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SHORT TITLE: ACCEPTABILITY OF AUTOMATED VEHICLES

THE DETERMINANTS OF ACCEPTABILITY AND BEHAVIOURAL
INTENTION OF AUTOMATED VEHICLES – A REVIEW

By/par Aurore Lemonnier¹, Sonia Adélé², & Corinne Dionisio³

RÉSUMÉ

LES DETERMINANTS DE L'ACCEPTABILITE ET DE L'INTENTION COMPORTEMENTALE ASSOCIEES
AUX VEHICULES AUTOMATISES – UNE REVUE

Sans le soutien du public, le déploiement des véhicules automatisés (VAs) est voué à l'échec. C'est pourquoi leur acceptabilité a été largement étudiée. Sur la base d'une revue de littérature incluant 113 études empiriques, ce document expose l'influence des modes de contact avec les VAs (aucune explication fournie, description écrite ou illustrée seulement, simulateur, expérience réelle) sur le lien entre l'acceptabilité et/ou l'intention comportementale et leurs déterminants sociodémographiques et psychologiques. L'analyse des variables dépendantes montre un manque de clarté sur ce qui est réellement mesuré et une hétérogénéité des mesures qui rendent les comparaisons difficiles. En effet, l'acceptabilité est souvent confondue avec l'intention d'usage. Les déterminants ont été séparés en deux groupes : les préférences, qui se réfèrent aux projections dans l'usage, et les perceptions, qui se réfèrent aux croyances. Les déterminants du groupe des préférences, et certains déterminants du groupe des perceptions (facilité d'utilisation, utilité perçue et attitudes), ne sont pas influencés par le mode de contact avec le VA. En effet, un mode de contact plus concret ne modifie pas les réponses des participants pour ces variables. Pour les autres déterminants du groupe des perceptions, le mode de contact avec le VA a un impact sur les réponses des participants. La confiance et la sécurité perçue sont influencées par le mode de contact. De manière plus marquée, nous avons observé que la relation entre l'acceptabilité et le niveau de connaissance ou de contrôle perçu pourrait être modérée par le mode de contact avec les VAs. Ces résultats nous amènent à encourager les recherches favorisant l'expérience réelle avec les VAs pour étudier leur acceptabilité. Enfin, il nous est impossible de statuer sur l'influence de plusieurs déterminants sur l'acceptabilité des VAs en raison de résultats contradictoires ou isolés. En conséquence, nous encourageons notamment la réplication systématique des effets observés et l'utilisation de méta-analyses. Une discussion des résultats récurrents mais aussi des lacunes tant théoriques que méthodologiques des études analysées est présentée. En outre, l'article souligne les défauts des recherches en termes d'échantillonnage, de robustesse statistique et met en évidence le manque d'études sur certains groupes tels que les non conducteurs, certains types de véhicules (par exemple les trains), et certains aspects impliqués dans l'acceptabilité des VAs (notamment les questions éthiques). En conclusion, quelques pistes méthodologiques sont proposées pour l'étude des

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dispositifs technologiques peu ou pas connus des futurs utilisateurs ainsi qu'une réflexion sur l'utilité d'étudier l'acceptabilité de ces dispositifs méconnus.

MOTS CLES : véhicules autonomes/automatisés, acceptation, acceptabilité, intention d'usage, mode de contact, automatisation complète.

I. INTRODUCTION

The rise of artificial intelligence has led to upheaval in many sectors, among which transport. Several car manufacturers have therefore actively embarked on the race for automation. The development of automated vehicles (AVs) has spread to shuttles and several cities have tested this new mode of transport. In the same vein, automatic subways experienced a major development in the 1990s around the world. Numerous benefits are expected from these deployments of AVs (Dean et al., 2019; Gkartzonikas & Gkritza, 2019): improving road safety, reducing network and parking congestion, increasing network reliability, public transport frequency, and time savings, enhancing mobility for the most vulnerable citizens. Despite all the appealing attributes of AVs, their success relies heavily on how they are received by potential users.

In the study of the conditions of use and adoption of technologies, there are three main complementary orientations that are based on different theoretical and methodological paradigms (summarized in Bobillier Chaumon, 2016; Brangier et al., 2010; Sagnier et al., 2019). Practical acceptability is based on ergonomics and aims to act on the interaction between the user and the technology to bring the latter more in line with the user and his activity. Social acceptability is based on social psychology and seeks to predict use (intention to use) from subjective representations of the technology, such as attitudes and opinions. Situated acceptability is based on activity and action theories and studies the contributions and limitations of technology in the user's activity. The paradigm favoured by the vast majority of studies conducted to date on the acceptability of AVs is social acceptability. Perhaps this theoretical field seems best suited to the current deployment phase of AVs? This point will be discussed later. Whatever the reason, following recognized social acceptability¹ studies (Payre et al., 2014; Schoettle & Sivak, 2014), this field has become an important part of the scientific literature during the last decade. Since then, studies have been extended to various transport modes (cars, buses, shuttles, and subways). At the time of writing, the driverless train is still in its infancy. However, after falling behind car manufacturers in the race for automation, the railway industry has recently regained momentum and is working on the development of driverless trains.

Two classifications are used to define the level of automation of rail and road vehicles. The classification of train automation is called Grades of Automation (GoA; UITP, 2011) and is divided into four levels, which depend on the extent of staff involvement in basic functions of train operation. In the highest grade (GoA4), the train is fully automatic, without any staff member on board. For cars, the Society of Automotive Engineers has defined 6 levels of automation (SAE, 2018) which are also used for all modes of road transportation². In Level 4 (High automation), the vehicle can drive in some limited conditions (for example, on certain routes) and does not require a human operator to take over in emergencies. In Level 5 (Full

¹ Despite the fact that the literature overwhelmingly uses the term acceptance, we have chosen to use only the term acceptability as the papers mainly refer to evaluations "prior to first-hand experience" with AVs (Ledger et al., 2018). Acceptance will only be used in part III.2.2 to specify the content of the articles.

² It should be noted that other classifications have existed (NHTSA, BAst) and that these classifications as well as the vocabulary used evolve over time, which makes it difficult to ascertain the exact level of automation studied in the oldest references.

automation) the vehicle can perform all driving functions and can drive anywhere in all conditions. In this review, we have chosen to focus on the highest levels of automation (GoA4, Levels 4 and 5) for several reasons. Firstly, the intermediate levels, that have been studied for years in the aeronautical field, pose multiple problems of human-machine cooperation (well summarized by Navarro (2019) and de Winter et al. (2014)). Some parallels have already been made between aviation and the automotive sector (Bellet et al., 2011; Young et al., 2007). These problems of human-machine cooperation are less in evidence or not present at all in the highest levels of automation. For this reason, some of the traditional automakers and new stakeholders have elected not to pursue the development of Level 3 systems, considering that it is easier to build a complete self-driving system than to keep human drivers involved³. Secondly, the explanatory variables of acceptability are specific to the level of automation and differ depending on whether this level is high or low (Schoettle & Sivak, 2014). It would have been too ambitious to cover all levels in a single literature review. Thirdly, Levels 4 and 5 are those that are likely to bring about the greatest disruption in the mobility of individuals and thus cause the greatest difficulty in entering travel patterns.

The acceptability of AVs is a hot topic, but the methodologies used to study it, and the impact of these methodologies on the results, have been insufficiently investigated so far. Some existing literature reviews about AVs focused indirectly or partially on acceptability issues considering in particular: car sickness (Iskander et al., 2019), trust (Adnan et al., 2018), and pedestrian-vehicle communication (Deb et al., 2018; Rouchitsas & Alm, 2019). Other reviews addressed acceptability through benefits and concerns (Sun et al., 2017), or stated preference and choice studies (Gkartzonikas & Gkritza, 2019). Some focus on the acceptability of a specific use-case of AVs, ridesharing (Merat et al., 2017). Lastly, two reviews proposed a model of AV acceptability structuring the determinants found in the literature (Nordhoff et al., 2016; Nordhoff et al., 2019). The review closest to the aim of the present paper is that of Becker and Axhausen (2017). They investigated the various survey methods being applied with respect to the acceptability of AVs. They showed that for some predictors, the results differ significantly depending on how the sampling and the study were carried out. In the present review, we include all rail and road transportation modes and our aim is slightly different in that we wish to put the results obtained by existing studies into perspective according to the way the vehicle is present in the respondent's mind (images from the media, given description, simulator or real experience). We believe that depending on the contact the respondent has had with the vehicle, his/her responses will be affected accordingly. This review is now possible because automated shuttles and cars are in the prototyping phase in various countries around the world.

The aim of the current contribution was to identify the most significant determinants of the acceptability and intention to use an AV and the way these determinants are studied in the existing scientific literature. We studied the determinants of the acceptability of AVs by classifying them in two main dimensions: perceptions (seen as beliefs) and preferences (seen as projections in use). We also studied sociodemographic and dependent variables. In this literature review, we highlight that the perceptions and the preferences of respondents vary depending on the level of contact they have with AVs. More specifically, we assume that direct experience with an AV may change its acceptability. We expected that direct experience with an AV would change participants' perceptions of AVs, as compared to perceptions based on no information or only on a definition of the AV. We expected that participants' preferences would be less influenced by the type of contact with the vehicle in particular because studies involving use are very marked by the experimental context in which they take place. Thus, they would not promote better projection. Therefore, the interest of this contribution is twofold. On the one hand, we propose a critical analysis of how acceptability was studied. On the other hand, this

³ <https://www.autonews.com/shift/why-level-3-automated-technology-has-failed-take-hold>

is the first time that a literature review examines the impact of the manner in which the AV is presented on its acceptability.

This literature review is organised in five sections. Section 2 explains the methodology used to perform the review based on the PRISMA method (Moher et al., 2009). Section 3 provides a quantitative and qualitative analysis of the results, covering sociodemographic variables, dependent variables (acceptability and behavioural intention), preferences and perceptions of AVs. Each of these features is divided into sub-parts in order to highlight the results associated with each level of contact between the participants and the AV. The main findings and research gaps identified will be presented in Section 4 as well as potential implications for future research. Finally, Section 5 offers methodological and theoretical suggestions for studying the acceptability of a technological device that is little known or unknown to future users.

II. METHODOLOGY

To offer a systematic literature review of empirical research about the acceptability of highly automated transportation, we used the PRISMA method (Moher et al., 2009) to identify and analyse the relevant literature. The process includes three steps (Figure 1).

insérer Fig.1 ici

Figure 1. Process for identification of relevant literature (adapted from Moher et al., 2009).
Figure 1. Processus d'identification des références pertinentes (adapté de Moher et al., 2009).

First, searches were conducted on three large abstract and citation databases of peer-reviewed literature: Scopus, Web of Science and Google Scholar. Second, the titles and abstracts of the identified references were assessed using a set of inclusion and exclusion criteria. Third, the remaining references were read in their entirety in order to include only relevant references with the same set of criteria. Lastly, the included articles were analysed quantitatively and qualitatively to generate the results presented in this paper.

For the first step, we used a set of terms referring to acceptability, automation and land transport modes that we combined as presented in Table 1. Considering the rapid evolution of the subject and the existence of older literature reviews, the searches were limited to the last five years (available in digital or paper version from the beginning of 2015 to the end of 2019). All the articles were written in English, except one in French. 3797 references were assessed by reading their title. Removing duplicated papers and those that are totally outside the field of research, this left 591 references whose relevance was assessed based on the abstract. We excluded references that assess exclusively technical parameters of the vehicle (such as gap acceptance), focus only on experts or professional stakeholders' opinions, deal exclusively with possible environmental (mode choice, car purchase...) or economic impacts, study only low levels of automation (2 or 3), study the opinion of specific users such as car-sharing or electric vehicle users without comparing them with the general public, aim at proposing an economic model without including attitudinal variables (which includes studies exclusively measuring willingness-to-pay as the dependent variable), or do not provide results (i.e. model or method validation, literature review).

After this assessment, we kept 136 references that were read in their entirety. This led to the exclusion of a further 23 papers. The final sample of 113 references analysed are journal papers (including proceedings journals) and all involved users or citizens to measure and/or explain the acceptability of AVs of different modes and provide research on level 4 and 5 AVs. In many cases, the level of automation studied is not specified (see III.2). In these cases, we excluded only those items for which the use scenarios conflicted with the definition of Level 4

or 5 as defined by the SAE, for example, when control of the vehicle needs to be taken over in an emergency.

Table 1. Search terms (for Google Scholar, different searches were done because the full combination was not possible).

