Although Autonomous Cars Are Not Yet Manufactured, Their Acceptance Already Is

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Abstract. A range of terms and concepts referring to autonomous vehicle technologies are used both in the scientific and grey literature. Different, often overlapping, concepts and adjectives are used to describe automated vehicles. This abundance of terminology can create conditions for confusion and factual misinterpretation among audiences and between authors. This paper argues the lack of clarity between automated and autonomous cars contributes to increase expectations of current technology and to inappropriate predictions of both public and governments alike. The “autonomous” car, or vehicle, is a misnomer that could mislead potential users and its use may well result in a backlash of rejection, slowing development. To have an overview of driving automation vocabulary, a search of publications referencing “autonomous”, “automated”, “driverless” and “self-driving” cars or vehicles in the ScienceDirect library was conducted. Results showed they were largely used in the scientific literature investigated, despite obvious meaning differences between the concepts. The impact of the incorrect use of these terms on individuals' acceptance is discussed and clear definitions provided.

Keywords: Automation · Autonomy · Acceptance · Driving · Content Analysis

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1 Introduction

1.1 Public belief and market reality

Automation in transport is a hot topic nowadays, discussed in academia, journals and social media. Within that topic, "autonomous car" has already become one of the buzzwords probably since the 2004 DARPA Grand Challenge, which consisted of a race in a desert with automated vehicles. The risk is now to turn this term into a misnomer, misleading the public about the realistic attributes and capacities of automated cars. For instance, a worldwide survey including 1567 car owners showed that more than 70% of responders believed they could already purchase a car that drove itself (Euro NCAP, 2018). This confusion possibly comes from the use of "autonomous car", referring to automated technology, which insinuates cars do not rely on human operators at all to be driven. A previous study also showed that the capability of an artificial intelligence may not be accurately assessed by users (Semigran, Levine, Nundy & Mehrotra, 2016). While a range of automated functions are available, autonomous cars are not yet available on the market, and probably never will.

1.2 Definition of autonomy

In general, automated cars are referred to using a number of different terms: autonomous cars, self-driving cars and driverless cars, despite that meaning differing from one concept to another (Reilhac, Millett & Hottelart, 2016). Sometimes, they are even mentioned as semi-autonomous cars, which is quite inadequate regarding the meaning of autonomy. Autonomy comes from the Greek “autos”, self, and “nomos”, which means law; “autonomos” means having its own laws, or self-governed. Considering that so-called autonomous cars rely on inorganic, electricity-powered sensors, human-designed algorithms, infrastructure and connectivity, it is hard to believe they are self-governed vehicles. On the contrary, they are highly dependent on their environment, which encompasses the road, weather, sensors, infrastructure, connectivity (i.e., Vehicle to Vehicle, Vehicle to Infrastructure and Vehicle to Everything), driver, passengers and other road users (e.g. pedestrians, motorcyclists, cyclists, scooters, connected and non-connected cars). It could be argued that they do not actually make their own decisions, they respond to events according to a machine-learning process, which does not include self-consciousness, free will and the understanding of causality. Autonomy is also defined as self-sufficiency, which is the "capability of an entity to take care of itself" (Bradshaw, Hoffman, Woods & Johnson, 2013), and the capacity of self-generating goals (Luck, 2003). Kaber (2018) proposes a conceptual framework of autonomous agents and argues that they must be independent, viable and self-governing. Abbaas, Petraki, Merrick, Harvey and Barlow (2016) provide a very similar definition of autonomy in which viability is replaced with reliance on the agents' own laws.

1.3 Real-world examples and theoretical discussion

One example of the incorrect use of the word "autonomous" is the Navya AUTONOM shuttle, described by the company as 100% autonomous and driverless (Navya, 2018). One of these shuttles hit the front end of a truck pulling out into a street in Las Vegas in 2017. Las Vegas officials declared “the shuttle did what it was supposed to do, in that its sensors registered the truck and the shuttle stopped to avoid the accident”. If that vehicle was an autonomous shuttle, it could have also stopped earlier to prevent a collision with the truck coming from its left, or even tried to avoid the oncoming truck. Such a system is not capable of general intelligent behaviour in an instantiate environment, especially in terms of decision making (i.e. selection, application and evaluation of an operation), as defined by the Soar cognitive architecture (Laird, 2012). This illustrates the brittleness of the autonomous systems that lacks resilience when facing out-of-boundary conditions and surprising events (Woods, 2016). In the Las Vegas example the safety operator inside the shuttle eventually hit the emergency button to stop the vehicle, which was slowing down but did not make the decision to come to a full stop. It appears such vehicles are subordinates rather than independent agents on the road. An autonomous agent, and by extension an autonomous car, is resilient and can adapt to a variety of situations, be it unstable or unknown. It entails the capacity of recovering from its own error and coping with a large range of the unexpected hazards of the road environment. It also has the capability to change over time (de Visser, Pak & Shaw, 2018), and potentially evolve in an unpredictable way (Kurzweil, 2005) that will no longer fit its initial purpose of carrying over human-operated tasks.

