Could spending time in an AV be similar to travelling on a train? Lessons from the literature

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Keywords: Autonomous vehicle, activities, time use, multitasking

J.E.L. Classification: R41; O330

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Abstract

In a fully Autonomous Vehicle (AV), what activities could be performed when travelling to replace driving activity? The ideal would be to do activities similar to those done in a train or at home. This paper reviews the existing literature to compare the activities expected in an AV with findings obtained for trains and cars. It focuses on a selection of 36 papers mainly on transport economics published between 2000 and 2021. The findings show that train users are more multitask than others. They do several activities of which reading and sleeping are the most popular. Car travellers perform fewer activities other than driving except for making phone calls and listening to music. For AVs, the first studies show that future users would be more in the position of a car driver than a train passenger, thereby reducing the benefit of AVs. Finally, the analysis reveals heterogeneity in the definition of activities and imperfect consistency with the characteristics of AVs. We suggest considering physical involvement (hands and eyes), whether deliberate or not, to define an activity. Sleeping becomes an active activity and talking a passive activity.

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1. Introduction

Who has never dreamed of sleeping in one's car while driving during a long trip? This could become a reality in a few decades thanks to the development of automatic driving systems. Travelling by car would becoming productive time for work or doing a large spectrum of other activities like relaxing, watching video, gaming, etc. Between myth and reality (Rashidi *et al.*, 2020), autonomous vehicles (AVs) raise a basic question about the effect of driverless systems: what could be performed during travel to replace the driving activity?

An extensive academic literature exists on the activities performed during travel (Keseru & Macharis, 2017; Harb *et al.*, 2021). Initiated by Moktharian and Salomon (2001), the assumption is that the negative utility traditionally associated with a journey (Welch and Williams, 1997) could be less considerable than expected. This results from the activities that can be performed during a trip called secondary tasks as opposed to the primary task concerning the travel itself (Lyons & Urry, 2005). Consequently, the Value of Time (VoT) could be reduced to the benefit of AV and increase its attractiveness (Singleton, 2019). The debate is lively, especially among transport economists, about assessing the true potential of the AV and its acceptance (Bansal and Kockelman, 2018; De Almeida Correia *et al.*, 2019; Kolarova *et al.*, 2019; Rashidi *et al.*, 2020). The type of secondary tasks that could be performed during a trip is a key point. Lyons and Urry (2005) showed a wide spectrum of activities and differences between their practises according to the type of mode, the socioeconomic characteristics of users, and travel conditions. From the general standpoint, the train is reputed as a multitasking mode (Keseru and Macharis, 2017) in which different activities can be performed during a trip, contrary to the car in which it is difficult for the driver to perform activities other than driving (Laurier, 2004).

To fuel this debate, the paper gives empirical insights from the transport economics literature published between 2000 and 2021 on the question of performing secondary tasks when travelling by train, car and AV in the future. The method is based on the recommendations from Van Wee and Banister (2016) on building a literature review. The main contributions have been identified by keywords like "multitasking" and "travel time use" and the snowball method from the most recent literature reviews on a similar topic (Keseru & Macharis, 2017; Harb *et al.*, 2021). In total, 36 papers have been identified for their description of secondary tasks. Most of them concerned the train mode; the literature is less extensive for cars and AVs and no one has proposed a synthesis of the different results in the literature. This paper proposes to fill this gap.

The findings confirmed that train users are more multitask than those using the other modes. Passengers can perform several activities according to trip duration and pattern, like reading or sleeping for the most popular among them. Car travellers perform fewer activities other than driving, except for making telephone calls and listening to music. The first studies on AV travellers showed that future users would be more in the position of a car driver than a train passenger, thereby reducing the benefit of the AV. Finally, the analysis revealed heterogeneity in the definitions of the activities. We propose an adapted definition according to the features of the AV and find a real difficulty for users to perceive AVs and have a clear idea of what they could do inside one when traveling.