Tableau 1. Termes de recherche (pour Google Scholar, différentes recherches ont été effectuées car la combinaison complète n'était pas possible).

Acceptance		Automation		Transport modes
adoption OR	AND	autonomous OR	AND	train OR
acceptance OR		automated OR		trains OR
acceptability OR		driverless		vehicle* OR
intention OR				shuttle* OR
attitude OR				car OR
opinion				cars OR
				bus* OR
				“public transport*” OR
				subway* OR
				metro OR
				metros

*Truncation lets search for a word that could have multiple endings and share a common root. The keyword return results that include any ending of that root word.

III. RESULTS

III.1 OVERALL RESULTS

In order to provide a detailed summary of the 113 articles that make up this literature review, we have consolidated the quantitative and qualitative data in Table 2. In this table, the studies are classified according to the mode of contact with the AV. The table includes all the data considered in this review, both quantitatively and qualitatively: year of publication, type of vehicle, level of automation, methodology used, type and number of participants. It also includes qualitative information by specifying the determinants of acceptability and intention to use studied in each article, and how they are defined. Furthermore, for articles that linked several variables, the direction of the observed effect is mentioned in the table. In addition to this overall presentation and summary of the results, this section provides a detailed analysis of the results from a quantitative and then qualitative perspective. The latter sub-section covers the sociodemographic variables, the dependent variables (mainly acceptability and behavioural intention) and the determinants of these dependent variables grouped into preferences and perceptions of AVs. For each determinant, we analysed the influence of the mode of contact between the participant and the AV on results. Finally, each section concludes with a critical analysis of the concepts and their operationalization, assessing the degree of robustness of the results obtained in the studies on the acceptability of AVs.

Table 2. Summary of selected studies on acceptability of AVs according to their methodology and the dimensions explored.

Tableau 2. Résumé des études sélectionnées sur l'acceptabilité des VA en fonction de leur méthodologie et des dimensions explorées.

Mode of contact	References	Type of vehicles		Methods	Type of participants (nb.)	Preferences	Perceptions	Gender	Age	Location	Education	Income	Personality	Acceptability	Behavioural intention	Onboard activities	AV characteristics	Level of knowledge	PEU / EE	PU / PE	Subjective norms	Attitudes towards AVs	Concerns	Privacy concerns	Environmental	Perceived benefits	Trust	Control	Perceived safety/risks
		Level of automation																											
N	Ashkrof et al. (2019)	C	U	Q	Drivers (663)		x							3															
N	Bazilinskyy et al. (2015)	C	5	Q	Adults (1952, ♂)		x					-		1											+		+		
N	Bennett et al. (2019a)	C	U	Q	Adults (797)		x							3	IU								-	x					x
N	Bennett et al. (2019b)	C	U	I/Q	Adults (177, ♀)		x	o			o			3	IU			+											
N	Brell et al. (2019a)	C	M	I/Q	Adults (I: 19, ♂, Q: 443)		x	o	-		+			3									o	-	x		x	x	
N	Brell et al. (2019b)	C	5	Q/F	Adults (F:17, Q:516)		x	x						3		x									+		-	o	
N	Chen & Yan (2019)	C	U	Q	Adults (574)		x						x	4	IU							+	+				+	o	
N	Cho & Jung (2018)	C	U	I	Drivers (41, ♂)		x	x						3		x		+		x							-	x	
N	Choi & Ji (2015)	C	U	Q	Drivers (552, ♂)		x							4	IU				+	+						+		-	
N	Deb et al. (2017)	C	5	Q	Mturkers (482)		x	+	-	+			x	4	II														
N	Fortunati et al. (2019)	C	5	Q	Adults (55702)/Children (1505)		x	+	-		+			3					+										x
N	Fraszczyk et al. (2015)	Sub	GoA4	Q	Students & Univ. Staff (50, ♂)		x	+																	x		x		
N	Fraszczyk & Mulley (2017)	Sub	GoA4	Q	Adults (219)		x							3	IU							+			x		x		x
N	Haboucha et al. (2017)	C	U	Q	Adults (721, 131 Mturkers)		x	+	-		+			3	S									+					
N	Hassan et al. (2019)	C	U	Q	Old adults (4436)		x	+	+	+		+		3	IU										x		-		
N	Hegner et al. (2019)	C	U	Q	Adults (369)		x	o	o		o		x	4	IU				o	+					x		+		
N	Hulse et al. (2018)	C	5	Q	Adults (925, ♂)		x	+	-				x	3								+							
N	Hyde et al. (2017)	S	5	Q	Adults (233, ♂)		x	+						3				o				+	x			o			
N	Jing et al. (2019)	C	U	Q	Adults (906)		x							4	IU						+	+					x	+	
N	Karnouskos (2020)	C	U	Q	Adults (126, ♂)		x							4/5	IP		x												+
N	Kaur & Rampersad (2018)	All	5	Q	Students & Univ. Staff (101, ♀)		x							4	U					+				o		-		+	
N	Lee & Kolodge (2019)	C	5	Q	Drivers (6489)		x							4	IP												+		+
N	Lee & Mirman (2018)	C	U	Q	Parents (985, ♀)		x	x						3/4	U	x							x		x				
N	Liljamo et al. (2018)	C	U	Q	Adults (2036)		x	+	o	+	+			5								+	x				x	x	
N	López-Lambas & Alonso (2019)	B	U	F	Adults (16)		x	x						1		x							x		+	x		x	
N	Lu et al. (2017)	All	U	M	Adults (6300)		x																	x					+
N	Nishihori et al. (2017)	U	U	Q	Drivers (1250, ♂)		x	+	o		+			5	U						+			x		x			+
N	Panagiotopoulos & Dimitrakopoulos (2018)	U	M	Q	Adults (483, ♂)		x	-	-					4	IU			+	+	x	+	+		x					+
N	Pettigrew et al. (2019)	C	U	Q	Panel (1624)		x	o	-		+	+		4	1									x		x			+
N	Pettigrew et al. (2018a)	All	U	Q	Panel (1624)		x							3										x		x			
N	Pettigrew et al. (2018b)	U	U	Q	Panel (1624)		x	x	+	o				5		x								o		x			
N	Qu et al. (2019)	C	U	Q	Adults (726)		x	x	+	+		o	x	3	2	x		+					x		+				
N	Ro & Ha (2019)	C	U	Q/M	Panel (1506)		x	x						4	IU						+	x			x				
N	Sheela & Mannering (2020)	C	U	Q	Automobile Fed (2338, ♂)		x	o	+		+			4															
N	Shin et al. (2019)	C	5	Q	Panel (136388)		x		o	o	o	o		4	IP									-	+	x			
D	Acheampong & Cugurullo (2019)	C	5	Q	Adults (507)		x	+	-		+			4				+		+	+			+	+			+	
D	Bazilinskyy & de Winter (2015)	C	5	Q	Adults (1082, ♂)		x	x	o	o				4	IU		x				-								
D	Charness et al., (2018)	C	4	Q	Adults (414, ♀)		x	+	-				x	3				+											
D	Cunningham et al., (2019)	C	M	Q	Adults (5089)		x	x		-	-	o		3/4	3	x								x		x			
D	Das et al. (2019)	C	M	M	YouTube comments (25629)		x							3										x			-		-

Mode of contact	References	Type of vehicles		Methods	Type of participants (nb.)	Preferences	Perceptions	Gender	Age	Location	Education	Income	Personality	Acceptability	Behavioural intention	Onboard activities	AV characteristics	Level of knowledge	PEU / EE	PU / PE	Subjective norms	Attitudes towards AVs	Concerns	Privacy concerns	Environmental	Perceived benefits	Trust	Control	Perceived safety/risks			
		B	M			Q	x	+	-																							
D	Dong et al. (2019)	B	M	Q	Univ. Staff (891, ♀)	x	+	-				+		4	IU			+					-				x	x				
D	Hohenberger et al. (2017)	C	M	Q	Adults (1603)	x								4	IU											+		+				
D	Hohenberger et al. (2016)	C	M	Q	Adults (1603)	x	+	o						4	IU																	
D	Koul & Eydgahi (2019)	C	U	Q	Drivers (377, ♂)	x	+	-			o	+		4	3							+								+		
D	Koul & Eydgahi (2018)	C	5	Q	Drivers (377, ♂)	x	o	-			o	o		4	3							+										
D	Kyriakidis et al. (2015)	C	M	Q	Adults (4886, ♂)	x	o	o					o	4	IP								x							x		
D	Lavieri et al. (2017)	C	5	Q	Adults (1832)	x	+	+	+	+				4	S								-									
D	Ledger et al. (2018)	C	5	Q	Panel (6133)	x	x	+	-	+				3	U	x							x	x		x	+		x			
D	Lee et al. (2019a)	C	U	Q	Adults (313)	x								4	IU																+	
D	Leicht et al. (2018)	C	5	Q	Adults (241, ♂)	x	x							4	3	x							x			x	+					
D	Lijarcio et al. (2019)	C	M	Q	Drivers (1205)	x	+	+	o					3/4	U																	
D	Liu et al. (2019a)	C	M	Q	Adults (742)	x								3/4	4											+	o		o			
D	Liu et al. (2019b)	C	5	E/Q	Adults (1267, 1027 students)	x																									x	
D	Liu et al. (2019c)	C	5	Q	Students (1216)	x									IU											+	+			x		
D	Liu et al. (2019d)	C	5	Q	Adults (441)	x	+							3/4	4											+	+			x		
D	Liu et al. (2019e)	C	5	Q	Adults (604)	x		-						4																	-	
D	Lustgarten & Le Vine (2018)	C	M	Q	Adults (370)	x	x							1	IP	x									x			x	x			
D	Montoro et al. (2019)	C	M	Q	Drivers (1205)	x						+		4	3															-	+	
D	Nees (2019)	C	M	Q	Drivers, Mturkers (472)	x		+						1																	-	
D	Nielsen & Haustein (2018)	C	5	Q	Panel (3040)	x	+	-	+	+	o			4	4								-			x					-	
D	Nordhoff et al. (2018a)	S	M	Q	Inhabitants (7755, ♂)	x	o	o	+					3/4	5							+	+				+	x				
D	Rahman et al. (2019)	U	5	Q	Old Mturkers (173, ♀)	x	+	o	+					4	6							+	+	+	+		x	x		x		
D	Regan et al. (2017)	C	5	Q	Panel (5263)	x	+	+						4	U								o	x	x	x	+			x		
D	Roche-Cerasi (2019)	S	U	Q	Automobile Fed. (1419, ♂)	x					+			4	IU								+	+	o	x	x	x	x	x		
D	Rovira et al. (2019)	C	U	Q	Adults (138, 86 Mturkers)	x		o						1																	-	
D	Sanbonmatsu et al. (2018)	C	5	Q	Mturkers (114)	x							x	5	IP												+				+	
D	Sener et al. (2019)	C	4	Q	Inhabitants (3097)	x	+	-		+	o			4	IU							+	+	+	+	o	+	o	+			
D	Shabanpour et al. (2018a)	C	U	Q	Inhabitants (1013)	x	x	-			-			4	IP	x							x	x		x		+				
D	Shabanpour et al. (2018b)	C	U	Q	Inhabitants (1013)	x	o	-		+				4	IU																	
D	Stark et al. (2019)	B/S	U	O	Inhabitants (≈45)	x	x							2			x						x	x		x		x	x			
D	Tennant et al. (2019)	C	U	Q	Drivers (11827)	x	+	o						3/5																	o	
D	Wahlström (2017)	Sub	GoA4	Q/M	Inhabitants (913)	x	x							3	IU	x								x		x		x	x			
D	Wicki & Bernauer (2018)	S	5	Q	Inhabitants (1408)	x	+	+		+				5									+	x	x						x	
D	Wu et al. (2019)	U	U	Q	Panel (470)	x								4	4								+	+								
D	Zmud & Sener (2017)	C	4	Q/I	Inhabitants (Q:556, I:44)	x	x	o	o		o	o		4	IU	x							+	o	+	o	x	+		x	o	+
S	Ackermann et al. (2019)	C	U	F/E	Adults (31, 25 Students), ♀	x	x										x							x								
S	Du et al. (2019)	C	4	E/Q	Adults (32, ♂)	x								1														+				
S	Frison et al. (2019)	C	M	E/I	Students & Univ. Staff (57, ♂)	x	x						o	2			x	+									+	x	x			
S	Hartwich et al. (2018)	C	U	E/Q	Drivers (40)	x	x		+					3			x															
S	Khastgir et al. (2018)	C	4	E/B/Q	Drivers (48, ♂)	x								1														+				