Another discrepancy with respect to autonomy vocabulary is common. For instance, why do autonomous vehicles require human monitoring under certain circumstances? If monitoring is necessary, it means the vehicle is not independent, viable and self-sufficient. Therefore, it is not autonomous.

As of now, no autonomous cars exist. More generally, it is also asserted no autonomous systems exist, as none of them can perform adequately in every situation and task (Bradshaw, 2013). This is also pointed out by Doyle's catch which stipulates that "a system must have enough robustness in order to close the gap between demonstration and the real thing" (Alderson & Doyle, 2010). It seems reasonable to say some cars have been automated up to a certain level, enabling computers paired with sensors to handle both the longitudinal and lateral control of the vehicle under determined circumstances and roads. Within that configuration, the driver is assisted by automation, not replaced by autonomy. To summarize, autonomy is the ability of a system to viably achieve a set of self-generated goals and to adapt to environmental changes without human intervention. A car will probably never do this as it needs to take the driver and the passengers from point A to B, hence it does not decide its own goals.

1.4 Definition of automation

Automation is different from autonomy, albeit their objective and rule-based operations are comparable. The goal of automation is to "replace manual control, planning and problem solving by automatic devices and computer" (Bainbridge, 1983). Similarly, Parasuraman (2000) defined automation as the execution by a machine of a function either previously carried out by a human or a function that humans cannot perform as well as machines. Automation has also been defined as a "technology that actively selects data, transform information, makes decision, or control processes" (Lee & See, 2004). In manufacturing, automation is the "technology by which a process or procedure is performed without human assistance. Humans may be present as observers or even participants, but the process itself operates under its own self-direction. Automation is implemented by means of a control system that executes a program of instructions" (Groover, 2014, p.887). This definition is relatively consistent with the drivers' role in an automated car and encompasses the different levels of automation.

1.5 Levels of automation

Levels of automation designate the degree of individuals and computer control of a dynamic task (Sheridan, 1978; Endsley & Kaber, 1999; Kaber & Endsley, 2003). Levels of automation have been applied to the automotive industry to provide a framework (Table 1), such as the National Highway Traffic Safety Administration's 5 levels of vehicle automation (NHTSA, 2013), ranging from "0 No-automation" to "4 Full Self-Driving Automation" or the SAE's 6 levels of driving automation ranging from "0 No automation" to "5 Full Automation" (On-Road Automated Vehicle Standards Committee, 2014) and the BASt (Gaser & Westhoff, 2012) 5 degrees of automation. The NHTSA has now adopted SAE's levels of driving automation.

Table 1 Definitions of the different levels (SAE & NHTSA) or degrees (BASt) of automation

Level of automation		
SAE	NHTSA	BASt
0 No Automation	0 No Automation	Driver Only

1 Driver Assistance	1 Function-specific Automation	Driver Assistance
2 Partial Automation	2 Combined Function Automation	Partial Automation
3 Conditional Automation	3 Limited Self-Driving Automation	High Automation
4 High Automation	4 Full Self-Driving Automation	Full Automation
5 Full Automation	N/A	N/A

These frameworks are debated and discussed within the scientific community as their definitions are not yet complete (Inagaki & Sheridan, 2018). They are also sometimes used interchangeably. For instance, a NHTSA survey on public opinion about self-driving vehicles (Schoettle & Sivak, 2014) presented participants an adaptation of NHTSA's 5 levels of automation using “autonomous vehicles”, “autonomous-vehicle technology” or “self-driving technology” instead of the original word “automation”. It could be argued that it makes it easier for the public to understand, but the authors did use inequivalent terms to qualify NHTSA's five levels of automation.

1.6 Main similarity and difference between automation and autonomy

The concepts of automation and autonomy share a common goal, which is to carry over tasks previously handled by human operators. Nonetheless, they remain different in their characteristic. A simple way to differentiate automation from autonomy is that automation is deterministic whereas autonomy is indeterminate (Hancock, 2017). Now that the distinction between autonomy and automation has been described, the occurrences of those terms in a section of scientific literature will be analysed and discussed. The objective is to understand the metadata characteristics of science publications, which reference driverless, self-driving, automated and autonomous cars or vehicles.

2 Descriptive analysis of the ScienceDirect library for traces of driverless, self-driving, automated and autonomous cars and vehicles

2.1 Material and method

The present study reviews the uses of the four adjectives “automated”, “autonomous”, “self-driving” and “driverless” paired with both nouns “car” and “vehicle” (Table 2).

