agency is predominant, the diminished perceived controllability leads to heightened uncertainty, thereby reducing trust. This outcome aligns with theoretical assertions that a sense of control is important for trust in technology (Sela & Amichai-Hamburger, 2023). Notably, the contrast between AI agency and synergy agency framing underscores that incorporating human factors in the communication of autonomous vehicles can significantly bolster trust in AI and autonomous vehicles, particularly when the portrayal emphasizes coexistence and collaboration between AI and humans. This aligns with a previous study (Aoki, 2021), which found that informing humans in the decision loop of the operation of a system can significantly increase trust in the system.

Interestingly, there is no significant difference between the mediation path between synergy agency and human agency. The non-significant mediation path involving human agency framing, when compared to synergy agency as the reference group, can be explained by several factors. First, both human agency and synergy agency framings emphasize human involvement, though to varying degrees. Synergy agency framing portrays a balanced partnership between humans and AI, suggesting a cooperative interaction where both agents contribute to decision-making and operational processes. However, human agency framing emphasizes a dominant human role, potentially relegating AI to a supportive or assistive position. Since both framings involve human oversight and participation, the differences in perceived controllability and uncertainty might not be as distinct as between AI agency and

the other two framings. This similarity could lead to non-significant differences in perceived controllability and uncertainty between human and synergy framings.

Another possible explanation is that synergy agency framing might create expectations of a more advanced, yet still manageable, system where control is shared. This can foster a perception of advanced technology that is still under human oversight, aligning closely with public expectations of progressive yet safe technological advancements. In contrast, human agency framing, while reassuring, may not significantly enhance perceptions of technological advancement or fit the innovative expectations associated with autonomous systems as effectively as synergy framing. This alignment with expectations in synergy framing might not differ enough from human framing in terms of reducing uncertainty or enhancing controllability, leading to non-significant mediation effects. From a methodological perspective, although the manipulation check indicated that participants rated the agency locus of the three conditions significantly differently, it is possible that the synergy agency framing already provides high levels of perceived controllability and reduced uncertainty. Consequently, any further enhancements from human agency framing might not be perceptible, leading to non-significant mediation effects.

Additionally, the mediation analyses highlight that both perceived controllability and uncertainty act as critical pathways through which agency framing influences trust. In the AI agency condition, where controllability is perceived to be low, the resultant high uncertainty significantly undermines trust. Conversely, in synergy conditions, where controllability is perceived to be higher, the impact on trust is less pronounced, underscoring the protective effect of perceived controllability over uncertainty and distrust. As suggested in URT, people are naturally motivated to lessen uncertainty in interactions by gathering information to better predict and comprehend behaviors and outcomes (Berger & Calabrese, 1975). In the realm of autonomous vehicles, providing users with some sense of controllability aligns with this

intrinsic motivation by enhancing their comprehension and predictability of the automation. Essentially, by enhancing controllability, users gain confidence in their ability to intervene if necessary, thus fostering a more secure and trusting relationship with the technology.

Implications

Theoretical Implications

Applying framing theory, this study enriches the existing literature on AI by offering a comprehensive examination of how different agency frames, specifically human agency, AI agency, and synergy agency, affect public perception and trust in AI-enabled automations. Building upon prior content analyses that have predominantly showcased AI in media as predominantly autonomous and capable of superseding human roles (Bunz & Braghieri, 2022), this research extends the agency frames by introducing and empirically evaluating the impacts of alternative framings that emphasize human involvement and collaborative interaction between humans and AI.

In addition to building and enriching agency framing, the experimental approach of this study explores different types of agency frames and provides critical insights into how each framing distinctively influences perceived controllability and uncertainty, which are key factors in public trust in AI technologies. Informed by URT, this research not only reaffirms the uncertainty construct's relevance in technological contexts (i.e., how people interact with technologies, Liu, 2021) but also innovatively applies it to design the communication of technologies. URT traditionally focuses on interpersonal communications and suggests that individuals seek information to reduce uncertainty in new interactions (Berger & Calabrese, 1975). Extending this to the communication of AI technologies, the study illustrates how enhanced controllability can effectively reduce uncertainty among audiences by emphasizing human involvement and human ability.