Mode of contact	References	Type of vehicles	Level of automation	Methods	Type of participants (nb.)	Preferences	Perceptions	Gender	Age	Location	Education	Income	Personality	Acceptability	Behavioural intention	Onboard activities	AV characteristics	Level of knowledge	PEU / EE	PU / PE	Subjective norms	Attitudes towards AVs	Concerns	Privacy concerns	Environmental	Perceived benefits	Trust	Control	Perceived safety/risks			
						x	x	o	o																							
S	Lee et al. (2019b)	C	4	E/Q	Students (56)	x	x	o	o					2	IU	x		x														
S	Lee et al. (2019c)	C	U	E/Q	Students (158, ♀)	x	x							4	IU	x		+														
S	Park et al. (2019)	C	M	Q	Adults (26)		x		o					3/4				+	+		+						x	+				
S	Siebert & Wallis (2019)	C	4	E/Q	Students (35)	x								2		x																
S	Techer et al. (2019)	C	4	Q/I	Drivers (44)	x	x							1		x							x									
S	Voß, et al. (2019)	C	U	E/Q	Drivers (161)	x								2		x																
S	Walker et al. (2019)	C	5	Q/P	Students (26, ♀)	x										x											x					
S	Wintersberger et al. (2019)	C	5	Q/I/O	Students & Univ. staff (44, ♂)	x	x							4	IU	x		x	x		+						+	x				
S/D	Ebnali et al. (2019)	C	4	E/B/Q	Students (50)		x							3													o					
S/D	Kauer et al. (2015)	C	4	E/I	Drivers (E/I:50, I:25, ♂)		x						x	2/4													+				+	
R	Christie et al. (2016)	S	U	Q	Adults (181, ♂)	x	x							1	IU	x		+													+	
R	Habibovic et al. (2018)	C	4	E/Q/I	Adults (E/Q/I: 9, E/Q:24)	x	x							2	II	x											x	x			-	
R	Herrenkind et al. (2019a)	S	4	O	Adults (268)		x						x	4	IU			+	+	+			-	o		+	-					
R	Herrenkind et al. (2019b)	S	4	O	Adults (268)		x		-	+		+		4	IU			+	+	+			-	o		+						
R	Madigan et al. (2016)	S	4	Q	Adults (349, ♂)		x		+					4	IU			+	+													
R	Madigan et al. (2017)	S	4	Q	Adults (315)		x							4	IU			+	x	+												
R	Monéger et al. (2018)	S	5	I	Shuttles' supervisors (19)		x							2							x	x									x	
R	Nordhoff et al. (2018b)	S	4	Q	Riders (384, ♂)		x	o	+					3/4	5			-	-	o				x			x	o				
R	Nordhoff et al. (2019)	S	4	I	Tech-savvy (30, ♂)		x	x						2/4		x	x	x					x			x	x	x			+	
R	Oliveira et al. (2019)	C	4	Q/I	Car manufacturer staff (43, ♂)		x	x						2			x	+														
R	Penmetsa et al. (2019)	U	U	Q	Inhabitants (798)		x							5				+													+	
R	Piao et al. (2016)	All	5	Q	Inhabitants (425)		x	+	-		+			2				+					x	x		x		x		+		
R	Pucihar et al. (2019)	C/S	U	Q	Tech-savvy (153, ♂)		x	x						1	U	x											-					
R	Rehrl & Zankl (2018)	S	4	Q	Riders (294)		x							1	U			+													+	
R	Salonen (2018)	S	4	Q	Riders (197, ♀)		x	+	o		o	o		2																	x	
R	Salonen & Haavisto (2019)	S	4	Q	Riders (44)		x							2								x	x			x	x				+	
R	Xu et al. (2018)	S	5	Q	Students (300)		x							4	5			+	+				x				+				+	
R	Zoellick et al. (2019a)	S	4	Q	Adults (125)		x	o	+					3	IU												+				+	
R	Zoellick et al. (2019b)	S	4	Q	Adults (125)		x	x						3	IU	x							x				o				o	
R/D	Moták et al. (2017)	S	5	Q	Students (370)/Riders (54), ♀		x						x	4	IU			+	+	+	+						+	+				
R/D	Schieben et al. (2019)	S	4	I/Q/F	Drivers (I:26, Q:664, ♂, F:20)		x							2			x															
R/D	Sener & Zmud (2019)	C	U	Q/I	Inhabitants (3275)		x	x	+	-				4	S	x						+	x			x					+	
R/S	Mühl et al. (2019)	C	5	E/P/Q	Drivers (E:I1/S:24, ♀)		x	x						3			x										+					

Mode of contact with the AV (N = None; D = Description; S = Simulation; R = Real experience), Type of vehicles (C = Car; S = Shuttle; B = Bus; Sub = Subway; All = All road vehicles; U = Unclear)

Level of automation (5 = Level 5; 4 = Level 4; M = Multiple levels; U = Unclear)

Methods (Q = Questionnaire; I = Interview; F = Focus group; E = Experimental study; M = Media analysis; P = Physiological measure; B = Behavioural measure; O = Other)

Type of participants (Automobile Fed. = Automobile Federation Members; ♀ = More than 60% of women; ♂ = More than 60% of men)

PEU / EE = Perceived Ease of Use / Effort Expectancy, PU / PE = Perceived Usefulness / Performance Expectancy

Variables' relationship (+ = The higher the determinant's score, the more positive the impact on the perception of the AV; - = The higher the determinant's score, the more negative the impact on the perception of the AV; o = The score of the determinant has no impact on the perception of the AV; x = The determinant is not put in relation with another determinant). For gender, results are presented from the point of view of men, for location from the point of view of urban dwellers.

Acceptability (used definition: 1 = The word "accept*"; 2 = User experience, requirements and needs; 3 = A sum of attitudes; 4 = Behavioural intention; 5 = Approval for use in the society)

Behavioural intention (IU = Intention to Use; IP = Intention to Purchase and willingness to pay; II = Intention to Interact with; S = Shared vs. individual use; U = Use-cases; 1 = IP+S; 2 = IU+IP; 3 = IP+U; 4 = IU+IP+Intention to recommend to others; 5 = IU+IP+S; 6 = IU+U)

Mode de contact avec le VA (N = Aucun ; D = Description ; S = Simulation ; R = Expérience réelle), Type de véhicules (C = Voiture ; S = Navette ; B = Bus ; Sub = Métro ; Tous = Tous type de véhicules ; U = Imprécis)

Niveau d'automatisme (5 = Niveau 5 ; 4 = Niveau 4 ; M = Plusieurs niveaux ; U = Imprécis)

Méthodes (Q = Questionnaire ; I = Entretien ; F = Groupe de discussion ; E = Étude expérimentale ; M = Analyse des médias ; P = Mesure physiologique ; B = Mesure comportementale ; O = Autre)

Type de participants (Automobile Fed. = Membres d'une fédération automobile ; ♀ = Plus de 60% de femmes ; ♂ = Plus de 60% d'hommes)

PEU / EE = Facilité d'utilisation perçue / Efforts attendus, PU / PE = Utilité perçue / Performance attendue

Relation entre les variables (+ = Plus le score du déterminant est élevé, plus son impact sur la perception des VA est positif ; - = Plus le score du déterminant est élevé, plus son impact sur la perception des VA est négatif ; o = Le score du déterminant n'a pas d'impact sur la perception des VA ; x = Le déterminant n'est pas mis en relation avec un autre déterminant). Pour le genre, les résultats sont présentés selon le point de vue des hommes, pour la localisation selon le point de vue des habitants des zones urbaines.

Acceptabilité (définitions utilisées : 1 = Le mot "accept*" ; 2 = L'expérience, les exigences et les besoins de l'utilisateur ; 3 = Une somme d'attitudes ; 4 = L'intention comportementale ; 5 = L'approbation pour une utilisation dans la société)

Intention comportementale (IU = Intention d'usage ; IP = Intention d'achat et propension à payer ; II = Intention d'interagir avec ; S = Utilisation partagée vs. individuelle ; U = Cas d'usage ; 1 = IP+S ; 2 = IU+IP ; 3 = IP+U ; 4 = IU+IP+Intention de recommander aux d'autres ; 5 = IU+IP+S ; 6 = IU+U)

III.2 QUANTITATIVE ANALYSIS

Before exploring the content of the reviewed literature, we will first look at the constitution of our sample of papers (Table 2). Over the period covered, there has been a very sharp increase in the number of papers published each year, from less than 10 in 2015 to more than 60 in 2019 (Figure 2).

insérer Fig.2 ici

Figure 2. Number of publications per year between 2015 and 2019 (the dates reported are the online availability dates).

Figure 2. Nombre d'articles par an entre 2015 et 2019 (les dates reportées sont les dates de disponibilité en ligne).

Over half our sample (62 reports) are papers from journals that have transportation as one of their themes. European countries are strongly represented with 56 papers.

As far as the mode of transport studied is concerned, the papers published over the last five years are overwhelmingly devoted to road transport, mainly the car in 76 cases (individual or shared) and, to a lesser extent, public transport (23), primarily shuttles. Rail is very rarely studied (3) and all the studies concern the subway. It should also be noted that in 6 cases it was impossible to understand the type of AV studied. Moreover, in 39 cases it was impossible to determine the level of automation from the content of the article. 34 articles studied Level 5 (including 3 GoA4), and 24 Level 4. 16 papers studied several levels, among which at least Level 4 or 5. Concerning the methods (Figure 3), the majority (78 cases) used questionnaires, of which 48 were carried out online. In addition, the questionnaire was also used in experimental studies (10) and as a complement to other methods (12). The interview was the second most frequent method used, with 14 entries. There were also to a lesser extent behavioural (2) or physiological (2) measures as well as media analyses (4). Participants were not always representative of the population in terms of gender (42 studies), possession of a driving licence (18), interest in innovation or in cars (10), or socio-professional category, with an over-representation of Mechanical Turkers (6) or students (13).

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Figure 3. Methods used in the articles (the total is greater than the number of articles because some articles use more than one method).

Figure 3. Méthodes utilisées dans les articles (le total est supérieur au nombre d'articles car certains articles utilisent plus d'une méthode).

Lastly, we wished to differentiate the studies according to the way in which the AV is presented to the participants. In our sample, 35 papers gave participants no explanation about AVs other than the use of the words "self-driving" or "autonomous". 40 papers gave participants a brief written or pictorial description of what is meant by AVs, but only 15 of these papers provided the description in question. We chose to add to this category studies that preceded future implementations already presented to the public. 13 papers used simulation and 19 related to actual contact with an AV. In the latter case, the participant was either a user of the vehicle or was present in the same public space as the vehicle. Finally, 6 papers proposed several studies involving different modes of contact with the AV (including at least a real experiment in 4 cases or at least a simulation in 2 cases).

III.3 QUALITATIVE ANALYSIS

In this section, we will first present the relationship between socio-demographic variables and acceptability or behavioural intention. Next, we will provide an overview of the dependent variables used in the literature. Finally, we will focus on the links between acceptability or intention to use and their determinants in terms of preferences and perceptions, regarding the mode of contact with the AV (Table 2). In this section, we will only discuss the variables that have been most often studied, and the effects identified by more than one study. Therefore, when a link has only been studied by one contribution, it will not be reported. In the same vein, some determinants were not included in this literature review. Some because they were poorly studied (socio-professional categories, employment, marital status, medical conditions, ethnicity, household size, presence of children, and stage of adoption), and others because they appeared to be catch-all concepts that do not allow for comparisons (driving experience, other technology use, other technology acceptance, current mobility, and emotions).