Table 2 List of the eight keywords searched in the ScienceDirect library

driverless car	driverless vehicle
self-driving car	self-driving vehicle
automated car	automated vehicle
autonomous car	autonomous vehicle

These eight variations were selected as they were the most common terms used in the scientific literature addressing driving automation at the time of the analysis (Hyve, 2015). ScienceDirect library was used as its scientific database was one of the largest, and its interface allowed to conduct accurate searches of keywords within transportation dedicated journals. Other libraries were not utilized as their interface did not include one or several articles types (e.g. there is no filter to look for research papers for Springer and Scopus, and there is no article type filter at all for Google Scholar at the time of the study), therefore making content access more restrictive. The occurrences of the eight variations in proceedings, periodicals, books and news listed were examined. To do so, a retrieval process and search of publications referencing either one of the terms in their title, abstract or author-specified keywords were performed using the ScienceDirect advanced search interface. The research was conducted on Monday, 17th June 2019 at 09:25am and the results reported are those found at that date and time.

2.2 Results

A total of 6,874 occurrences were identified including all the keywords found in the title, the abstract, the highlights and the author-specified keywords. Some publications were counted more than once as they used one or more keywords searched. The search engine did not allow to specify which these publications were. The plural forms “cars” and “vehicles” did not affect the number of hits. Research article is the most frequent format identified for all the keywords: “automated vehicle” (90.92%), “autonomous vehicle” (89.93%), “autonomous car” (89.19%), “automated car” (85.26%), “self-driving car” (83.86%), and “driverless car” (59.72%). Within Table 3, the term ‘Journal Title’ refers to the name of the journal in which the term was published, in parentheses after the title is number of individual papers within this journal where the keyword was cited. The total number of journals is the same (10) for each keyword, which may be a cap of the search engine (Table 3).

Table 3. Number of occurrences of the searched terms over the years with the article type and the publication title.

Keywords	Total occurrences	Time span	Article type (searched term occurrences)	Journal title (searched term occurrences)
driverless car	79	1966 - 2019	Research article (49), Book chapters (8), Conference abstracts (3), Book reviews (1), Correspondence (1), News (8), Other (9)	New scientist (18), Transportation Research Part A: Policy and Practice (5), Transportation Research Procedia (5), Transportation Research Part C: Emerging Technologies (4), Accident Analysis & Prevention (3), Transportation Research Part F: Traffic Psychology and Behaviour (3), Journal of Transport & Health (3), Technology in Society (2), Transport Policy (2), Journal of Transport Geography (2)
self-driving car	309	1994 - 2019	Review articles (5), Research articles (260), Encyclopedia (1), Book chapters (6), Conference abstracts (10), Case reports (1), Correspondence (1), Discussion (1), Mini reviews (5), News (7), Short communications (10), Other (2)	Transportation Research Part F: Traffic Psychology and Behaviour (49), Accident Analysis & Prevention (44), Journal of Safety Research (12), Transportation Research Part A: Policy and Practice (10), New Scientist (7), Journal of Transport & Health (7), Transportation Research Procedia (7), Applied Ergonomics (5), Safety Science (5), Journal of Transport Geography (5)
automated car	488	1995 - 2019	Review articles (11), Research articles (408), Book chapters (27), Conference abstracts (24), Case reports (1), Discussion (2), Mini reviews (6), News (3), Short communications (5), Other (1)	IFAC Proceedings Volumes (32), Transportation Research Part F: Traffic Psychology and Behaviour (28), Transportation Research Part C: Emerging Technologies (23), Accident Analysis & Prevention (18), Transportation Research Procedia (14), IFAC-PapersOnLine (13),

				Transportation Research Part A: Policy and Practice (11), Procedia Computer Science (11), Procedia CIRP (10), Procedia Manufacturing (9)
autonomous car	455	1995 - 2019	Review articles (8), Research articles (406), Encyclopedia (1), Book chapters (17), Conference abstracts (2), Mini reviews (4), News (8), Short communications (7), Other (2)	IFAC Proceedings Volumes (60), Transportation Research Part C: Emerging Technologies (32), IFAC-PapersOnLine (28), Procedia Computer Science (19), Transportation Research Procedia (16), Transportation Research Part A: Policy and Practice (13), Accident Analysis & Prevention (12), Expert Systems with Applications (11), Robotics and Autonomous Systems (11), Transportation Research Part F: Traffic Psychology and Behaviour (10)
driverless vehicle	89	1980 - 2019	Research articles (72), Book chapters (10), Conference abstracts (3), Mini reviews (1), News (1), Short communications (1), Other (1)	Transportation Research Part C: Emerging Technologies (9), Transportation Research Procedia (7), Transport Policy (5), Transportation Research Part A: Policy and Practice (5), Accident Analysis & Prevention (4), Transportation Research Part F: Traffic Psychology and Behaviour (4), Journal of Transport & Health (4), IFAC-PapersOnLine (4), Procedia Computer Science (3), The End of Driving, 2019 (3)
self-driving vehicle	518	1996 - 2019	Review articles (10), Research articles (469), Encyclopedia (1), Book chapters (9), Conference abstracts (9), Case reports (1), Data articles (1), Discussion (1), Editorials (1), Mini reviews (1), News (2),	Accident Analysis & Prevention (113), Transportation Research Part F: Traffic Psychology and Behaviour (69), Journal of Safety Research (34), Applied Ergonomics (13), Transportation Research Part C: Emerging Technologies (10), Transportation Research Part A: Policy and Practice (10),