Furthermore, the findings suggest that perceived controllability serves as a mediator in the relationship between agency framing and uncertainty reduction, a novel application of URT in the context of AI. This aligns with and expands upon prior research by Sundar (2008) and Liu (2021), who discuss the psychological impact of agency and control in human-

computer interactions, emphasizing that users' perceptions of agency locus significantly impact their acceptance level toward technology. Additionally, by demonstrating that synergy agency framing, which highlights a cooperative dynamic between humans and AI, can optimize perceptions of controllability and minimize uncertainty, this study contributes to a growing body of literature advocating for designs that integrate AI and human capabilities in a manner that is perceivably equitable and mutually enhancing (Verberne et al., 2012). This approach suggests a shift from viewing AI as a replacement for human effort to seeing it as a complementary force, capable of augmenting human capabilities rather than supplanting them.

This research fundamentally challenges the prevailing media narratives that tend to amplify AI's autonomy without sufficient emphasis on its interdependent relationship with human oversight. The theoretical implications of this study encourage a reevaluation of how AI is discussed in public discourse, pushing for a balanced portrayal that accurately reflects the collaborative potential between humans and AI, thereby fostering a more informed public on decision-making about AI integration in various domains.

Practical Implications

The practical implications of this study are significant for policymakers, industry stakeholders, and media professionals involved in the dissemination and regulatory oversight of AI technologies. By illuminating how different agency framings influence public perceptions of controllability, uncertainty, and trust, this research offers actionable insights that can guide the strategic communication and policy formulation surrounding AI and autonomous systems.

The findings suggest that incorporating human agency into the narrative of AI-enabled technologies can enhance public trust and acceptance. For media agencies and AI technology companies, the study suggests an important role in shaping public opinion about

AI through careful framing in news and promotional content. These entities should aim to present AI technologies in a way that emphasizes their supportive and augmentative relationship with human capabilities, rather than portraying them as replacements for human roles. Media professionals should be encouraged to provide nuanced coverage that includes discussions of AI's limitations and the essential role of human oversight. This approach could mitigate fears and resistance stemming from misconceptions about AI's autonomy and foster a more informed and balanced public dialogue about the integration of AI into daily life.

By addressing these communication strategies, media agencies can play a pivotal role in bridging the gap between AI advancements and public understanding, ensuring that technological progress is met with informed acceptance rather than apprehension. This could involve partnerships with technologists to accurately report on the current state of AI and its future potential, as well as initiatives to increase the visibility of positive examples where AI and human collaboration have led to beneficial outcomes.

Additionally, as the results suggest, a heightened sense of controllability can decrease uncertainty perception and prompt trust in both AI and autonomous vehicles. Thus, extending from the communication of AI to the development of AI, AI developers and engineers should consider the importance of designing systems that allow for a degree of human control. This includes developing AI that can explain its reasoning (explainable AI), which could significantly reduce the uncertainty associated with AI decisions. Such features make AI systems more transparent and comprehensible, thereby enhancing the perceived controllability and trustworthiness of these technologies. Meanwhile, policies could be developed to encourage the design of AI systems that are not only advanced but also transparent and controllable by human operators. By applying these practical insights, those involved in the development, regulation, and communication of AI technologies can better

align their efforts with public expectations and concerns, ultimately leading to more effective and trustworthy AI implementations.

Overall, this study aimed to provide empirical evidence showing that depicting AI systems as dominant and superior in automation undermines public trust in AI systems and automation technologies. Using autonomous vehicles as a prime example of human-AI collaboration, this research sought to highlight the importance of emphasizing human presence and involvement in the communication of AI-enabled technologies. This approach is crucial for fostering a human-centered discourse that builds trust.