III.3.1 Socio-demographic variables and personality

Gender: The influence of gender on the acceptability of AVs has been extensively studied (43 articles). Overall, the results of these studies agreed that the acceptability of AVs is higher among men than among women. Men reported more behavioural intention (Charness et al., 2018; Dong et al., 2019; Hassan et al., 2019; Hohenberger et al., 2016; Lijarcio et al., 2019; Piao et al., 2016; Sener et al., 2019; see Panagiotopoulos & Dimitrakopoulos, 2018 for contradictory results) and felt more comfortable travelling in an AV (Fortunati et al., 2019; Fraszczyk et al., 2015; Ledger et al., 2018; Salonen, 2018; Sener & Zmud, 2019). Concerning the link between gender and other variables, the perceived benefits of AVs (Acheampong & Cugurolo, 2019; Ledger et al., 2018) as well as their perceived usefulness (Qu et al., 2019; Rahman et al., 2019) were found to be higher among men. Men also reported lower concerns about the safety of AVs (Acheampong & Cugurolo, 2019; Charness et al., 2018; Ledger et al., 2018; Lijarcio et al., 2019; Rahman et al., 2019; Regan et al., 2017; Wicki & Bernauer, 2018), and more positive attitudes than women (Haboucha et al., 2017; Hyde et al., 2017; Liljamo et al., 2018; Nielsen & Haustein, 2018; Nishihori et al., 2017; Pettigrew et al., 2018b; Rahman et al., 2019; Tennant et al., 2019). However, 13 studies among the 43 articles did not show an impact of gender on the acceptability of AVs (Bazilinskyy & de Winter, 2015; Brell et al., 2019a; Hegner et al., 2019; Koul & Eydaghi, 2018; Kyriakidis et al., 2015; Lee et al., 2019b; Nordhoff et al., 2018a, 2018b; Pettigrew et al., 2019; Shabanpour et al., 2018b; Sheela & Mannering, 2020; Zmud & Sener, 2017; Zoellick et al., 2019a). Finally, most studies that addressed the effect of gender on acceptability did not provide an explanation or definition of the AVs. The 5 studies based on direct experience with AVs showed either a lack of gender impact on acceptability or a higher acceptability in men than in women. These results did not differ from those obtained in studies that give little information about the AVs. Based on the numerous studies conducted in recent years on the influence of gender on the acceptability of the AV, we can conclude that: a) the acceptability of the AV is higher among men than among women, regardless of the mode of contact with the vehicle; b) this effect is robust. Thus, it would be worthwhile to study other sociodemographic or psychological determinants of acceptability in the future.

Age: The socio-demographic variable most frequently linked with AV acceptability is age (51 articles). Most studies showed that older people expressed a lower intention to use AVs (Cunningham et al., 2019; Dong et al., 2019; Koul & Eydaghi, 2018; Panagiotopoulos & Dimitrakopoulos, 2018; Piao et al., 2016; Sener & Zmud, 2019; Sener et al., 2019; Shabanpour et al., 2018a, 2018b). However, contradictory results are also reported in the literature (Hartwich et al., 2018; Lijarcio et al., 2019; Nordhoff et al., 2018b; Qu et al., 2019; Regan et al., 2017; Sheela & Mannering, 2020). In the same vein, studies that questioned the influence

of age on the determinants of acceptability reported contradictory results. Several studies showed that middle-aged and more generally older participants perceived fewer benefits of AVs (Acheampong & Cugurullo, 2019; Cunningham et al., 2019; Ledger et al., 2018; Liu et al., 2019e; but see Regan et al., 2017 for contradictory results), were worried about privacy (Regan et al., 2017; but Wicki & Bernauer (2018) showed that older adults were least worried about this) and safety of AVs (Charness et al., 2018; Cunningham et al., 2019; Hassan et al., 2019; Ledger et al., 2018; Liu et al., 2019e; Nees, 2019), expressed more negative attitudes (Deb et al., 2017; Liu et al., 2019e) and felt less comfortable traveling in an AV (Fortunati et al., 2019; Ledger et al., 2018). Younger adults were more concerned about loss of jobs and loss of driving control (Qu et al., 2019; Wicki & Bernauer, 2018; see Brell et al. (2019a) for contradictory results). Finally, 17 studies showed that age did not influence the acceptability of AVs (Bazilinskyy & de Winter, 2015; Bennett et al., 2019b; Hegner et al., 2019; Hohenberger et al., 2016; Kyriakidis et al., 2015; Lee et al., 2019b; Liljamo et al., 2019; Nishihori et al., 2017; Nordhoff et al., 2018a; Park et al., 2019; Pettigrew et al., 2018b; Rahman et al., 2019; Rovira et al., 2019; Salonen, 2018; Shin et al., 2019; Tennant et al., 2019; Zmud & Sener, 2017). We observed that the results described previously were not dependent on the different mode of contact (16 none, 25 descriptions, 3 simulators, 7 real use). However, the proportion of participants over the age of 65 was low, especially for studies involving direct experience (about 10% on average). This bias did not allow us to make a robust decision on the effect of the mode of contact on age. It would therefore be appropriate to include a greater proportion of older people in future experiments involving real contact with AVs. In view of the contradictory results of studies questioning the influence of age on the acceptability of the AV, we recommend an equivalent representation of the different age groups within the studies. It is therefore necessary to undertake a meta-analysis of the results obtained in order to decide on the meaning and power of this effect.

Location: The effect of location on the acceptability of AVs was one of the least studied socio-demographic variables (11 papers). Overall, results showed a higher acceptability among urban residents than among those in rural areas (Deb et al., 2017; Hassan et al., 2019; Lavieri et al., 2017; Ledger et al., 2018; Liljamo et al., 2018; Nielsen & Haustein, 2018; Nordhoff et al., 2018a; Rahman et al., 2019). Nevertheless, it is difficult to conclude on the effect of the mode of contact because only one study involved direct experience with AVs.

Education: 22 articles deal with the level of education. Most of them showed that participants with a high level of education expressed more behavioural intentions than respondents with a low level of education (Montoro et al., 2019; Piao et al., 2016; Sener et al., 2019; see Cunningham et al. (2019) for contradictory results). Moreover, those with higher levels of education perceived more benefits of AVs (Acheampong & Cugurullo, 2019; Cunningham et al., 2019) and had more positive attitudes towards AVs (Haboucha et al., 2017; Liljamo et al., 2018; Nielsen & Haustein, 2018; Roche-Cerasi, 2019). Seven studies did not show any effect of the level of education on the acceptability of the AV (Hegner et al., 2019; Koul & Eydgahi, 2018, 2019; Qu et al., 2019; Salonen, 2018; Shin et al., 2019; Zmud & Sener, 2017). The studies interested in the link between level of education and acceptability were not equally distributed among different modes of contact. Consequently, it was not possible to decide on the influence of the level of education on acceptability according to the mode of contact with the AV. Overall, it would appear that a high level of education promotes the acceptability of the AV. However, 7 studies show a lack of effect of this variable on the acceptability of the AV. This may in particular result from a sampling problem (sample too small or unbalanced groups). In order to determine this effect, we encourage researchers to include this variable in their future studies or to initiate replications of studies already conducted.

Income: The last socio-demographic variable frequently related to acceptability is income (18 papers). Participants with a high level of income expressed more intentions to use AVs (Dong et al., 2019; Hassan et al., 2019; Herrenkind et al., 2019b; Lavieri et al., 2017; Nishihori et al., 2017) but were also more concerned about their use: they were more likely to express negative attitudes (Bazilinsky et al., 2015) and to be concerned by the emission levels of AVs (Shabanpour et al., 2018a). Finally, 8 articles did not show any link between income and acceptability (Bennett et al., 2019b; Cunningham et al., 2019; Koul & Eydgahi, 2018; Nielsen & Haustein, 2018; Salonen, 2018; Sener et al., 2019; Shin et al., 2019; Zmud & Sener, 2017). The low proportion of studies that included real contact with the AV (2) did not allow us to conclude reliably on the influence of income on acceptability according to the mode of contact with AVs. As with the previous variable, it seems impossible at present to rule on the influence of income on the acceptability of the AV. This effect seems consistent because income is often positively correlated with education level. A lack of effect of income on acceptability seems to be the most frequently observed result. In order to be able to determine in a robust manner the influence of income on the acceptability of the AV, we encourage researchers to initiate new studies including this variable and to turn to replicating studies already carried out.

Personality: A final variable that may influence the acceptability of participants was personality (12 articles). Some studies showed that the personal innovativeness trait was correlated with behavioural intention (Chen & Yan, 2019; Deb et al., 2017; Hegner et al., 2019) and perceived ease of use (Herrenkind et al., 2019a). Nevertheless, very few studies have tested the relationship between personality traits and acceptability. Even if other personality traits have been tested, without replication of these isolated results it is not possible to conclude reliably, especially because 2 studies did not show any link between personality traits and acceptability (Frison et al., 2019; Kyriakidis et al., 2015). The mode of contact with the AV did not seem to influence personality, as the results obtained through these 12 articles are relatively consensual, regardless of the mode of contact with AVs.

III.3.2 Operationalization and definition of acceptability and intention to use

Two main kinds of dependent variables are common to the papers: those related to acceptability and those related to behavioural intentions. Various aspects of these variables are considered: acceptability, acceptance (the most frequently used term), adoption, and approval for the former, and intention to use, to purchase, willingness to pay or intention to recommend to others for the latter.

Acceptability/acceptance/adoption/approval: Despite the widespread focus on acceptance, most researchers have studied it without defining it precisely. To analyse our corpus, we borrowed some of the categories of definitions identified by Adell (2009). The first is the use of the word whose root is “accept” without any further explanation of what it really implies. The second focuses on user experience, requirements and needs. The third sees acceptance as a sum of attitudes. Authors in this category use the attitudinal definitions proposed by Van der Laan et al. (1997) or Schuitema et al. (2010). The fourth, and the most frequently encountered in our corpus, is based on behavioural intention as defined by Adell (2009, p. 31), “*the degree to which an individual intends to use a system and, when available, incorporates the system in his/her driving*”, or by Davis (1989). A few references stress the importance of making a distinction between acceptability and acceptance using Ledger et al.’s (2018) or Schade and Schlag’s (2003) definitions. Both emphasise that acceptance refers to a judgement following a first experience, whereas acceptability comes before any experience. The concept of acceptability is used in only 10 of the references. This is rather surprising given that most of the studies consulted refer to an AV as an overall concept, without real existence. In a few isolated cases too, acceptance is conceptualized as approval for use in society (Liljamo

et al., 2018; Nishihori et al., 2017; Pettigrew et al., 2018b; Sanbonmatsu et al., 2018, Tennant et al., 2019) or approval of the road tests (Penmetsa et al., 2019; Wicki & Bernauer, 2018). The given results are mixed, approval for use in society is assessed positively (Karnouskos, 2020; Nishihori et al., 2017) as well as negatively (Sanbonmatsu et al., 2018; Tennant et al., 2019).

For the 105 papers that study acceptability/acceptance/adoption (Table 2), we compared ways of defining acceptance or acceptability based on the content of the articles and very rarely on the definitions given (only 15 references provide a definition of acceptance). Globally, behavioural intention is the most prevalent way of defining acceptance (54 papers), followed by the sum of attitudes (31 papers). Differences can be seen depending on how the AV is present in the respondent's mind. Acceptance as a behavioural intention is proportionally more present for studies based on the respondents' imagination and short descriptions. Definitions based on the satisfaction of user needs are absent from these studies. However, there is a difference between studies that provide no explanation about AVs and studies that provide a description. In the first case, acceptance is defined in almost equal proportions as the sum of attitudes and as behavioural intention. In the second case, behavioural intention is overwhelmingly the majority. In simulations and real experience studies, acceptance is more frequently defined as the fulfilment of user needs, but other definitions are still present. Finally, the simple use of the word whose root is "accept", without further specification, is rare and not specific to a mode of presentation of AVs.