			Short communications (12), Other (1)	Safety Science (9), Transportation Research Procedia (9), Journal of Power Sources (8), American Journal of Preventive Medicine (7)
automated vehicle	1942	1995 - 2019	Review articles (32), Research articles (1,763), Encyclopedia (3), Book chapters (80), Conference abstracts (15), Book reviews (4), Case reports (1), Conference info (2), Correspondence (1), Data articles (1), Discussion (1), Editorials (3), Errata (2), Mini reviews (3), News (2), Short communications (25), Other (4)	IFAC Proceedings Volumes (279), Transportation Research Part C: Emerging Technologies (130), IFAC-PapersOnLine (98), Transportation Research Part F: Traffic Psychology and Behaviour (66), Accident Analysis & Prevention (57), Computers & Industrial Engineering (48), Transportation Research Procedia (45), European Journal of Operational Research (31), Transportation Research Part B: Methodological (29), Control Engineering Practice (26)
autonomous vehicle	3824	1995 - 2019	Review articles (74), Research articles (3,658), Encyclopedia (15), Book chapters (133), Conference abstracts (40), Book reviews (6), Conference info (2), Correspondence (1), Data articles (1), Discussion (4), Editorials (9), Errata (3), Mini reviews (9), News (14), Short communications (86), Software publications (1), Other (11)	IFAC Proceedings Volumes (1,074), IFAC-PapersOnLine (351), Ocean Engineering (198), Robotics and Autonomous Systems (185), Control Engineering Practice (118), Transportation Research Part C: Emerging Technologies (116), Procedia Computer Science (84), Transportation Research Procedia (56), Acta Astronautica (55), Automatica (54)

The journals publishing papers on these topics encompass different fields of research, such as social, physical and computer sciences, human factors, engineering, prevention, transportation, policies and legislation.

The term “driverless car” (n=79; 1%) was the least frequent whereas “autonomous vehicle” (n=3824; 49.6%) was the most frequent one. The term “automated vehicle” was quite frequent (n=1942; 25.2%) and ranked second among the eight terms investigated in the amount of occurrences observed. The total number of occurrences for self-driving vehicle (n=518; 6.7%), “automated car” (n=488; 6.3%), “autonomous car” (n=455; 5.9%) and “self-driving car” (n=309; 4%) was similar, whereas “driverless vehicle” (n=89; 1.2%) was far less used. There is a tendency for each term to be used more frequently over the years, with some peaks for “autonomous vehicle” in 1995, 1998 and 2004, the latest being congruent with the first DARPA Grand Challenge (Figure 1. To enhance the figure’s visibility, earlier occurrences have not been included and are reported in Table 1).