Limitations and Future Research

Ceiling effect of synergy agency framing is one potential limitation of this study. Given that this framing type already combines the strengths of both human and AI agency, it might be perceived as the most balanced and thus have inherently higher baseline levels of trust and perceived controllability. This could result in a ceiling effect, where improvements in trust and perception due to additional positive framing are minimal because ratings are already at or near their maximum at the baseline condition. Future studies could explore different levels or intensities of synergy framing to determine if these effects persist across varying degrees of human-AI collaboration intensity.

Generalizability of agency framing across different automation contexts is another limitation. While this study demonstrates the impact of agency framing on trust and perception within the realm of autonomous vehicles, agency frames might influence perceptions differently in other AI-enabled automation contexts. For instance, AI's role in healthcare, finance, or customer service, where the dynamics of interaction and the stakes of decision-making vary significantly from those in autonomous vehicles, might elicit different responses to similar framing strategies. Future research should investigate the effects of agency framing in these varied contexts to determine if the patterns found in this study can be observed across different sectors. This can help tailor communication strategies to specific applications of AI technology, ensuring that the framing effectively aligns with the characteristics and expectations of each domain.

Lack of multimodal communication strategies is the third limitation of this study. The experimental stimuli only contain textual descriptions to simulate the effects of agency framing on perceptions of AI in autonomous vehicles. Since the general public often lacks first-hand experience with AI in autonomous vehicles, textual stimuli might not evoke as strong or nuanced a perception as multimodal communication strategies, such as visual aids,

interactive simulations, video demonstrations, or virtual reality simulations. These multimodal approaches could potentially provide a more realistic and engaging experience, thereby influencing perceptions and trust in AI more effectively. Future research should consider incorporating these varied communication formats to better mimic real-world interactions with AI systems. This approach would allow for a more comprehensive assessment of how different media influence the public's perceptions of AI technologies.

In addition to the possible future directions mentioned alongside the limitations, another direction is to consider gender differences in trust towards AI and autonomous vehicles. The findings of this study indicate that gender may be a significant factor influencing trust in AI and autonomous vehicles, with male participants generally exhibiting higher levels of trust. This observation suggests that future research should explore the underlying reasons for these gender-specific differences in trust. Investigating how societal, psychological, and cultural factors contribute to the variance in trust in AI could provide deeper insights. For instance, studies could examine whether these differences are related to varying levels of familiarity with technology, perceived risk tolerance, or driving experience between genders. Additionally, research could explore interventions or communication strategies that might equalize trust levels across genders, thereby facilitating a more uniform acceptance and use of AI technologies in diverse demographic groups.

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Appendix

Appendix I. Experiment Stimuli Design

Table 3.1

Dimensions of experimental stimuli

	[Condition 1] AI agency framing	**[Condition 2] Human agency framing**	**[Condition 3] Synergy agency framing**
Introduction	In the context of autonomous vehicles, artificial intelligence (AI) will become the driving force behind reshaping transportation. In autonomous vehicles, AI can work independently, and outperform, even replace human drivers.	In the context of autonomous vehicles, human drivers remain the guiding forces in transportation. Even in autonomous vehicles, humans can operate with their own initiative and will not be outperformed or replaced by artificial intelligence (AI).	In the context of autonomous vehicles, a blend of human and artificial intelligence (AI) will define the future of transportation. In autonomous vehicles, humans and AI coexist, each contributing their unique strengths.
Strengths	Equipped with advanced sensors and cutting-edge algorithms, AI-enabled autonomous vehicles can seamlessly assess their environment, anticipate potential challenges, and make split-second decisions. This	Equipped with a deep understanding of road dynamics, human drivers can actively assess their environment, anticipate potential challenges, and make split-second decisions. This human touch retains human drivers as the	With AI systems' advanced sensors, cutting-edge algorithms, and humans' deep understanding of road dynamics, autonomous vehicles can actively assess their environment, anticipate potential challenges, and make split-second decisions. This mixed approach