The paper is structured in five sections. The method used to carry out the literature review and its overview are described in Section 2. The analysis of the activities is given in

Section 3 while the categorization of the activities is discussed in Section 4 before the conclusion in Section 5.

2. Overview of the literature for activities

This section gives the method used to draw up the literature review, then the overview of the selected papers.

2.1 The literature collection

The method used to collect the main contribution to the literature is based on the guideline from Van Wee and Banister (2016). In the first step, we used Google scholar to perform searches by keyword. The keywords were identified according to the list proposed by Keseru and Macharis (2017). There are several such as "travel time and multitasking", "travel behaviour and multitasking", "travel time use" and "in-vehicle behaviour". The area of application was not restricted to the AV only but extended to all transport modes, urban and non-urban. Table 1 shows a large number of references with several duplicates from one search result to another.

Table 1: keywords and number of collected papers until 2021

Database	"Travel time" AND "multitasking"	"Travel behaviour" AND "multitasking"	"Travel time use"	"In-vehicle behaviour"
Google scholar	206	67	62	15

Source: Authors

The second step was to consolidate the literature review by identifying major contributions. We chose to select the literature review papers and apply the snowball method through their references. The two contributions selected were Keseru and Macharis (2017) and Harb *et al.* (2021). Keseru and Macharis (2017) proposed a large literature review on the determinants of multitasking behaviours. They focused on trains and found 55 papers on the topic. Harb *et al.* (2021) carried out a literature review on knowledge about AVs based on several questions such as the willingness to pay for automation, the results on in-vehicle behaviour, the change in value of time, the choice of residential location, etc. In total, they found 116 papers of which 8 papers focused on in-vehicle activities.

In total, 79 papers were identified, mainly from scientific journals specialized in transport economics (Transportation, Transportation Research Part A – C, Transport Reviews, Transport Policy, etc.) but also in other fields such as psychology (Transportation Research Part F), ergonomics (Ergonomics) and geography (Journal of Transport Geography, Journal of Economic and Human geography).

2.2 – Overview of paper collection

The literature was selected according to two criteria for a final total of 36 papers. Firstly, the paper had to present or describe factual activities performed in vehicles during a trip (sleeping, watching movies, window watching, etc.). Secondly, the paper had to concern at least one transport mode selected for the analysis such as train, car driver/passenger or AV. The other modes were excluded (bus, subway, etc.). Table 2 gives an overview of the final panel. It is organised by year, authors, data collection method, panel size, country, representativeness of the panel and mode of transport studied to give a detailed overview of the papers.

Table 2: overview of the selected papers

Year	Authors	Data collection	Country	Panel	Representative	Train	Car-Driver	Car-Passenger	AV
2001	Mokhtarian & Salomon	Survey	US	1900		x	x		
2004	Laurier	Observation	UK	1			x		
2005	Lyons & Urry	Literatur				x	x		
2007	Ettema & Vershuren	Survey	NL	226				x	
2007	Lyons *et al.*	Survey	UK	26 000	Yes	x			
2008	Laurier *et al.*	Observation	UK	24			x	x	
2008	Timmermans	Observation	US	161		x			
2009	Ohmori & Harata	Survey	Japan	503		x			
2009	Ferguson	Observation	UK				x		
2009	Hislop & Axtell	Interviews	UK	18			x		
2010	Ettema et al.	Survey							
2010	Zhang & Timmermans	Survey	Japan	523					
2010	White *et al.*	Survey	Australia	796	Yes		x		
2011	Russell *et al.*	Observation	NZ	812		x			
2011	Kamp *et al.*	Observation	DE	734		x			
2012	Ettema *et al.*	Survey	SE	996		x			
2012	Gripsrud & Hjorthol	Survey	Norway	1196	Yes	x			
2012	Circella *et al.*	Theoretical							
2013	Lyons *et al.*	Survey	UK	20 000	Yes	x			
2013	Rhee *et al.*	Survey	South Korea	400			x	x	
2013	Hislop	Survey	UK	149			x		
2014	Groenesteijn *et al.*	Observation	Europe	786		x			
2014	Cyganski *et al.*	Survey	DE	1000	Yes	x	x		x
2014	Schoettle & Sivak	Survey	US	3255					x
2015	Kyriakidis *et al.*	Survey	World	5000					x
2015	Guo *et al.*	survey	Canada	1937					
2016	Pfleging *et al.*	Survey	DE	300		x	x	x	x
2016	Hagen *et al.*	Literatur	NL			x			
2016	Bansal & Kockelman	Survey	US	1088	Yes				x
2017	Keseru & Macharis	Literatur							
2018	Tang *et al.*	Survey	China	901		x			
2018	Singleton	Survey	US	650		x	x	x	
2018	Pudane *et al.*	Theoretical							x
2019	Malokin *et al.*	Survey	US	2229	Yes	x	x		
2020	Varghese *et al.*	Survey	Japan	500	Yes	x			
2021	Wadud & Huda	Survey	Bangladesh	621				x	x