Behavioural intention (intention to use, to purchase or to recommend to others): Behavioural intention was measured in 68 of the papers retrieved. Most studies that do not explore behavioural intention focus exclusively on the antecedents of behavioural intention (which become the dependent variables), and a minority assesses specific functionalities such as driving behaviour or communication features. There are two ways to measure intention to use: intention to use for some use-cases or for a shared or owned vehicle, or general intention to use. When participants are asked to evaluate different use cases, they tend to approve of all of them (Cunningham et al., 2019; Ledger et al., 2018; Leicht et al., 2018; Lijarcio et al., 2019; Nielsen & Haustein, 2018; Nishihori et al., 2017; Nordhoff et al., 2019; Pucihar et al., 2019; Rahman et al., 2019; Regan et al., 2017; Rehrl & Zankl, 2018), except driving children without an adult present (Kaur & Rampersad, 2018; Ledger et al., 2018; Lee & Mirman, 2018; Lustgarten & Le Vine, 2018; Regan et al., 2017). This result is similar in studies that provide no information, only a brief definition or that include AV experience. However, some reservations are expressed (Kaur & Rampersad, 2018; Nordhoff et al., 2019) but they are too disparate to draw a conclusion. When intention to use is measured by comparing shared or individual use of a car or public transport, individual use seems to be more often preferred (Haboucha et al., 2017; Lavieri et al., 2017; Ledger et al., 2018; Lustgarten & Le Vine, 2018; Nielsen & Haustein, 2018; Pettigrew et al., 2019; Piao et al., 2016). Note that for Nordhoff et al. (2019) and Sener and Zmud (2019), only one-third of respondents favoured individual use, but the samples (public transport and bicycle users or shared mobility service users) were quite different from those usually found. Regarding the assessment of general intention to use, results are rather inconsistent. Sixteen studies showed a fairly strong intention to use AVs (Bennett et al., 2019a; Choi & Ji, 2015; Jing et al., 2019; Panagiotopoulos & Dimitrakopoulos, 2018; Hohenberger et al., 2017; Lee et al., 2019b; Madigan et al., 2016, 2017; Moták et al., 2017 for the real use study (Study 2); Nordhoff et al., 2018a, 2018b; Piao et al., 2016; Sener & Zmud, 2019; Wu et al., 2019; Xu et al., 2018; Zoellick et al., 2019a, 2019b). Seven highlighted a majority of people unlikely to use (Dong et al., 2019; Fraszczyk & Mulley, 2017; Hegner et al., 2019; Lavieri et al., 2017; Nielsen & Haustein, 2018; Pettigrew et al., 2019; Zmud & Sener, 2017), and in 6 studies respondents were more in a wait-and-see mode (Liu et al., 2019c, 2019d; Moták et al., 2017 for the questionnaire study (Study 1); Rahman et al., 2019; Sener et al., 2019; Wintersberger et al., 2019). Real contact studies seem to show a higher intention to use.

Concerning intention to purchase, most studies showed a positive intention (Karnouskos, 2020; Nordhoff et al., 2018a; Piao et al., 2016; Sanbonmatsu et al., 2018; Shin et al., 2019; Wu et al., 2019). However, 4 studies reported a low (Pettigrew et al., 2019) or medium intention to purchase (Liu et al., 2019a, 2019d; Xu et al., 2018). The results of studies using willingness to pay are rather contradictory. Respondents do not want to pay any more or want to pay very little for buying a car or a ticket (Cunningham et al., 2019; Kyriakidis et al., 2015; Nordhoff et al., 2018b). In those papers that present descriptive results on the issue of intention to encourage others to use or purchase, respondents were most often moderately inclined to recommend AVs (Xu et al., 2018; Liu et al., 2019a, 2019d). Only one study showed a positive intention to recommend (Wu et al., 2019). Finally, it should be noted that when the modality “unsure” is proposed, it is selected by a large number of respondents (Fraszczuk & Mulley, 2017; Nielsen & Haustein, 2018; Pettigrew et al., 2019; Shin et al., 2019). Many studies focused on the predictive relationship between variables and did not provide descriptive results about intentions. Some researchers also grouped the results of different behavioural variables (Nielsen & Haustein, 2018; Lee et al., 2019b).

III.3.3 Preferences

In 35 papers, the authors seek to project likely future users into the use of AVs. This projection is based on AVs that are described in varying degrees of detail. It is difficult to draw conclusions in this regard, however, as many topics are only explored by a single study. Two topics were particularly studied: the activities that could be carried out in the AV and the characteristics of the vehicle and, more rarely, of the associated service.

Onboard activities: This topic has been studied based either on a brief description or on real use, with quite similar results in both cases. In the first case, respondents imagined themselves carrying out certain activities during the trip such as taking care of personal matters, writing a grocery list, or using their cell phone (Cunningham et al., 2019; Ledger et al., 2018; Zmud & Sener, 2017). Two studies showed that the fact of being able to carry out an activity during the trip is considered to be of little importance (Cho & Jung, 2018; Lustgarten & Le Vine, 2018). The majority of respondents perceived a better use of time (Brell et al., 2019b; Leicht et al., 2018; López-Lambas & Alonso, 2019; Pettigrew et al., 2018b; Qu et al., 2019; Sener & Zmud, 2019; Shabanpour et al., 2018a; Wahlström, 2017; Zmud & Sener, 2017). However, studies based on a brief definition of the AV, as well as those involving real experience, seem to show that users tend to stick with the way they use their car today. The user always saw him/herself in the driver's seat (Zmud & Sener, 2017) and his/her preferred activities were those that everyone already does in their vehicle: admiring the landscape and interacting with the other occupants of the vehicle (Ledger et al., 2018), in particular children (Lee & Mirman, 2018), or listening to music (Pucihar et al., 2019). For shuttle trips, riders do not believe that the trips will allow them to engage in cognitively demanding tasks, due to the lack of isolation (Nordhoff et al., 2019). Many participants appear to perceive a better use of time inside an AV. However, the activities they consider doing inside the AV are the same as those they can already do today. This result may indicate that participants lack knowledge about AVs, but also that they encounter difficulties in projecting themselves into a concrete use of this type of vehicle. This projection is even more difficult in studies that do not allow direct contact with the AV.

Characteristics of the vehicles or the service: Many different characteristics have been explored, but mostly by a single study: this is the case, for instance, for the ethical frameworks that could be used in the car's decision-making (Karnouskos, 2020), and for a sound filter system (Bazilinsky & de Winter, 2015). Therefore, we will not expand on their results and will limit ourselves to expressing their general theme. Few studies deal with driving parameters, which are mostly conducted on a simulator. However, the parameters evaluated

were varied: driving style (Techer et al., 2019; Hartwich et al., 2018; Mühl et al., 2019; Oliveira et al., 2019), driving behaviour (time headway, lateral offset, quality of driving; Siebert & Wallis, 2019; Voß et al., 2018; Walker et al., 2019). These studies highlighted the crucial role of the conditions such as road type, time pressure, traffic volume, visibility, weather, other vehicle behaviour, presence of explanations or side of the seat in the evaluation (Frison et al., 2019; Wintersberger et al., 2019), indicating the need to multiply studies to investigate combinations of conditions. They also demonstrate the importance of understandability and predictability. Few studies focused on communication parameters: only 3 studies dealt with car to pedestrian communication, 1 with photo descriptions (Ackermann et al., 2019) and 2 with real experience (Habibovic et al., 2018; Schieben et al., 2019). They highlighted pedestrian needs for information. In studies dealing with car users, the tone (Lee et al., 2019b) and the voice (Lee et al., 2019c) were evaluated. In this case too, the preferences were linked to the conditions under which the message is sent. Three studies focused on public transport users, exploring the expected characteristics of an automated shuttle service. They stressed the importance of registration to compensate for the lack of human presence, spatial equity of access (Stark et al., 2019), availability, convenience, flexibility, reliability (Nordhoff et al., 2019), comfort, sound environment, and sight (Christie et al., 2016; Zoellick et al., 2019b). Many characteristics of the vehicle have been studied, as well as driving parameters or communication between the AV and its passengers or its environment. Nevertheless, very few of the effects observed have been replicated. On the basis of this observation, it is impossible to come to a robust conclusion on the influence of the characteristics of the AV on its acceptability.

III.3.4 Perceptions

In 108 papers, the authors seek to study how individuals perceive AVs based on several psychological determinants relating to level of knowledge, ease of use, utility, subjective norms, attitudes, concerns, benefits, trust, control and security. For this purpose, several modes of contact with AVs were tested (table 2). In this section, the results of the studies will be compared according to the mode of contact that the participants had with the AV for each determinant of acceptability.

Level of knowledge: 26 papers deal with the level of knowledge of AVs. Participants' self-assessed level of knowledge of AVs was generally medium or good (Cho & Jung, 2018; Ledger et al., 2018; Nees, 2019; Panagiotopoulos & Dimitrakopoulos, 2018; Penmetsa et al., 2019; Piao et al., 2016; Regan et al., 2017; Rehr & Zankl, 2018; Roche-Cerasi, 2019; Wicki & Bernauer, 2018; see Pettigrew et al. (2019) and Sanbonmatsu et al. (2018) for contradictory results). Most studies agreed that a good knowledge of AVs is positively correlated with their acceptability (Bennett et al., 2019b; Charness et al., 2018; Dong et al., 2019; Frison et al., 2019; Khastgir et al., 2018; Liu et al., 2019d; Penmetsa et al., 2019; Rahman et al., 2019). More specifically, a good level of knowledge increased trust in AVs (Khastgir et al., 2018; Oliveira et al., 2019; Rahman et al., 2019) and led to more positive attitudes towards AVs (Jing et al., 2019; Liu et al., 2019d; Rahman et al., 2019; Wahlström, 2017). Nevertheless, a few researchers found that the level of knowledge did not necessarily lead to higher acceptability of AVs (Dong et al., 2019; Hyde et al., 2017) and did not influence the behavioural intention to use these AVs (Jing et al., 2019). The mode of contact with the AV appears to influence the level of knowledge and its effects on other predictors of acceptability. The results of studies carried out on simulators or by direct experience with AVs consistently showed a positive correlation between the level of knowledge and acceptability. The results of studies using other modes of vehicle contact were more heterogeneous. This indicates that the mode of contact with the vehicle seemed to be a moderator variable of the relationship between level of knowledge and acceptability. New studies directly testing this moderation would be necessary to substantiate

this hypothesis. Many of the participants report having an average or good level of knowledge about the AV. The studies agree that a good level of knowledge would promote the acceptability of the vehicle. Since the level of knowledge of participants is always self-reported, we stress the importance of measuring it objectively, as did Sanbonmatsu et al. (2018) who showed that the participants' level of knowledge about AVs is low. Indeed, the assumption that a participant can assess his/her level of knowledge about AVs seems questionable since the representation of the AV is unstable. Thus, we strongly encourage researchers to measure the level of knowledge of participants towards AVs objectively using scales, or at least to question it using an open-ended question. This methodological precaution seems mandatory to test the hypothesis of moderation of the relationship between level of knowledge and acceptability by the contact mode with the vehicle mentioned above.

Perceived ease of use/effort expectancy: 22 papers deal with the perceived ease of use of AVs. Three studies showed that participants rated ease of use of AVs as high (Christie et al., 2016; Panagiotopoulos & Dimitrakopoulos, 2018; Park et al., 2019), whereas Hegner et al. (2019) showed that the ease of use of AVs is perceived as moderate and Wintersberger et al. (2019) highlighted that this ease of use improved when explanations on the handling of the vehicle were provided. However, some authors had more mixed results. In Kyriakidis et al. (2015), participants rated fully automated driving easier than manual driving but highly automated driving more difficult than manual driving. Furthermore, in one study participants reported that travelling on an automated shuttle was not more convenient than the current transport mode (Nordhoff et al., 2018b). Perceived ease of use was correlated with many of the other psychological determinants. Specifically, the more participants felt at ease traveling in an AV, the higher the positive attitude was (Acheampong & Cugurrullo, 2019; Fortunati et al., 2019; Herrenkind et al., 2019a, 2019b). Perceived ease of use was also positively linked to behavioural intention (Choi & Ji, 2015; Koul & Eydgahi, 2018; Lee et al., 2019a; Madigan et al., 2016; Sener et al., 2019; Wu et al., 2019; Xu et al., 2018; Zmud & Sener, 2017; only Hegner et al. (2019) showed of the absence of any link between these two variables). At the same time, results highlighted that perceived ease of use was positively linked to perceived usefulness (Hegner et al., 2019; Herrenking et al., 2019b; Lee et al., 2019a, 2019b; Madigan et al., 2017; see Choi and Ji (2015) for a contradictory result) and trust (Hegner et al., 2019; Herrenkind et al., 2019b; Xu et al., 2018). Modes of contact were evenly represented through the different levels of perceived ease of use of AVs. We thus observed that the ease of use was not influenced by the mode of contact with the AV. In conclusion, many participants perceive AVs as easy to use. This perceived ease of use leads to a positive attitude towards AVs as well as the intention to use this type of vehicle. However, the mode of contact with the vehicle does not seem to influence the participants' perception of ease of use. Nevertheless, this result needs to be qualified in the light of the study by Osswald, Wurhofer, Trösterer, Beck, and Tscheligi (2012), who suggest that ease of use requires direct experience to be assessed.