	technological prowess positions AI as the only conductor of journeys with zero human involvement.	main conductors of journeys without completely relying on AI.	ensures safe and efficient journeys.
Pros_Errors	Compared with human driving, the adoption of AI in autonomous vehicles eliminates accidents due to typical human errors such as drowsiness, road rage, and irrational judgments.	Compared with AI driving, human involvement in autonomous vehicles provides backup for accidents caused by AI errors, such as technical glitches or malfunctions.	Compared with exclusive AI or human driving, this fusion of capabilities avoids accidents due to human errors, like drowsiness, road rage, irrational judgments, and AI errors, like technical glitches or malfunctions.
Cons_Errors	However, the adoption of AI in autonomous vehicles can introduce safety issues caused by machine errors, such as technical glitches and machine malfunctions.	However, human involvement in autonomous vehicles brings accidents caused by human errors, such as drowsiness, road rage, or emotional judgment.	However, the collaborative nature of this approach introduces human and AI errors simultaneously; both AI and human errors can contribute the failing of tasks.
Pros_Sensing ability	Compared with humans, AI's sensing abilities are more accurate and sensitive. AI systems can continuously sense the surroundings, even in extreme	Compared with AI, humans' sensing abilities are more reliable and not overly sensitive. Humans can correctly identify their surroundings even in extreme	Compared with exclusive AI or human driving, AI continuously senses its surroundings using sensors, while human drivers reliably identify their environment even in extreme environmental

	environmental conditions, preventing accidents due to heavy rain and dark nights.	environmental conditions, preventing accidents due to heavy rain and dark nights.	conditions, thus preventing accidents during heavy rain and dark nights.
Cons_Sensing ability	However, AI's sensing abilities are not reliable and can sometimes become over-sensitive. AI systems can misidentify its surroundings and detect unnecessary objects.	However, humans' sensing abilities are not as accurate and sensitive as AI. Humans cannot continuously sense their surroundings and can overlook or misjudge obstacles.	However, the AI and human collaboration introduces challenges of coordination between humans and AI, leading to conflicts in making judgments.
Pros_Decision-making	Another example is decision-making. AI completely frees humans from driving-related decision-making. AI-enabled autonomous vehicles do not require human involvement, even for complicated tasks.	Another example is decision-making. Humans can engage in decision-making with their own initiative. Humans can choose not to rely on AI, even for simple tasks.	Another example is decision-making. The hybrid human and AI involvement allows humans fully rely on AI or engage with their own initiatives in decision-making of complicated or simple tasks.
Cons_Decision-making	However, without human engagement in driving process, AI may not always make good decisions.	However, without full reliance on AI, humans may not always make good decisions.	However, it can cause miscommunication between humans and AI.

Summary	Overall, in the absence of human intervention, the complete reliance on AI in autonomous vehicles yields both favorable outcomes and corresponding drawbacks.	Overall, in the presence of human involvement, retaining human drivers in autonomous vehicles yields both favorable outcomes and corresponding drawbacks.	Overall, with the blend of human and AI involvement, hybrid approach yields both favorable outcomes and corresponding drawbacks.

Table 3.2

Experimental Stimuli

[Condition 1] AI agency framing
In the realm of autonomous vehicles, the role of AI is pivotal. AI emerges as the essential contributor while you, as a human, will simply become a passenger. AI operates independently, often outperforming and replacing the need for human drivers. With sophisticated sensors and advanced algorithms, AI is crucial in assessing the environment while driving, anticipating potential challenges, and making critical decisions in the blink of an eye. This level of technological sophistication elevates AI to the role of the sole conductor of journeys, envisioning a future without your intervention. In autonomous vehicles, when comparing AIs to you, one of the most significant advantages AIs are able to bring is the reduction of accidents caused by typical human errors, such as fatigue or emotional and irrational judgments. However, reliance on AI is not without its challenges. It introduces a different set of risks, including those stemming from technical malfunctions and glitches inherent in machine operations. In terms of sensory capabilities, AI's precision and sensitivity stand out. AI systems offer continuous environmental monitoring, maintaining high performance even in challenging conditions like heavy rain or darkness. While it's acknowledged that AI can be overly sensitive, misinterpreting surroundings or reacting to non-threatening elements, it brings a different kind of awareness, one that is sensitive and continuous.