Source: Authors

The review highlighted a large literature on the topic. Moktharian and Salomon (2001) were the first to assume that travel can have a positive utility as opposed to the traditional

approach that considers that travel is a derived demand and a waste of time (Welch, M., Williams, H., 1997). They proposed to distinguish three elements in a journey: (1) The activities carried out at the destination; (2) Activities that can be carried out while travelling; (3) The activity of travelling itself. Using this classification, they opened a new path to better understand time-use during travel and improve the assessment of the Value of Time. They were also the first to highlight the importance of the secondary task during traveling. Using a survey, they found that nearly 50% of respondents disagreed that travel is generally wasted time and more than 30% saw their trip as a useful transition and used their time productively. Of course, the use of time and activities differ from one mode to another. Several authors investigated the question of activities and perception of travel time use for car drivers, train passengers, and more recently AV. The largest part of the literature analysed activities in trains with a major contribution from Lyons *et al.* in 2007. Based on the national survey for British rail users, they added questions about the activities performed in trains during travel to test on a large scale the assumption that travel time can be productive with positive utility. They listed 6 activities on the basis of previous work (Lyons & Urry, 2005) like reading, window gazing, sleeping, etc. They found that the two main activities were window gazing and reading, with a difference for business travellers for whom working is the main activity. They concluded that commuters are more likely to consider their time use wasted than persons travelling for specific business purposes or leisure. Nevertheless, the type of activities and the feeling of wasted time depend strongly on key factors such as trip duration, distance, travel direction (in/out), the class of travel and other socio-demographic characteristics. These factors and others like crowding in public transport, congestion on the road, comfort and the development of electronic devices have been extensively tested in the rest of the literature to assess their effect on the likelihood of performing another activity during a trip.

The second observation concerns the method used for data collection. Most data come from surveys and observations carried out in a large number of countries. There are several limits and biases in these methods. First of all, most of them are not representative because of limited panels. Admittedly, it is very hard to be representative for the observations. Also, many surveys were too small or imperfect in their spread to be representative. Secondly, the studies had a potentially strong cultural bias (Sivak & Schoettle, 2014). The countries were very diverse and it is questionable whether the results obtained can be fully transferable from one country to another (Schoettle & Sivak, 2014; Sivak & Schoettle, 2016). Sivak & Schoettle (2014) conducted a similar survey on AVs in six different countries (US, UK, Australia, China, India and Japan). Their panels were not representative but highlighted a strong cultural effect from one country to another. More concretely, Ohmori and Harata (2009) observed that fewer people called during train trips in Japan in comparison to the study conducted by Lyons *et al.* (2007) in Great Britain. The difference of culture was the main factor explaining the difference, according to them. Finally, as French researchers we observed that no study on the topic has yet been carried out in France.