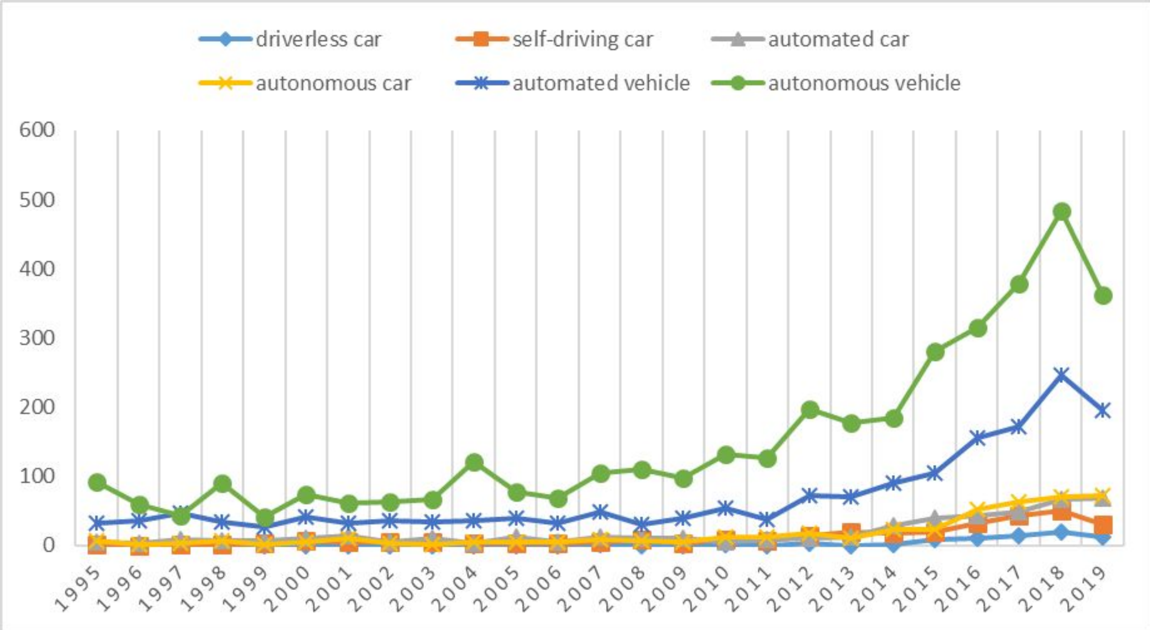

Fig. 1. Number of occurrences for each keyword per year from January 1st, 1995 to June 17th, 2019.

3 Discussion

The terms "driverless car", "driverless vehicle" "self-driving car", "self-driving vehicle", "automated car", "autonomous car", "automated vehicle" and "autonomous vehicle" seem to be sometimes synonymous in the scientific literature despite the fundamental differences between them. For instance, within the same publication (de Visser, Pak & Shaw, 2018), a failure from the machine vision system of Tesla Autopilot is mentioned as an "autonomy error" although this driver-assistance system falls into NHTSA's level 2 automation. Similarly, "autonomy" and "automation" are sometimes used interchangeably in different contexts (e.g. Endsley, 2018), or when using SAE levels of driving automation in expressions such as "SAE level 4 autonomous vehicle" instead of level 4 high automation (Vedecom Institute, 2019). These examples illustrate some incorrect uses of the term “autonomy”, but not all scientific publications are mixing the concepts of autonomy and automation. Both terms are sometimes even treated synonymously on purpose (Endsley, 2017). The present paper does not aim at referencing all the incorrect uses of both terms in the grey literature, but rather stress some vocabulary inconsistencies in the field of driving automation.

The multiple variations of “automated car” may bring confusion to audiences on the object being investigated. In the following paragraphs, the incorrect use of “autonomous” is discussed in order to understand why it is so widespread, and how it may be contributing to affect individuals’ acceptance. Technology acceptance is composed of perceived ease of use and perceived usefulness (Davis, 1989), and this model has been deemed fit to evaluate automated vehicles acceptance (Adnan, Nordin, bin Bahruddin & Ali, 2018). This discussion reflects Herman and Chomsky’s work on communication (2010), applied to the research field of driving automation. They argue that institutions can convey internalised assumptions, in the present case the benefits of driving automation and so-called autonomy, to affect public’s acceptance, whether intentionally or not.

3.1 Why using the term autonomous instead of automated?

Automation, and by extension automated cars, are usually presented as a contribution to societal progress (Hancock, 2014), even though the benefits and the 'good' provided are complex to evaluate regarding all the actors involved at the different levels of an industry (Hancock, 2017). Levels of automation allow machines and robots to replace functions previously carried out by human operators (Sheridan, 1978). The societal perception of that process may be negative regarding employment, even though this is difficult to estimate. To mitigate this negative perception of automation, using the concept of autonomy rather than automation may promote a more human-like transportation technology. Indeed, the idea of autonomy involves self-governance, independence and consciousness of one's action. In a certain way, autonomous cars could be considered to be anthropomorphised automated cars. A driving simulator study showed that anthropomorphism enhanced individuals' trust toward automated cars by attributing human characteristics to the vehicle (Waytz, 2014). Anthropomorphizing automation has also been suggested to enhance appropriate trust in the system (Lee & See, 2007). Alternatively, with respect to driving style of a real-world automated vehicle, a study by Oliveira et al (2019) suggested that there was little effect on subjective trust ratings depending on the driving style adopted by the vehicle, which was either 'machine' or 'human' like, but qualitative responses suggested that human-like behaviour inspires confidence due to familiarity. In similar fashion, the more human a robot seems the more positive the individual's emotional response to the robot is until the level of the uncanny / unsafe valley is reached (Mori, 2012). The unsafe and uncanny valley is a metaphor used in robotics to illustrate the drop of trust and positive response to a robotic system when it fails despite its similarities with humans. In vehicle automation, the unsafe and uncanny valley explains how users' high expectations would collapse if automated systems were to fail before being fully automated (Flemisch, 2017). Attributing a robot human's characteristics, by calling automated cars autonomous cars for instance, could help users passing the uncanny valley and facilitate automated vehicles' acceptance. Individuals may see autonomy as a social progress contrarily to automation. Hence, they are less likely to consider autonomous technology a potential threat to employment and are keener on embracing it. The assumed effect of anthropomorphism on automated cars maybe more efficient on women, elderly people and those living outside dense urban areas as they are more concerned about robots (Hudson 2019;21).