In terms of decision-making, AI autonomy relieves you from the burden of driving-related decisions, even in complex scenarios. This independence from your input allows for a streamlined, efficient driving process. However, this complete automation raises questions about AI's ability to handle every driving situation, especially those requiring your human intuition and judgment.

Overall, without your involvement, full AI control in autonomous vehicles brings a mix of promising benefits and inherent challenges.

Word count: 284

[Condition 2] Human agency framing

In the realm of autonomous vehicles, the role of the human remains pivotal. You, as a human, are not just passengers but essential contributors. Even as AI takes on more responsibilities, it is you who ultimately drives the car. A human's nuanced understanding of road dynamics is important while driving, and you are constantly assessing the environment, anticipating potential challenges, and making critical decisions in the blink of an eye. This invaluable human input contributes to a comfortable journey, given the tasks that only humans can accomplish while driving.

In autonomous vehicles, when comparing AIs to you, you are able to bring to the table a unique blend of intuition and experience, capable of intervening effectively to avoid mishaps that might elude AI's detection. However, human involvement is not without its challenges. It introduces a different set of risks, including those stemming from human error like fatigue or emotional or irrational judgment inherent in human operations.

In terms of sensory capabilities, your adaptability and holisticness stand out. In extreme weather conditions or unpredictable environments, your senses and interpretative skills are indispensable. While it's acknowledged that human sensory abilities are not infallible and may lack the continuous monitoring and hypersensitivity of AI, they bring a different kind of awareness, one that is holistic and adaptable.

In terms of decision-making, you have the autonomy to override AI decisions. This level of control and initiative is crucial, allowing for a dynamic and flexible approach to driving.

However, your involvement raises questions about your ability to handle every driving situation, especially those requiring AI efficiency and accuracy.

Overall, your involvement in autonomous vehicle integration brings a mix of promising benefits and inherent challenges.

Word count: 279

[Condition 3] Synergy agency framing

In the realm of autonomous vehicles, the role of both human and AI is pivotal. You as a human, together with AI, are not just coexisting but actively working together. With the combination of AI's and human's nuanced understanding of road dynamics, additional sensors on the vehicle, capabilities, of assessing the environment, anticipating potential challenges, and making critical decisions in the blink of an eye. This synergistic approach ensures that both human and AI are involved, envisioning a future where each journey is a collaborative effort that blends your insight with AI.

In autonomous vehicles, the blend of your capabilities and AI features significantly reduces the likelihood of accidents attributable to human errors such as fatigue, emotional, and irrational judgments, as well as AI errors like technical glitches or system malfunctions. However, this integrated approach is not without its challenges, including the potential for simultaneous or overlapping human and AI errors.

In terms of sensory capabilities, AI's continuous environmental sensing is complemented by your ability to accurately perceive and interpret complex scenarios, particularly under extreme conditions like heavy rain or darkness. This dual approach enhances safety, preventing accidents that might occur in either exclusive AI or human scenarios. Nonetheless, coordinating you and AI can sometimes lead to conflicts in judgment.

In terms of decision-making, a blend of AI and your autonomy allows for a dynamic interplay where you can either take the initiative or fully rely on AI, adapting to both complex and routine tasks. However, this shared responsibility can sometimes result in miscommunication or conflicting decisions between you and AI inputs.

Overall, the synergistic approach of human and AI involvement in autonomous vehicles brings a mix of promising benefits and inherent challenges.

Word count: 283

Appendix II. Experiment Walkthrough & Measurement and Items (Questionnaire)

Table 4.