The last observation concerns the mode of transportation considered. Rail transport has been studied most because of the possibility of easy multitasking; in addition, this mode facilitates carrying out observations and surveys. There are fewer contributions on car travel. Studies on AV started more recently in the 2010s with the development of the concept. The main limit of these studies is currently the difficulty of testing under real conditions (Harb *et al.*, 2021; Laroche & Souche-Le Corvec, 2021). The results are currently based only on projections and can be biased by several factors such as habits in terms of transport mode, the

relationship with new technologies and sociodemographic characteristics. Finally, table 2 shows a limited number of multimodal studies. Only 6 in the total consider more than one mode and only 2 compare rail with AV. Also, no study proposed a global synthesis of the results already obtained by the literature about the question of carrying out secondary tasks while travelling.

The aim of this paper is to fill these gaps regarding two aspects. It proposes a global synthesis of the main results obtained by the literature from the 2000s and compares AV to the studies produced for rail and cars.

3. Analysis of activities

This purpose of this section is to identify the main activities performed in the different modes of transport: train, car and AV. Subsection 3.1 gives the list of the activities identified by the literature. Subsection 3.2 proposes a ranking of the main activities mode by mode.

3.1 Identification of activities

Table 3 provides an overview of the different activities identified by the literature. The first columns give the year of publication, the authors and the mode of transportation. The fourth column indicates the method used to identify the activities. There are usually two methods. The most common is to give a predefined panel of activities to the users. The observation is the other one and practised less because of constraints in terms of organisation and cost. The last column summarizes the activities selected in each paper.