3.2 Impact on acceptance

If 70% of car owners from a worldwide survey believed they could already purchase a car that drove itself (Hyve, 2015), it possibly means that confusion around automation and autonomy have already affected individuals' perception and attitudes towards driving automation, although it is hard to prove the causality of "autonomous car" incorrect use and overuse on acceptance. An investigation on a rear-end collision between a Tesla car using the "Autopilot" feature and a fire truck underlined that the driver did not understand the system limitation (National Transportation Safety Board, 2019). Recent findings do stress the importance of social context and representations on the acceptance of driving automation. Indeed, when evaluating individuals' behavioural intentions to use automated shuttles in public transport, previous studies exploring the unified theory of acceptance and use of technology (UTAUT; developed by Venkatesh, 2012) found that hedonic motivation (e.g. enjoyment), social influence and performance expectancy were important constructs impacting potential users' attitudes (Madigan, 2017; Nordhoff, 2018). The first representation of automated driving seems to be crucial and could be very difficult to change overtime. In fact, neurosciences point out that memory robustness is a potential threat to make accurate predictions about future situations. Memory robustness may hinder memories change and, therefore, individuals' behaviour could be rooted on an inadequate representation of the current situation (Nilssen et al. 2019). Results from a set of vignette-based experiments showed that participants had a tendency to estimate traffic crashes involving "self-driving vehicles" to be more severe (i.e. injury or fatality) than those involving vehicles driven by human drivers (Liu, Du & Xu; 2019). If such factors influence the adoption of automated cars, it is crucial to be careful about the wording and concepts used to describe that novel kind of mobility, especially when "autonomous driving" is already at the peak of the hype cycle (Hyve, 2015). Scholars should be cautious and more accurate when they emphasise the distinction between automation and autonomy, as research findings from academia, and especially industry, can then be reported in the social and mass media (e.g. ScienceDirect articles' metrics include *Mentions* and *Social Media* categories). Using automation and autonomy interchangeably may well contribute to inappropriate predictions and technology awareness of both public and government alike.

A review of studies regarding automated vehicles has found that transportation experts and tech-savvy people are more optimistic towards automated vehicles compared to the general public (Gkartzonikas, 2019; Fraedrich, 2016). However, sharing an erroneous and sometimes overoptimistic vision of automated mobility may lead users to reject and disuse automation (Parasuraman, 1997), if expectations do not reach technology's capacity. In order to mitigate expectations, automated driving technology should be explained and presented precisely instead of being marketed with erroneous terms. Appropriate trust in automation is better than greater trust (Lee & See, 2004), as it prevents from misusing and disusing automation (Jeddi, 2010). Driving simulator studies also suggested that by informing the drivers about the potential and limits of the automated system this enabled them to calibrate their trust in the system to an appropriate level (Khastgir, Birrell, Dhadyalla & Jennings, 2018; Payre, Cestac & Delhomme, 2015; Payre, Cestac, Dang, Vienne & Delhomme, 2017).

The link between the terminology associated with a particular product and users' perception and intentions to use is well understood in the field of marketing and advertising. Numerous studies have pointed out the impact of brands and labels on consumers' attitudes towards goods and their intentions of purchase. For instance, the greater the product implication (i.e. the level of interest in an object) and the perceived risk are, the higher the effect of the label perception on consumers' purchase intention (Wicks, 1999). Considering the mobility potential (e.g. travelling on demand and delegating the driving task) and the assumed safety assets (e.g. potentially reducing crashes and collisions) offered by automated driving technologies, the terminology used is one of the factors contributing to consumers' acceptance. Moreover, brand assets such as name awareness can add to the value provided by a product (Aaker, 1991). Name awareness supports customers' purchase intentions as familiarity makes individuals more comfortable at the time of making a decision. With respect to fully automated cars, even though they are not yet available on the market, they already have a massive media coverage, therefore they are more likely to be purchased when available. However, conversely, if opacity between automation and autonomy lingers on, there could be a negative backlash leading to public rejection of highly and fully automated cars.