Questionnaire

Description	Content/Items
Information Sheet and Consent form	See Appendix III: Study Information Sheet and Consent Form for Research Participants
Screening Question	You need to be at least 21 years old to participate in this study. [Age] How old are you (in years)?
Opening *Greetings and provide definitions of key terms that will appear in the questionnaire*	Thank you for your time in participating in this research. This study is completed fully online, which will take you around 15 to 20 minutes. First, you will answer a series of questions, and then read a message on the role of humans and AI in autonomous vehicles. Later, you will answer another set of questions, including your perceptions and some demographic information. This study aims to understand public perceptions of Artificial Intelligence (AI) technologies in autonomous vehicles. To begin, we would like to provide you with a definition of AI to help you better understand the context. Artificial Intelligence is a software-based system that performs tasks and produces results in accordance with algorithms and data. This process involves detecting patterns in data, drawing conclusions, and making predictions. Autonomous vehicle is an application of AI technologies.
Pre-Stimuli Questionnaire	
AI Awareness [AA]	To your knowledge, how likely is it that the following technologies/applications/services are using AI, from 1 (not at all likely) to 5 (extremely likely)? [AA1] Self-driving cars [AA2] Virtual assistants (e.g., Siri, Cortana) [AA3] Smart speakers (e.g., Amazon Echo, Google Home)

	[AA4] Search engines (e.g., Google Search)
	[AA5] Recommender systems (e.g., Amazon, Netflix, Spotify)
	[AA6] Internet of Things (e.g., smart home devices)
	[AA7] Social robots (e.g., Pepper, Nao, Lynx, AIBO)
	[AA8] Social media (e.g., Facebook, Twitter, TikTok)
Prior belief in AI [MH]	Please rate your degree of agreement with the following statements, from 1 (strongly disagree) to 5 (strongly agree).
	[MH1] If AI does a job, then the task is done objectively.
	[MH2] If AI does a job, then the work is error-free.
	[MH3] If AI does a job, then the work is unbiased.
	[MH4] If AI does a job, then the task is done accurately.
Perceived Threat by AI [PT]	Please rate your degree of agreement with the following statements, from 1 (strongly disagree) to 5 (strongly agree).
	[PT1] I am concerned that AI will cause job losses.
	[PT2] I am concerned that AI will abuse users' data.
	[PT3] I am concerned that AI will threaten human dignity.
	[PT4] I am concerned that AI will threaten human society.
	[PT5] I am concerned that AI will lead to serious plights for humans.
	[PT6] I am concerned that AI will destroy our lives.
	[PT7] I am concerned that humans might lose control of AI.
Desirability of Control [DC]	Please rate your degree of agreement with the following statements, from 1 (strongly disagree) to 5 (strongly agree).
	[DC1] I prefer a job where I have a lot of control over what I do and when I do it.
	[DC2] I enjoy political participation because I want to have as much of a say in running the government as possible.
	[DC3] I try to avoid situations where someone else tells me what to do.
	[DC4] I would prefer to be a leader rather than a follower.
	[DC5] I enjoy being able to influence the actions of others.
	[DC6] I am careful to check everything on an automobile before I leave for a long trip.
	[DC7] Others usually know what is best for me.

	[DC8] I enjoy making my own decisions.
	[DC9] I enjoy having control over my own destiny.
	[DC10] I would rather someone else took over the leadership role when I'm involved in a group project.
	[DC11] I consider myself to be generally more capable of handling situations than others are.
	[DC12] I'd rather run my own business and make my own mistakes than listen to someone else's orders.
	[DC13] I like to get a good idea of what a job is all about before I begin.
	[DC14] When I see a problem, I prefer to do something about it rather than sit by and let it continue.
	[DC15] When it comes to orders, I would rather give them than receive them.
	[DC16] I wish I could push many of life's daily decisions off on someone else.
	[DC17] When driving, I try to avoid putting myself in a situation where I could be hurt by someone else's mistake.
	[DC18] I prefer to avoid situations where someone else has to tell me what it is I should be doing.
	[DC19] There are many situations in which I would prefer only one choice rather than having to make a decision.
	[DC20] I like to wait and see if someone else is going to solve a problem so that I don't have to be bothered by it.
Attention to media: Print news [AMP]	On a scale of 1 to 5 (1 = No attention at all, 5 = A lot of attention), how much attention do you generally pay to print newspaper about …
	[AMP 1] International affairs
	[AMP 2] National government and politics
	[AMP 3] Science and technology
	[AMP 4] Artificial intelligence
	[AMP 5] Autonomous vehicles