Table 3: List of activities per paper

Year	Author	Mode	Identification Act	Activities
2001	Mokhtarian & Salomon	ALL	Given	Mobile phone calls; reading; listening to music; watching video
2004	Laurier	CAR	Observed	Driving; calling; Paperwork
2005	Lyons & Urry	TRAIN	Given	Sleeping/snoozing; reading for leisure; working (reading, writing, thinking); talking to other passengers; window gazing; playing games; text messages/phone call-work; listening to music; text messages/phone call-personal; eating/drinking; entertaining children
2007	Ettema & Vershuren	CAR	Given	Listening to music; window gazing; Making phone calls; talking to cotravelers; reading for leisure; reading for work; sleeping; using a laptop
2007	Lyons et al.	TRAIN	Given	Window gazing/people watching; reading for leisure; working/studying; talking to other passengers; sleeping/snoozing; listening to music
2008	Timmermans	TRAIN	Given	Nothing; talking socially; sleeping; read newspaper; Phone-don't know; text messaging; read book; listening to music; personal care; work computer; computer game; romancing; game special; phone-socially; read material
2009	Ohmori & Harata	TRAIN	Given	Sleeping; reading newspaper; doing nothing; reading magazines; e-mailing by mobile phone; reading books; web-browsing by mobile phone; eating; drinking; listening to music; listening to radio; reading documents, using PDA
2009	Ferguson	CAR	Observed	Mobile office; phone call; paperwork
2009	Hislop & Axtell	CAR	Observed	Driving; phone call, mobile office
2010	White et al.	CAR	Observed	Answering call; making call; reading text message: sending text message
2011	Russell et al.	TRAIN	Given	Looking ahead/out window; reading; headphones in; talking; sleeping/eyes closed; texting; handling wallet; using computer; other eating/drinking; writing; on phone
2011	Kamp et al	TRAIN	Observed	Talking/discussing; relaxing; reading; sleeping; watching; using small electronic device; working-using larger electronic device; eating/drinking
2012	Ettema et al.	TRAIN	Given	Entertainment; relax; ICTs; study/work; talk
2012	Gripsrud & Hjorthol	TRAIN	Given	Window gazing/people watching; work/studying; sent SMS/Called by mobile phone (private purpose); sleeping/snoozing; reading for leisure; thinking about/planning personal matters; listening to music/radio; sent SMS/called by mobile phone (worh); talked with other passengers; use mobile phone in other ways (private); use mobile phone in other ways (work); other activities; playing games (electronic); kitting/needlework; took care of the children
2013	Lyons et al.	TRAIN	Given	Reading for leisure; window gazing/people watching; text messages/phone calls (personal); working/studying; listening to music/radio/podcast; checking emails; eating/drinking: text messages/phone calls-work; talked with other passengers; sleeping/snoozing; being bored; internet browsing
2013	Hislop	CAR	Observed	Use of mobilephone; conflict between phone and driving; thinking
2014	Groenesteijn et al.	TRAIN	Observed	Reading from paper; staring or sleeping; working on laptop; talking: using PDA; listening to music; eating/drinking; other; writing; making phone call
2014	Cyganski et al.	CAR	Given	I concentrate on the trip and my route; listening to music (reading, video, surfing on the web); talk to companions or other passengers; enjoy the trip and landscape; relax; social networking (social media, sms, mail or phone); working
2014	Schoettle & Sivak	AV	Given	Watch the road; would not ride in an AV; read; text or talk; sleep; watch movies; work; play games; other
2015	Kyriakidis et al.	AV	Given	Music/radio; eating/drinking; interaction with other passenger; window gazing; mobile phone-call/messaging; email check/internet surfing; watch movie/play games; reading; rest/sleep; doing nothing; prefer not to respond
2016	Pfleging et al.	ALL	Given	Watch ou of the window; texting; music, radio; talk to passengers, internet, social media, reading, eating, drinking; e-mail; sleeping; calling; office tasks; watch movies; interact with passengers; video games; language learning;
2016	Hagen et al.	TRAIN	Given	Looking outside; reading; talking; surfing the internet; social media; listening to music; relaxing; daydreaming; eating/drinking; working/studying; gaming; sleeping; looking up travel info; phoning; making puzzles
2016	Bansal & Kockelman	AV	Given	Interaction with other passengers; window gazing; eating/drinking; mobile phone-calls messaging; email check/internet surfing; watch movies/play games; reading: rest/sleep; maintenance activity, work, exercise
2018	Tang et al.	TRAIN	Given	work related communication via e-device; listening to music; non work related communication via e-device; sleeping/window watching; reading/searching information for leisure via e-device; reading work related documents via e-device; watching video; eating/drinking; playing video games; talking to passengers; reading work related paper document; browsing travel information; reading paper books/magazines for leisure; checking work related emails; shopping online; editing work related electronics; editing work related paper documents
2018	Singleton	CAR	Given	Listening to music; passive activities (window, daydreaming); eating/drinking; planning this trip; talking on the phone; talking with people you know; doing nothing; ICTs (texting, reading, social network); singing/dancing; personal grooming (makeup); talking with strangers; exercising; playing game; reading print; sleeping/snoozing
2019	Malokin et al.	CAR	Given	Audio; thinking/planning; eating/drinking; watching scenery; daydreaming; talking on phone; smartphone; messaging; navigating; internet; talking to friends; grooming; reading electronically; reading from paper; laptop/tablet; talking to strangers; watching video; gaming electronically; writing on paper; writing electronically; sleeping/resting; gaming non electronically; exercising
2020	Varghese et al.	TRAIN	Given	Non ICT passive; window gazing; ICT private; Non ICT private; ICT leisure; Non ICT work; ICT work
2021	Wadud & Huda	CAR	Given	Thinking/planning; talking to other passengers; online social media; window gazing; listening to music/radio; phone calls/messaging; emailing/browsing internet; sleeping; working/studying; eating/drinking: reading for leisure; watching video/playing games

Source: Authors

In general, there is a wide range of different activities with an average of 10 activities per study. There are more activities on average for trips by train (11.7) than by car (8.3) or AV (10.3). The difference can be explained by the assumption in the literature that train users are

more multitasking than others and may therefore do more activities. However, that does not mean train users actually do more activities.