There are limitations to the present study. The different terms and concepts appearing within a same publication have not been addressed. The words “pod” and “shuttle” have not been investigated as they usually refer to last-mile solutions in dedicated areas, which is quite different from the conventional use of private vehicles on public roads. The term “vehicle” not only includes cars, but also many other means of transportation such as rail, water and air transport. Such a level of detail has not been examined in our results and should be taken into consideration in future research. The number of publication outlets appearing in the results per search is capped at ten, due to the ScienceDirect search engine limitation, which does not allow getting a precise overview of all the scientific journals investigating automated driving. ScienceDirect is primarily for Elsevier journals, which are mainly European. Therefore, the results presented do not include a large amount of publications from the USA and Asia. Eventually, the focus is on how many times these terms are observed rather than how they are used. A qualitative approach could better explain the abundance of terminology.

4 Conclusion

The present study on the search of publications in a scientific library shed light on the abundance of terminology used to depict automated cars. If the scientific literature cannot get it right now, how can we expect the public to fully understand the capabilities of current or near-to-market automated vehicles? In post-impressionism art period, the mode of representation was more important than the object. In social sciences, a similar relation in language and taste is aestheticisation (Bourdieux, 1984). It consists in stylising a common object to make it aesthetic. This process creates a disruption between the original object and its stylised version, which is supposedly more outstanding, noticeable and worthy. An autonomous car, per se, is an aesthetic version of an automated car. Promoting automated cars to autonomous cars might be a lever to artificially impact audiences' acceptance. The risk is a backlash of rejection as expectations cannot be met. The use of adequate and precise terms regarding driving automation is crucial to tackle misconceptions among audiences, which will better serve the development and adoption of driving automation.

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Declaration of interest

None.

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Table 1 Definitions of the different levels (SAE & NHTSA) or degrees (BASt) of automation

Levels of automation		
SAE	NHTSA	BASt
0 No Automation	0 No Automation	Driver Only
1 Driver Assistance	1 Function-specific Automation	Driver Assistance
2 Partial Automation	2 Combined Function Automation	Partial Automation
3 Conditional Automation	3 Limited Self-Driving Automation	High Automation
4 High Automation	4 Full Self-Driving Automation	Full Automation
5 Full Automation	N/A	N/A

Table 2 List of the eight keywords searched in the ScienceDirect library

driverless car	driverless vehicle
self-driving car	self-driving vehicle
automated car	automated vehicle
autonomous car	autonomous vehicle

Table 3. Number of occurrences of the searched terms over the years with the article type and the publication title.

Keywords	Total occurrences	Time span	Article type (searched term occurrences)	Journal title (searched term occurrences)
driverless car	79	1966 - 2019	Research article (49), Book chapters (8), Conference abstracts (3), Book reviews (1), Correspondence (1), News (8), Other (9)	New scientist (18), Transportation Research Part A: Policy and Practice (5), Transportation Research Procedia (5), Transportation Research Part C: Emerging Technologies (4), Accident Analysis & Prevention (3), Transportation Research Part F: Traffic Psychology and Behaviour (3), Journal of Transport & Health (3), Technology in Society (2), Transport Policy (2), Journal of Transport Geography (2)
self-driving car	309	1994 - 2019	Review articles (5), Research articles (260), Encyclopedia (1), Book chapters (6), Conference abstracts (10), Case reports (1), Correspondence (1), Discussion (1), Mini reviews (5), News (7), Short communications (10), Other (2)	Transportation Research Part F: Traffic Psychology and Behaviour (49), Accident Analysis & Prevention (44), Journal of Safety Research (12), Transportation Research Part A: Policy and Practice (10), New Scientist (7), Journal of Transport & Health (7), Transportation Research Procedia (7), Applied Ergonomics (5), Safety Science

				(5), Journal of Transport Geography (5)
automated car	488	1995 - 2019	Review articles (11), Research articles (408), Book chapters (27), Conference abstracts (24), Case reports (1), Discussion (2), Mini reviews (6), News (3), Short communications (5), Other (1)	IFAC Proceedings Volumes (32), Transportation Research Part F: Traffic Psychology and Behaviour (28), Transportation Research Part C: Emerging Technologies (23), Accident Analysis & Prevention (18), Transportation Research Procedia (14), IFAC-PapersOnLine (13), Transportation Research Part A: Policy and Practice (11), Procedia Computer Science (11), Procedia CIRP (10), Procedia Manufacturing (9)
autonomous car	455	1995 - 2019	Review articles (8), Research articles (406), Encyclopedia (1), Book chapters (17), Conference abstracts (2), Mini reviews (4), News (8), Short communications (7), Other (2)	IFAC Proceedings Volumes (60), Transportation Research Part C: Emerging Technologies (32), IFAC-PapersOnLine (28), Procedia Computer Science (19), Transportation Research Procedia (16), Transportation Research Part A: Policy and Practice (13), Accident Analysis & Prevention (12), Expert Systems with Applications (11), Robotics and Autonomous Systems (11), Transportation Research Part F: Traffic Psychology and Behaviour (10)