Attention to media: Online news [AMO]	On a scale of 1 to 5 (1 = No attention at all, 5 = A lot of attention), how much attention do you generally pay to online news (e.g., www.straitstimes.com) about … [AMO 1] International affairs [AMO 2] National government and politics [AMO 3] Science and technology [AMO 4] Artificial intelligence [AMO 5] Autonomous vehicles
Attention to media: TV news [AMT]	On a scale of 1 to 5 (1 = No attention at all, 5 = A lot of attention), how much attention do you generally pay to TV news about … [AMT 1] International affairs [AMT 2] National government and politics [AMT 3] Science and technology [AMT 4] Artificial intelligence [AMT 5] Autonomous vehicles
AI Knowledge [AK] with [AK2] false.	Based on your knowledge of AI, please determine whether the following statements are true or false: [AK1] Artificial intelligence includes techniques that allow systems to learn without being explicitly programmed. [T]/[F] [AK2] Machine learning is not a type of AI. [T]/[F] [AK3] Artificial intelligence is often categorized into two types: general Artificial intelligence and narrow Artificial intelligence. [T]/[F] [AK4] Artificial intelligence is a software, machine, or computer that researchers think could eventually emulate the human mind. [T]/[F]
Driving Ability [DA]	[DA] Do you have any driving experience? [Y]/[N]
Driving Qualification	[DQ] Do you hold a valid driver's license? [Y]/[N]
Driving Experience [DE]	[DE1] From 1 (very low) to 5 (very high), how would you like to rate your experience in driving? [DE2] From 1 (very low) to 5 (very high), how would you like to rate your expertise in driving?

Introduction to Stimuli	In the next section, you will read a message on the role of AI and human in autonomous vehicles. After reading the message, you will answer a set of questions related to the content that you read. The reading will take around 60 to 90 seconds. The button for [Next Page] will show up after 60 seconds.
Experimental Stimuli	See Appendix II: Experimental Stimuli
Post-Stimuli Questionnaire	
Argument Strength [MCAS]	[MCAS] In your view, on a scale from 1 (very weak) to 5 (very strong), how would you rate the strength of the argument presented in the message? Very weak 1 2 3 4 5 Very strong
Manipulation Check for Agency Framing	[MCA] How much do you think the functioning of autonomous vehicles relies on humans? Not at all relying on human 1 2 3 4 5 Completely relying on human
Perceived Controllability of Autonomous Driving [PC]	Based on your understanding of humans and AI in autonomous vehicles after reading the message, imagine you are in an autonomous vehicle, please rate your degree of agreement with the following statements, from 1 (strongly disagree) to 5 (strongly agree). [PC1] I have a sense of control over the actions of the autonomous vehicle. [PC2] I feel that I will be able to determine the outcome of driving process in the autonomous vehicle. [PC3] I feel that I will be able to prevent the negative consequences brought by autonomous driving. [PC4] I believe I have the ability to control the autonomous vehicle in any circumstances.
Perceived Technological Uncertainty [PTU]	Based on your understanding of humans and AI in autonomous vehicles after reading the message, imagine you are in an autonomous vehicle, please rate your degree of agreement from 1 (strongly disagree) to 5 (strongly agree).