Perceived usefulness/performance expectancy: 24 papers deal with the perceived usefulness of AVs. Four studies showed that the usefulness of AVs was perceived as good (Nishihori et al., 2017; Nordhoff et al., 2018a; Park et al., 2019; Roche-Cerasi, 2019), and Wintersberger et al. (2019) suggested that usefulness was higher with explanations on the handling of the vehicle. In 2 studies, the usefulness of AVs was perceived as moderate for both users and pedestrians (Hegner et al., 2019; Rahman et al., 2019). Finally, Nordhoff et al. (2018b) mitigated these results by arguing that the usefulness was good but compromised by the reduced speed of the automated shuttle, in comparison with current transport modes. Again, the perceived usefulness can be linked to several other determinants of acceptability. First, perceived usefulness was a significant predictor of behavioural intention as regards AVs (Choi & Ji, 2015; Hegner et al., 2019; Kaur & Rampersad, 2018; Koul & Eydgahi, 2018; Lee et al., 2019a; Moták et al., 2017; Sener et al., 2019; Wu et al., 2019; Xu et al., 2018). Furthermore,

perceived usefulness correlated positively with attitudes (Herrenkind et al., 2019a, 2019b) and trust (Choi & Ji, 2015; Herrenkind et al., 2019a; Xu et al., 2018). Like perceived ease of use, perceived usefulness was not influenced by the mode of contact with the vehicle. Direct experience with the AV did not appear to be required to assess its usefulness. Nevertheless, it could lead participants to become aware of limitations associated with the AV such as its speed, as reported in the experiment by Nordhoff et al. (2018b), and thus modify their perception of the usefulness of such a vehicle. Finally, several studies show a positive correlation between perceived usefulness and attitude or intention to use. Nevertheless, few studies directly question participants' perception of the usefulness of the AV. In our view, it would be interesting to ask participants about the criteria that make an AV useful, but also about the differences between conventional vehicles and AVs in terms of utility. This would serve a dual purpose. On the one hand, it would allow researchers to study the representation of the AV. On the other hand, it would allow designers to consider the most important criteria of usefulness for the population.

Subjective norms/social influence: 15 papers deal with subjective norms. Subjective norms were considered as a good determinant of acceptability (Nordhoff et al., 2018a). Subjective norms positively influenced perceived ease of use (Acheampong & Cugurullo, 2019; Madigan et al., 2017), perceived usefulness (Herrenkind et al., 2019a, 2019b; Madigan et al., 2017), attitudes toward AVs (Herrenkind et al., 2019a, 2019b; Monéger et al., 2018; Panagiotopoulos & Dimitrakopoulos, 2018) and behavioural intention (Chen & Yan, 2019; Herrenkind et al., 2019a, 2019b; Jing et al., 2019; Koul & Eydgahi, 2019; Moták et al., 2017; Sener et al., 2019; Zmud & Sener, 2017). Among the studies dealing with subjective norms, 5 involved direct experience with an AV, 6 provided a definition of AVs, 1 proposed 2 studies including a definition and a real experience and 3 provided no indication. This relatively even distribution of the different modes of contact with AVs allows us to suggest that the mode of contact did not influence the link between subjective norms and the dependent variables. Subjective norms robustly influence intention to use, acceptability and their determinants, regardless of the mode of contact with the vehicle.

Attitudes toward AVs: 22 papers deal with attitudes toward AVs. Most participants had a positive general opinion of AVs, especially men and young people (Hartwich et al., 2018; Hulse et al., 2018; Hyde et al., 2017; Liljamo et al., 2018; Panagiotopoulos & Dimitrakopoulos, 2018; Rahman et al., 2019; Wicki & Bernauer, 2018). Attitudes were more favourable when participants had a high level of knowledge of AVs (Sanbonmatsu et al., 2018; Wintersberger et al., 2019) and were positive both for manual mode and for higher levels of automation such as the fully automated driving mode (Park et al., 2019). For the subway, users were more positive than non-users towards different aspects of AVs such as the absence of a driver (Fraszczyk & Mulley, 2017). Concerning non-users, pedestrians and passengers declared a neutral attitude towards AVs (Hulse et al., 2018; Rahman et al., 2019). Nevertheless, Bennett et al. (2019a) showed that eight out of ten respondents expressed reservations about AVs. Moreover, positive attitudes were positively correlated with behavioural intentions (Chen & Yan, 2019; Jing et al., 2019; Moták et al., 2017; Sener & Zmud, 2019; Sener et al., 2019; Tennant et al., 2019). Finally, 3 studies did not show any effect of attitude on acceptability (Regan et al., 2017; Roche-Cerasi, 2019; Zmud & Sener, 2017). Concerning the influence of the mode of contact with AVs on attitudes, only 4 studies involved real experience with the AV. We cannot therefore come to any viable conclusions on this effect. The results show that the attitude towards AVs is positive, even more so among men, young people and subway users. In addition, a positive attitude towards AVs seems to be a predictor of the intention to use this type of vehicle. However, the positive attitude of participants towards AVs does not prevent them from expressing reservations about these vehicles.

Concerns: 36 papers deal with concerns about AVs. In response to the large number of concerns expressed by participants, we chose to categorize them into 3 groups. The first related

to the vehicle itself and its deployment on the road. In this group, we identified the following concerns: the transition between manual and AVs (Hyde et al., 2017; López-Lambas & Alonso, 2019), the technical unreliability (Liljamo et al., 2018; Nishihori et al., 2017; Piao et al., 2016; Qu et al., 2019; Shin et al., 2019; Stark et al., 2019; Wahlström, 2017; Zmud & Sener, 2017), the poor performance in unexpected situations (Ackerman et al., 2019; López-Lambas & Alonso, 2019; Shabanpour et al., 2018a; Techer et al., 2019), the impact on traffic safety (Liljamo et al., 2018; Lee & Mirman, 2018; Lu et al., 2017) and the loss of driving skills (Nishihori et al., 2017; Pettigrew et al., 2018a; Zmud & Sener, 2017). The second group corresponded to ethical, legal and safety questions. It included the following concerns: the safety of the software (Dong et al., 2019; Kyriakidis et al., 2015; Piao et al., 2016; Wicki & Bernauer, 2018; Zmud & Sener, 2017), the ethical questions raised by the introduction of the technology (Das et al., 2019; Hyde et al., 2017; Liljamo et al., 2018; Nordhoff et al., 2019), the need for new policies and legislation to regulate the use of AVs (Hyde et al., 2017; Kyriakidis et al., 2015; Lu et al., 2017; Piao et al., 2016; Wicki & Bernauer, 2018). Finally, the third group comprises the financial (Leicht et al., 2018; Nishihori et al., 2017; Piao et al., 2016; Ro & Ha, 2019; Sener & Zmud, 2019; Shabanpour et al., 2018a; Shin et al., 2019; Wahlström, 2017; Zmud & Sener, 2017) and societal barriers, such as job losses (Nishihori et al., 2017; Nordhoff et al., 2019; Pettigrew et al., 2018a, 2019; Wahlström, 2017; Wicki & Bernauer, 2018). Of these 36 articles, the majority gave no indication about the AV or provided a definition, and only 5 offered direct experience with the AV. Two hypotheses can be put forward to explain these figures: either the concerns were not studied in the simulator studies or by direct experience, or participants reported few or no concerns in this type of experience. However, Brell et al. (2019b) explained that experience did not decrease negative perceptions of the barriers. These results need to be considered with caution because the study did not give access to direct experience with the AV. As done by Xu et al. (2018), it would be appropriate in the future to record participants' concerns before and after using the AV in order to observe their evolution, especially as those who had a higher level of concerns about AVs were less likely to adopt them (Dong et al., 2019; Lavieri et al., 2017; Nielsen & Haustein, 2018; Shin et al., 2019). To summarize, participants' concerns can be divided into 3 broad categories. The first is related to the vehicle itself and its deployment on the road, where the main concern is the technical unreliability of the AV. The second relates to ethical, legal and safety issues, where the main concerns are the safety of the software and the need for new policies and legislation to regulate the use of AVs. Finally, the third comprises the financial and societal barriers. In addition to these many topics, two major concerns were studied in greater depth: privacy and environmental concerns.

Privacy concerns: 15 papers deal with privacy concerns. Most participants were worried about privacy (Ledger et al., 2018; Panagiotopoulos & Dimitrakopoulos, 2018; Piao et al., 2016; Regan et al., 2017; Shabanpour et al., 2018a; Stark et al., 2019; Wicki & Bernauer, 2018). Roche-Cerasi (2019) showed that women were more concerned by loss of privacy than men. Participants who said they were concerned about privacy were also concerned about cybersecurity (Panagiotopoulos & Dimitrakopoulos, 2018). Of these 15 dealing with privacy concerns, only 3 allowed participants direct contact with the vehicle. The others provided at best a definition of the AV. People expressed privacy concerns regardless of the level of contact with the AV. Consequently, real experience is not necessarily reassuring for them. Moreover, as few studies explored the links between privacy concerns and other predictors of acceptability, we cannot conclude on the robustness of this link. However, studies agreed that privacy was a major concern for individuals. Therefore, it seems essential in the future to study this explanatory variable of acceptability in more detail regardless of the level of contact with the AV.

Environmental concerns: 11 papers deal with environmental concerns. López-Lambas and Alonso (2019) explained that even if environmental concerns attracted few comments in general in their focus groups, it was believed that the implementation of AVs would have positive outcomes. Pettigrew et al. (2018b) also showed that people do not mention the environmental benefits associated with the deployment of AVs. Consequently, environmental concerns influence intention to use positively (Haboucha et al., 2017; Liu et al., 2019c; Wu et al., 2019) and pro-environmental attitudes correlated positively both with perceived benefits (Acheampong & Cugurullo, 2019) and perceived usefulness of AVs (Ashkrof et al., 2019). Finally, Herrenkind et al. (2019a, 2019b) did not show any effect of environmental concerns or environmental awareness on the acceptability of AVs. These results show that environmental concerns are at present only loosely linked to the acceptability of AVs. When they were, little or no information is given about the AV. Indeed, of the 3 studies that inquired into environmental concerns after direct experience with the AV, 2 showed the absence of any link between this variable and acceptability. Studies examining environmental concerns show that many participants who are concerned about the environment have a positive perception of AVs. Studies that focus on environmental concerns are sparse, however. In the future, we encourage researchers to consider this variable more systematically when studying the acceptability of AVs. Nevertheless, many studies have shown that people's behaviour is driven by a set of diverse motivations, both egoistic and altruistic, including ecological motivation (for a review see Steg, Lindenberg, and Keizer (2016)).

Benefits: 32 papers deal with the perceived benefits of AVs. We categorized the large number of benefits identified by the researchers into 3 groups. The first concerns the psychosocial benefits. In this group, we identified the following benefits: comfort (Leicht et al., 2018; López-Lambas & Alonso, 2019; Pettigrew et al., 2018b; Ro & Ha, 2019), reduction of stress (López-Lambas & Alonso, 2019; Pettigrew et al., 2018b; Sener & Zmud, 2019; Shabanpour et al., 2018a; Shin et al., 2019; Zmud & Sener, 2017), greater mobility with the possibility of doing something else during the journey (Nishihori et al., 2017; Pettigrew et al., 2018a, 2018b; Qu et al., 2019; Regan et al., 2017), enhancement of accessibility (Cunningham et al., 2019; Ledger et al., 2018; Lee & Mirman, 2018; López-Lambas & Alonso, 2019; Nishihori et al., 2017; Pettigrew et al., 2018b; Regan et al., 2017; Ro & Ha, 2019; Roche-Cerasi, 2019; Shin et al., 2019; Zmud & Sener, 2017), and reduction of human errors, thus increasing safety (Leicht et al., 2018; López-Lambas & Alonso, 2019; Nielsen & Hausteine, 2018; Pettigrew et al., 2018a, 2018b; Piao et al., 2016; Regan et al., 2017; Ro & Ha, 2019; Sener & Zmud, 2019; Shabanpour et al., 2018a; Shin et al., 2019; Stark et al., 2019; Wahlström, 2017; Zmud & Sener, 2017). The second group corresponded to environmental benefits. It included the following benefits: energy saving, clean energy resources, minimization of damage to flora (López-Lambas & Alonso, 2019; Nishihori et al., 2017; Pettigrew et al., 2018b; Piao et al., 2016; Roche-Cerasi, 2019). Finally, the third group comprised socioeconomic benefits such as reduced insurance cost/ticket price (Cunningham et al., 2019; Fraszczyk et al., 2015; Fraszczyk & Mulley, 2017; Ledger et al., 2018; Nishihori et al., 2017; Qu et al., 2019; Regan et al., 2017; Ro & Ha, 2019; Sener & Zmud, 2019; Shabanpour et al., 2018a; Wahlström, 2017) and increased train frequency (Fraszczyk et al., 2015; Fraszczyk & Mulley, 2017). The links between perceived benefits and other determinants of acceptability were seldom studied. Concerning the mode of contact with AVs, the majority of papers gave no indication about the AV or provided a definition, and only 4 offered direct experience with the AV. As for the concerns, the perceived benefits have not been studied in simulator studies or by direct experience. In addition, Brell et al. (2019b) suggested that direct experience increased the positive perspective of respondents. It would seem relevant to encourage direct experiences with AVs because higher levels of perceived benefits were found to lead to greater willingness to use AVs (Hohenberger et al., 2017; Qu et al., 2019). To summarize, perceived benefits can

be divided into 3 broad categories. The first concerns the psychosocial benefits, among which the main ones are the enhancement of accessibility and the reduction of human errors to increase safety. The second corresponds to environmental benefits: here, the main benefits are energy saving, clean energy resources and minimization of damage to flora. Finally, the third comprises the socioeconomic benefits and increased public transport frequency. The results also showed that studies questioning benefits often list them. Nevertheless, the presentation of the benefits associated with AVs in the form of a list influences the perception of the participants by giving them an idea that they might not have spontaneously evoked. To avoid this type of bias, we encourage the use of interviews which allow for spontaneous discourse. Furthermore, we deplore the scarcity of studies relating perceived benefits to other determinants of acceptability. Indeed, we encourage researchers to go beyond a simple list of perceived benefits and to relate these benefits to the other psychological determinants of acceptability and behavioural intention.