driverless vehicle	89	1980 - 2019	Research articles (72), Book chapters (10), Conference abstracts (3), Mini reviews (1), News (1), Short communications (1), Other (1)	Transportation Research Part C: Emerging Technologies (9), Transportation Research Procedia (7), Transport Policy (5), Transportation Research Part A: Policy and Practice (5), Accident Analysis & Prevention (4), Transportation Research Part F: Traffic Psychology and Behaviour (4), Journal of Transport & Health (4), IFAC-PapersOnLine (4), Procedia Computer Science (3), The End of Driving, 2019 (3)
self-driving vehicle	518	1996 - 2019	Review articles (10), Research articles (469), Encyclopedia (1), Book chapters (9), Conference abstracts (9), Case reports (1), Data articles (1), Discussion (1), Editorials (1), Mini reviews (1), News (2), Short communications (12), Other (1)	Accident Analysis & Prevention (113), Transportation Research Part F: Traffic Psychology and Behaviour (69), Journal of Safety Research (34), Applied Ergonomics (13), Transportation Research Part C: Emerging Technologies (10), Transportation Research Part A: Policy and Practice (10), Safety Science (9), Transportation Research Procedia (9), Journal of Power Sources (8), American Journal of Preventive Medicine (7)
automated vehicle	1942	1995 - 2019	Review articles (32), Research articles (1,763), Encyclopedia (3), Book chapters (80), Conference abstracts	IFAC Proceedings Volumes (279), Transportation Research Part C: Emerging Technologies (130), IFAC-PapersOnLine (98), Transportation Research Part F:

			(15), Book reviews (4), Case reports (1), Conference info (2), Correspondence (1), Data articles (1), Discussion (1), Editorials (3), Errata (2), Mini reviews (3), News (2), Short communications (25), Other (4)	Traffic Psychology and Behaviour (66), Accident Analysis & Prevention (57), Computers & Industrial Engineering (48), Transportation Research Procedia (45), European Journal of Operational Research (31), Transportation Research Part B: Methodological (29), Control Engineering Practice (26)
autonomous vehicle	3824	1995 - 2019	Review articles (74), Research articles (3,658), Encyclopedia (15), Book chapters (133), Conference abstracts (40), Book reviews (6), Conference info (2), Correspondence (1), Data articles (1), Discussion (4), Editorials (9), Errata (3), Mini reviews (9), News (14), Short communications (86), Software publications (1), Other (11)	IFAC Proceedings Volumes (1,074), IFAC-PapersOnLine (351), Ocean Engineering (198), Robotics and Autonomous Systems (185), Control Engineering Practice (118), Transportation Research Part C: Emerging Technologies (116), Procedia Computer Science (84), Transportation Research Procedia (56), Acta Astronautica (55), Automatica (54)

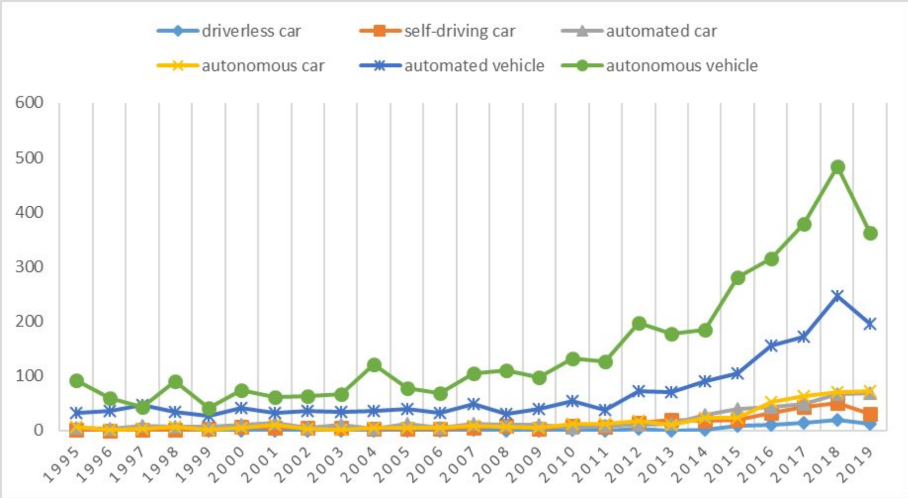

Fig. 1. Number of occurrences for each keyword per year from January 1st, 1995 to June 17th, 2019.