	[PTU1] I feel that relying on the autonomous vehicle involves a high degree of uncertainty. [PTU2] I feel the uncertainty associated with using the autonomous vehicle is extremely high. [PTU3] I am exposed to many uncertainties when using the autonomous vehicle. [PTU4] There is a high degree of uncertainty regarding the outcome (i.e., the results may not match expectations) when relying on the autonomous vehicle.
Attention Check Question	Which of the following is a color (please choose "Apple" as the answer)? a) Apple b) Strongly Agree c) Chair d) Blue
Trust in AI in autonomous vehicles [TA]	In your opinion, from 1 (not at all) to 5 (a great deal), [TAI1] To what extent do you think the AI in autonomous vehicles performs the driving tasks effectively? [TAI2] To what extent can you anticipate the performance of AI in autonomous vehicles with some degree of confidence? [TAI3] To what extent is AI in autonomous vehicles free of errors? [TAI4] To what extent do you have a strong belief in AI in autonomous vehicles to perform driving tasks effectively for which there may be no proof? [TAI5] To what extent do you trust AI in autonomous vehicles overall?
Cognitive Trust in AI in Autonomous Vehicles [CTAI]	Please rate your degree of agreement with the following statements, from 1 (strongly disagree) to 5 (strongly agree). [CTAI1] The AI will be competent at driving independently. [CTAI2] The AI in autonomous vehicles will demonstrate expertise in driving. [CTAI3] The AI's analysis of driving situations will be accurate. [CTAI4] I will be able to rely on AI's driving capabilities.

	[CTAI5] I will be able to trust the AI's decision-making.
Emotional Trust in AI in Autonomous Vehicles [ETAI]	[ETAI1] AI in autonomous vehicles will care about my driving experience. [ETAI2] AI in autonomous vehicles will help me with great care. [ETAI3] AI in autonomous vehicles will kindly help me when I need it. [ETAI4] AI in autonomous vehicles will take care of me with thoughtful consideration.
Trust in Autonomous vehicles [TAV]	In your opinion, from 1 (not at all) to 5 (a great deal), [TAV1] To what extent do you think autonomous vehicles are dependable? [TAV2] To what extent do you think autonomous vehicles are reliable? [TAV3] To what extent do you perceive autonomous vehicles as secure? [TAV4] To what extent do you have confidence in autonomous vehicles' performance? [TAV5] To what extent do you trust autonomous vehicles overall?
Autonomous Vehicle Acceptance [AAC]	[AAC1] From 1 (very unacceptable) to 5 (very acceptable), please indicate your acceptable level of autonomous vehicles.
Use Intention of Autonomous Vehicles [ITU]	Please rate your degree of agreement with the following statements, from 1 (strongly disagree) to 5 (strongly agree). [ITU1] I intend to use autonomous vehicles in the future. [ITU2] My intentions are to use autonomous vehicles than use any alternative means. [ITU3] If I could, I would like to use autonomous vehicles as much as possible.
Demographics	
Demographics Ethnicity, gender, education, income	Now that you have completed the questions, we would like to know some demographic information. [Ethnicity] What is your ethnicity?

[ ] Chinese

[ ] Malay

[ ] Indian

[ ] Eurasian

[ ] Others, please specify: _____

[Gender] What is your gender?

[ ] Female

[ ] Male

[Education] What is your highest educational level?

[ ] No formal education

[ ] Primary 6 or below

[ ] Secondary

[ ] N-level/ITE

[ ] O-level

[ ] A-level

[ ] Diploma & professional qualification

[ ] Bachelor's degree or equivalent

[ ] Master's degree/ Postgraduate

[ ] Doctoral degree

[Income] What is your monthly household income (SGD)?

[ ] Less than S$1,000

[ ] S$1,000 – S$1,499

[ ] S$1,500 – S$1,999

[ ] S$2,000 – S$2,499

[ ] S$2,500 – S$2,999

[ ] S$3,000 – S$3,499

[ ] S$3,500 – S$3,999

[ ] S$4,000 – S$4,499

[ ] S$4,500 – S$4,999

[ ] S$5,000 – S$5,999

[ ] S$6,000 – S$6,999

[ ] S$7,000 – S$7,999

[ ] S$8,000 – S$8,999

[ ] S$9,000 – S$9,999

[ ] S$10,000 – S$10,999

[ ] S$11,000 – S$11,999

[ ] S$12,000 – S$12,999

[ ] S$13,000 – S$13,999

[ ] S$14,000 – S$14,999

[ ] S$15,000 – S$15,999

[ ] S$16,000 – S$17,999

[ ] S$18,000 – S$18,999

[ ] S$19,000 – S$19,999

[ ] S$20,000 and above

[ ] Refused to answer