Trust: 37 papers deal with trust in AVs. Results showed that there is no consensus among the public on trust in AVs (Salonen & Haavisto, 2019), with more studies highlighting a lack of trust in AVs than a high level of trust in them. For studies that undertook qualitative analysis, the word trust was one of the words with the highest frequencies, which implies a lack of trust in AVs, especially for frequent drivers (Cho & Jung, 2018; Das et al., 2019). The results also showed that trust may vary depending on the reliability. Trust was higher when the AV was reliable than when it performed poorly (Pucihar et al., 2019; Rovira et al., 2019). Trust was thus negatively affected by perceived risks (Choi & Ji, 2015; Rovira et al., 2019). Moreover, trust was higher for users than for pedestrians (Rahman et al., 2019) and increased with experience (Mühl et al., 2019; Xu et al., 2018), explanations about AV operation (Du et al., 2019; Wintersberger et al., 2019) and for the higher levels of automation (Khastgir et al., 2018). Moreover, trust was a strong determinant of acceptability and results showed consensually a positive correlation between trust and attitudes (Bazilinsky et al., 2015; Frison et al., 2019; Kauer et al., 2015; Ledger et al., 2018; Lee & Kolodge, 2019; Leicht et al., 2018; Regan et al., 2017). Trust was also positively linked with intention to use AVs (Ashkrof et al., 2019; Choi & Ji, 2015; Hegner et al., 2019; Herrenkind et al., 2019a; Liu et al., 2019c; Moták et al., 2017; Sanbonmatsu et al., 2018; Sener et al., 2019; Zoellick et al., 2019a; for contradictory results see Kaur and Rampersad (2018)) and acceptability (Nordhoff et al., 2018a). The different modes of contact with AVs are evenly represented in the studies on trust. Overall, studies that gave no information or definition of AVs seemed to show the same level of trust as those that involved more direct contact. To conclude, trust is one of the most robust determinants of the acceptability of AVs. This variable is, however, almost systematically studied based on self-reported measurements. When this measurement method is associated with an absence of contact between the participants and the AV, biases may be present, since without direct contact with the vehicle, the participant cannot reliably and objectively assess the trust he/she places in it. This bias is further reinforced by the absence of a social representation of the AV, since in order to assess his/her level of trust, the participant can only rely on his/her own experience with this vehicle, which is sometimes non-existent. When a social representation exists, the participant can, on the contrary, rely on a normative evaluation of the object to form an opinion of it and thus estimate the confidence he/she has in it. Moreover, when the self-reported measurement was carried out after a simulator experiment, participants were still able to apprehend the AV even if it was an interaction in virtual conditions. Using a simulator study and behavioural measures, Khastgir et al. (2018) showed that although users say they trust the AV, this was not always the case when they experienced more direct contact with it. These results again confirmed the value of using different methodologies and more realistic conditions to study the acceptability of AVs. In view of these results, we recommend coupling subjective and objective measures of trust in future studies on the acceptability of AVs. Objective

measures correspond to behavioural (lack of supervision, lack of vehicle takeover) or physiological measures (heart rate, skin conductance). Behavioural measures were used by Frison et al. (2019) and Wintersberger et al. (2019) but were not directly related to trust.

Control: 21 deal papers with desire for control and 7 with perceived control of AVs. Perceived control was defined as the possibility of individuals to choose whether to use AVs or not (Jing et al., 2019). The use of an AV could lead to a feeling of a loss of control (Wintersberger et al., 2019) that was an important barrier (López-Lambas & Alonso, 2019; Wicki & Bernauer, 2018). Indeed, individuals wished to participate in the driving task on an operational level and they complained of not being able to intervene in driving fully AVs (Frison et al., 2019; Lustgarten & Le Vine, 2018). For public transport, they prefer a human to supervise the vehicle (Dong et al., 2019; Fraszczyk et al., 2015; López-Lambas & Alonso, 2019; Nordhoff et al., 2018a, 2018b; Piao et al., 2016; Roche-Cerasi, 2019; Walström, 2017; see Nordhoff et al. (2019) for contradictory results). For cars, participants were thus not comfortable with vehicles that have no control devices (Liljamo et al., 2018). In addition, many older adults (81.10%) reported that they would prefer to be personally in control of their car because AVs cannot be foolproof (Hassan et al., 2019). This desire for control negatively influenced attitudes and trust towards AVs (Herrenkind et al., 2019a; Montoro et al., 2019). Finally, perceived control was found to be a significant predictor of behavioural intention (Chen & Yan, 2019; Moták et al., 2017). Nevertheless, according to Sener et al. (2019), desire for control was a reason for not intending to use AVs but was not linked with intention to use. Regarding the modes of contact with AVs, the papers in our sample that studied control mainly included direct experience in the case of shuttles and provided a definition of AVs in the case of cars. In the context of direct experience, it was easier for participants to perceive a loss of control compared to their daily mobility habits and thus to express reservations about their intention to use the AV. In summary, the delegation of vehicle control to artificial intelligence represents a major obstacle for participants, both for cars and for public transport. This loss of control is detrimental to the intention to use an AV as well as to its acceptability. Indeed, many participants state that they prefer to participate in the driving task in the car or to have a supervisor present in the vehicle for public transport.

Perceived safety or risks: 53 papers deal with the perceived safety or risks of AVs. As mentioned above, safety is one of the major concerns of participants (Brell et al., 2019a; Dong et al., 2019; Kyriakidis et al., 2015; Liljamo et al., 2018; Regan et al., 2017; Roche-Cerasi, 2019; Wahlström, 2017; see Stark et al. (2019) for contradictory results). They also have high expectations (Liu et al., 2019b; Nees, 2019). Both drivers and other road users were worried about the safety of AVs (Ledger et al., 2018; Rahman et al., 2019). For the automated subway, 50% of users and 67% of non-users were worried about safety (Fraszczyk & Mulley, 2017). The perceived safety varied according to the level of automation, but the meaning of this effect was interpreted differently. Some researchers showed that perceived safety decreased significantly with an increase in automation level (Das et al., 2019; Brell et al., 2019b; Nees, 2019) whereas other researchers found that perceived safety was higher for highly or fully AVs (Lee & Kolodge, 2019; Pettigrew et al., 2019). These results were corroborated by showing that AV technology was positively evaluated, created a perceived safety improvement and allowed drivers to be more relaxed (Lu et al., 2017; Kauer et al., 2015; Nishihori et al., 2017). Moreover, the conditions of the trip played a major role in the perception of safety because fully automated driving on highways and rural roads was perceived as relatively safe and trustworthy, while the greatest safety concern related to driving in urban areas (Frison et al., 2019). However, Fortunati et al. (2019) reported that individuals who live in a large community felt safer in AVs than those who live in a medium-sized or small community. Finally, most studies showed that perceived safety (or perceived risk) had a positive (negative) effect on behavioural intention (Hohenberger et al., 2017; Jing et al., 2019; Koul & Eydgahi, 2019; Lee et al., 2019a; Montoro et al., 2019;

Sener & Zmud, 2019; Sener et al., 2019; Xu et al., 2018; Zmud & Sener, 2017; Zoellick et al., 2019a). Nevertheless, 4 studies observed that perceived safety (or perceived risk) was not a significant predictor of behavioural intention (Chen & Yan, 2019; Liu et al., 2019a; Nordhoff et al., 2018b; Zoellick et al., 2019b). An overall meta-analysis could be used to determine the reliability of this effect. Furthermore, this literature review showed that direct experience with the AV systematically increased the perception of safety as a large proportion of individuals felt safe or very safe inside the AV (91% in Christie et al., 2016; 62% in Penmetsa et al., 2019; 71% in Piao et al., 2016; 90% in Rehrl & Zankl, 2018). Thus, for most passengers, the experience (direct or via a simulator) was better than expected and they generally felt safe (Nordhoff et al., 2019; Park et al., 2019; Salonen & Haavisto, 2019). The results of this literature review seemed to highlight that this variable was a major concern of individuals but that it is eliminated when they came into direct contact with the AV.

IV. DISCUSSION

This literature review has examined the relationship between the determinants of the acceptability of the AV and its mode of presentation (no explanation, written or pictorial description, simulator, real experience). To this end, we analysed the results of 113 scientific articles. A first finding is that the proportion of studies that did not provide information about the AV or that simply gave a definition is twice as large as that of studies using a simulator or direct experience (75 articles versus 38). This result can be explained by the fact that the first prototypes of AVs were produced recently, but also because more concrete experimental protocols such as the simulator or real experience are more difficult and more expensive to set up for researchers. Nevertheless, our results showed that the mode of contact with the AV did not affect all the determinants of acceptability. Consequently, we recommend research involving real conditions to study some determinants of acceptability but not necessarily for all.

The sociodemographic variables most frequently related to the acceptability of AVs are gender, age, location, education, income, and personality. Among these 6 variables, the most robust conclusion concerns gender: there is a general consensus among the studies conducted that acceptability of AVs is greater among men than among women. For the other variables, the results are less conclusive. The studies on age do not allow us to conclude. We therefore make two recommendations. First, future studies should ensure that there is an equitable distribution within age groups. Second, a meta-analysis of the many results already available is needed to determine the meaning and robustness of the relationship between age and the acceptability of the AV. For the other variables (location, education, income, and personality), there are few studies and the results do not all point in the same direction. Consequently, we recommend the implementation of new studies but also and above all, the replication of effects already observed.

Concerning dependant variables, this review shows a great variability in how acceptability is conceptualized, and the frequent lack of a solid theoretical basis for these conceptualisations. It seems particularly strange to measure acceptability (actually more frequently acceptance) without clearly defining it. Finally, the variability in the way intention to use is measured makes it difficult to compare the results of different studies. The meta-analysis by Nishihori et al. (2018) showed in particular the impact of the definition of acceptability (approval of use in society *vs* personal intention to use) on the results.

Concerning preferences, the first point to mention is that the topics studied vary depending on the level of concreteness of the AV for the respondent, which is low in studies that provide no explanation or only a brief description, and high in those involving a simulator or direct experience. While the expected onboard activities are covered by all types of studies, the characteristics of the vehicle are mainly investigated in simulator and real experiment studies. Second, this review of studies on individuals' preferences for AVs highlights some

recurring results but also some major shortcomings. The expected driving style is not clearly defined, and contradictory results are reported, first because the different characteristics are insufficiently studied but also perhaps because some contextual explanatory variables are not properly assessed. The contradictions identified could reflect variability in the use of traditional vehicles (driving style, reasons for using it, activities carried out, etc.). Future studies will have to consider these variabilities and how to integrate them into AVs. Too few studies explore realistic conditions of use, such as a time constraint, weather, congestion, to see their impact on the intention to use an AV or an automated mode. In addition, there are many studies on vehicle characteristics, but among the effects observed very few have been replicated. Thus, it is difficult to draw reliable conclusions as to the link between this variable and the acceptability of the AV. Regarding onboard activities, many participants noted a better use of time thanks to the AV. However, when participants are asked about the activities which they could do in such a vehicle, they remain focused on "traditional" activities carried out on board (looking at the landscape, listening to music, talking with other passengers, etc.). Two hypotheses can be formulated regarding this result: either the participants have a poor knowledge of how AVs work, or they do not trust the vehicle enough to free themselves completely from the driving task. This would mean that preferences in terms of onboard activities should be related to other determinants of acceptability and intention to use such as level of knowledge, trust, or loss of control. Either it is difficult for participants to project themselves into a concrete use of an AV. Indeed, we believe that the methods used are not appropriate for projection into probable future use, which is an essential parameter to measure acceptability. In their study on the acceptability of Level 3 vehicles, Pettersson and Karlsson (2015) proposed an original method based on drawings and collages as well as enactment from a vehicle drawn on the ground and equipment made available to participants. We encourage this type of innovative methodology for future studies investigating the link between preferences and acceptability of AVs. Generally speaking, acceptability's studies are more focused on how to change individual perceptions than on adapting vehicle parameters to the expectations.

Perceptions are studied extensively in the literature. The most frequently studied psychological determinants are trust, benefits of AVs, concerns about AVs, and perceived safety/risks. In comparison, other psychological determinants of the acceptability of AVs have been less frequently studied: level of knowledge, loss of control, attitudes, subjective norms and perceived ease of use and usefulness. Among these 10 psychological determinants related to participants' perception of AVs, 7 can be considered as predictors of acceptability and/or behavioural intention. First, subjective norms and trust are related to both acceptability and behavioural intention. Second, the level of knowledge is primarily related to acceptability. Third, perceived ease of use and usefulness, attitudes and loss of control are mostly related to behavioural intention. Loss of control is negatively related to behavioural intention while the other determinants are positively related to this variable or to acceptability (Figure 4). It should be noted that, although these variables seem to reliably predict the acceptability of the AV, there are some methodological biases in their operationalization. This is particularly the case for level of knowledge and trust, which are very largely assessed by means of self-reported measures. To increase the reliability of the results, we encourage researchers to measure these variables more objectively. The level of knowledge can be assessed by means of a knowledge questionnaire or by means of an open-ended question, the results of which give rise to a content analysis. For trust, the use of behavioural or physiological measures would allow a more objective evaluation. For the 3 other psychological determinants studied in this contribution, the results do not allow us to rule on their relationship with the acceptability of AVs. The perception of safety is a variable that has been extensively studied in the literature but whose effect on acceptability lacks robustness. Thus, a meta-analysis would make it possible to rule on the strength and meaning of this effect. Finally, the concerns and benefits perceived are

numerous but rarely directly related to acceptability, behavioural intention, or their determinants. In order to better identify the influence of these variables on acceptability, we encourage future research to study the impact of the benefits and/or concerns on acceptability of the AV. The opposite criticism can be made with respect to utility: this variable is very often related to acceptability and/or behavioural intention, but few studies have directly questioned the utility criteria of an AV for the population. Such studies would support the knowledge of the representation of the AV and would inform designers on the criteria to be considered in the development of AVs and the communication carried out around these vehicles.

Concerning the relationship between these 10 variables and the mode of contact with the AV, we observed four types of results. Firstly, for perceived ease of use, usefulness and subjective norms, the mode of contact with the AV did not influence the participants' perception: the results obtained were identical for all the participants, whatever their mode of contact with the AV. Secondly, trust and perceived safety were influenced by the mode of contact with the AV. The perceptions of individuals who had direct experience with the AV or via a simulator were thus different from those who had access only to a definition of AVs or no information at all. Thirdly, the relationship between acceptability or behavioural intention and the level of knowledge or loss of control was moderated by the mode of contact with AVs. Finally, too few studies in one of the modes of contact did not allow us to conclude on the effect of this variable; this was the case for attitudes toward AVs and sociodemographic variables. All these results therefore led us to encourage studies favouring direct experience with the AV to study its acceptability. To conclude, we assume that in direct experience the perceived level of knowledge would be higher. Therefore, this variable could be a mediator of the link between acceptability and its determinants.

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Figure 4. Main determinants of behavioural intention and acceptability of AVs (the solid line corresponds to a positive relationship between the two variables, the dashed line to a negative relationship.).

Figure 4. Principaux déterminants de l'intention comportementale et de l'acceptabilité des VAs (le trait plein correspond à une relation positive entre les deux variables, le trait en pointillés à une relation négative).

Finally, this review of studies on acceptability of AVs highlights some recurring results but also important methodological shortcomings. We can say that the way certain studies have been carried out leads us to question the scope of the results obtained. What was done to understand what image(s) of automation the participant had in mind when answering? How were topics and questions presented? How were participants sampled? (Tennant et al., 2019). Firstly, in view of the lack of clarity on the level of automation, even on the type of vehicle, we are not convinced that respondents can make a valid assessment. Similarly, when several levels of automation are evaluated, are the differences between them clear to the participant? Moreover, as mentioned above, the variables explaining acceptability are specific to the level of automation (Schoettle & Sivak, 2014). Therefore, the assessment of several different levels should be done with different measurement tools. Secondly, as the AV has no precise contours for the respondent, the massive use of questionnaires, without checking what the respondent has in mind, is debatable (a criticism also formulated by Panagiotopoulos and Dimitrakopoulos, (2018)). We found only one questionnaire study (Pettigrew & al., 2018b) which first asks an open-ended question on respondents' preconceptions; unfortunately, however, the study does not then exploit the answers obtained. Indeed, it is more than likely that the framework proposed by the questionnaire serves as a reference for the respondent to create a picture of what this

object could be. It should be remembered that a little over 30% of the studies give participants no indication as to what an AV could be. Nees (2018) showed that the terms “autonomous”, “self-driving” and “full automation” do not imply the same level of responsibility of the driver *versus* the vehicle, in people’s minds. Sanbonmatsu et al. (2018), however, reported that consumers had only very approximate knowledge of what a fully AV (“*completely autonomous and not requiring a human driver*”) really is. Only 32.50% of participants knew that the vehicles may not have a steering wheel and 44.70% believed that human control will be necessary. Qualitative studies are too rarely used, although they are particularly effective in exploring relatively new or unknown phenomena such as AVs (Nordhoff et al., 2019). In fact, interview studies propose initial questions relating to the respondent’s preconceptions about AVs (Bennett et al., 2019b; Cho & Jung, 2019). Some studies indeed explain their results by a lack of understanding of what an AV is (Bazilinsky & de Winter, 2015) or a “yea-saying” effect without critically reflecting on the meaning of each question (Nordhoff et al., 2018b). The results of the studies are also subject to debate because of the samples selected. These samples rarely reflect the entire population that might use AVs. For instance, there is little or no research on people who do not have a driver’s licence, people with physical or mental disabilities, or children and adolescents. Concerning the elderly, they are often interviewed in the questionnaire studies, but much more rarely integrated into studies involving direct contact with the AV. More methodological research is needed to confirm and expand upon these findings. Moreover, we agree with Piao et al. (2016) that the experiments used are insufficient to convince the public what vehicles can do in real conditions. It should be pointed out that they are often quite remote from a real situation (Salonen, 2018). For shuttles, the speed is very low (between 8 and 20km/h), the trip is short, and an operator is present. The duration of the experiment is also short (maximum 6 months). For cars, the experimentation is carried out in a real AV (Sener & Zmud, 2019; Penmetsa et al., 2019) or in conditions close to reality (Habibovic et al., 2018; Mühl et al., 2019) when in “laboratory” conditions (Oliveira et al., 2019), but studies are scarce.

V. CONCLUSION

To conclude, we would like to propose a few perspectives for future research: first, by identifying subjects that have been insufficiently studied, then by proposing some methodological recommendations in response to the limitations of existing studies, and finally by discussing the usefulness of the current craze for the acceptability of a device without real representation by suggesting some theoretical avenues to explore.

Among the topics to be studied, the automated car has been extensively studied –more than 70% of the papers that make up this literature review deal with cars– but this is not the case for other driverless modes of transport such as buses, shuttles, subways or trains. More surprisingly, no article has examined the acceptability of the driverless train even though it is being designed in several countries. Finally, many results are supported by only one study. These results cannot therefore be considered statistically robust and require replication with additional studies. Similarly, for the many effects where contradictory results are reported, replication associated with the use of meta-analyses will enable the true effects to be identified (Maxwell et al., 2015). To our knowledge, only one recent meta-analysis exists on the acceptability of AVs (Nishihori et al., 2018). Moreover, consideration of the ethical aspect in the deployment of AVs seems to us essential. The few studies that address this issue do so from the perspective of moral dilemmas (Bergmann et al., 2018; Bigman & Gray, 2018; Bonnefon et al., 2016) without linking it with acceptability. More innovatively, Karnouskos (2020) deals with the characteristics of an AV and the role of ethics in AV acceptability. Five different ethical frameworks that could be used in the car’s decision-making process in an unavoidable accident context are considered (utilitarianism, deontology, relativism, absolutism, pluralism). Although

these frameworks do not agree with each other, respondents appear to agree with all of them. More research must be carry out to understand whether the apparent conflicts are related to paradoxes present in the same person or inter-individual differences in preferred ethical frameworks.

From a methodological point of view, we strongly recommend identifying the mental representation of the participant before questioning the acceptability of any AV. This identification could be made more accurate and complete by the use of interviews. In fact, we find it inappropriate in general to use questionnaires to study a technology that is out of touch with the current reality of the subject. While the questionnaire is a very good tool for collecting a large number of comparable answers, it should nonetheless be used with caution: great care should be taken in how the questions are formulated and their possible influence on the image of the object being evaluated in the respondent's mind. An open-ended question should systematically seek to find out, first and foremost, what an AV is for the respondent. Whichever method is used, this vehicle must systematically be positioned in the reality of its potential user. Which kind of AV (level of automation and mode)? What will it be used for? Who will own it? How will it be used? etc. Experimentation can be misleading and may suggest that the participant can easily evaluate the technological object. However, in many cases there is such a large gap between the experimental conditions and the likely future reality of use that we may wonder whether it would not be better to give a precise and neutral written or video description (given in the published paper). We also suggest favouring creative methods in which the participant is concretely involved such as scenario-based methodologies (Pettersson & Karlsson, 2015) or other methods used in design. They can be used to identify the relevant factors to be tested in a second step by more classical interrogative methods. Lastly, the sample should be representative of the general population in terms of age, gender, and socio-professional category.

From a theoretical point of view, we doubt the relevance of the intense interest in the acceptability of AV, as it is currently mostly conceptualized. Indeed, in Davis's initial work (1989) in particular, the technology to be accepted was already present as a reality in the daily lives of the people surveyed. In addition, the usefulness of such approaches consists first of all in changing perceptions in order to promote acceptance of the device. We are still a long way from there. From this point of view, studies that seek to promote acceptability by taking into account the needs of users in order to modify the technology seem to us to be more appropriate at present. This is the case, for example, for some studies that highlight the preferences of individuals. They appear to be more in line with individuals' current state of knowledge about the AV even if they do so using rather inappropriate methods. With simulations (even in a rather rudimentary form), it would be possible to address practical acceptability as well as situated acceptability issues in a simulated situation.

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SUMMARY

Without public support, the deployment of Automated Vehicles (AVs) is doomed to failure. Therefore, their acceptability has been widely studied. On the basis of a systematic literature review of 113 empirical studies, the present paper studies the influence of the modes of contact with the AV (no explanation provided, written or pictorial description only, simulator, real experience) on sociodemographic variables, acceptability, behavioural intention and their determinants. The analysis of the dependent variables shows a lack of clarification of what is actually measured and a heterogeneity of measurements that makes comparisons difficult. The determinants were separated in two groups: preferences, which refer to projections in use, and perceptions, which refer to beliefs. The determinants in the preferences group, and some determinants in the perceptions group (perceived ease of use and usefulness and attitudes), are not influenced by the mode of contact with the AV. Indeed, a more concrete mode of contact does not change the participants' responses for these variables. For the other determinants of the perceptions group, the mode of contact with AVs impacts participants' responses. Trust and perceived safety are influenced by the mode of contact. More significantly, we observed that the relationship between acceptability and the level of knowledge or control was moderated by the mode of contact with AVs. These results lead us to encourage research favouring direct experience with the AV to study its acceptability. A discussion of these recurring results but also the significant methodological and theoretical shortcomings highlighted by the review is presented such as the research gaps in terms of sampling or statistical robustness. In conclusion, a few methodological approaches are proposed for the study of technological devices that are little or not known to future users, as well as a reflection on the usefulness of studying the acceptability of these little-known devices.

KEYWORDS: automated/autonomous vehicles, acceptance, acceptability, intention to use, mode of contact, full automation.