First of all, the activities practised appear to be very diverse. However, most of the literature is based on the original list of activities proposed by Mokhtarian and Salomon (2001), then improved by Lyons and Urry (2005) in their literature review. This base was later diversified according to the need of the studies to take into account the effect of digital technology on activities and the place of work in the activities. Keseru *et al.* (2017) showed that in spite of a large number of activities, there are finally few categories of activities in the literature with several possible definitions according to the needs of the study. For example, relaxing can include activities like gazing, sleeping, doing nothing, etc. Also, reading can encompass different activities like reading books, magazines on paper or electronically. In total, they identified 10 categories and around 20 individual activities. There are more than 60 different activities in table 3. It shows a desire from the authors to go further into detail regarding their research question. Two aspects drove the diversification: work or pleasure activities and the presence or not of electronic activities. Consequently, we find considerable heterogeneity for reading activities: reading for work, reading for pleasure, reading on an electronic device, reading on paper, etc. likewise for the use of electronic e-devices: for work, play, calling (private, work), sending text messages, etc.

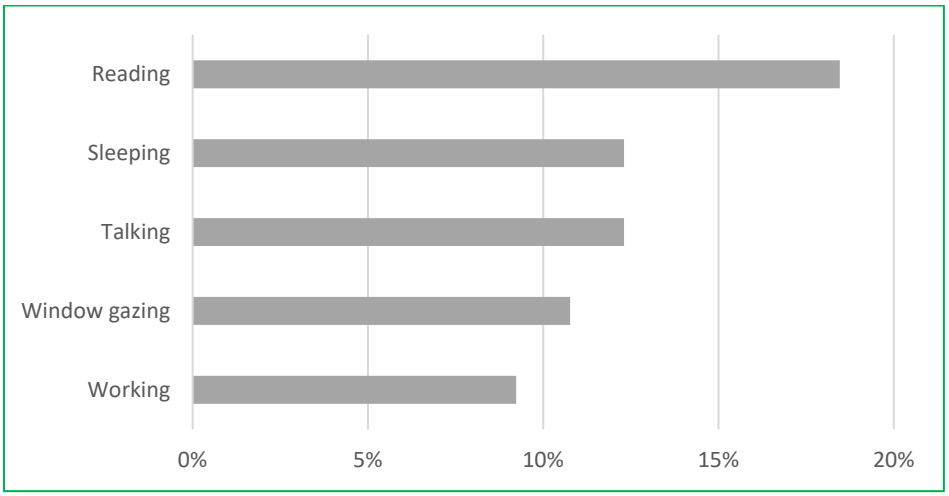
To summarize, the ten most frequent activities among the 60 identified in table 3 are as follows: listening to music, talking, reading, eating/drinking, calling, working/studying, sleeping, window gazing, playing games, text messaging. Unsurprisingly, these activities are similar to those of the initial list proposed by Lyons and Urry (2005) with a strong limit concerning the AV. In their list, the authors considered the activities of texting a message and making a call together as mobile phone use. In the context of AVs, the relevance of the association of these two activities can be questioned as making a call is different in terms of concentration from sending a text message. Other samples can be found in the literature such as the association of sleeping with relaxing or doing nothing. The need to update the definition of activities in the context of AV analysis is discussed in section 4.

3.2 Top five activities per mode

This subsection gives an overview of the main activities performed during travelling by train, car and AV. It is limited to the top 5 and the calculation is based on the aggregation of the results obtained by the different studies.

Figure 1 is based on 13 studies and concerns rail travel for all passengers. It shows that the main activity performed by train users is reading followed by sleeping, talking to other travellers, window gazing and working. It is interesting to observe that all the activities are well represented, assuming that train users are multitasking. Also, it shows that few train users are productive, as they take time to relax, talk, and window gaze. The productive tasks arrive in last position. In detail, work and studying strongly depend on the pattern of the trip. For business, it is often in first or second position but most of the time in fifth position or lower for commuters and other passengers. According to Mokhtarian and Salomon (2001), travel time seems to be a privileged time for itself.

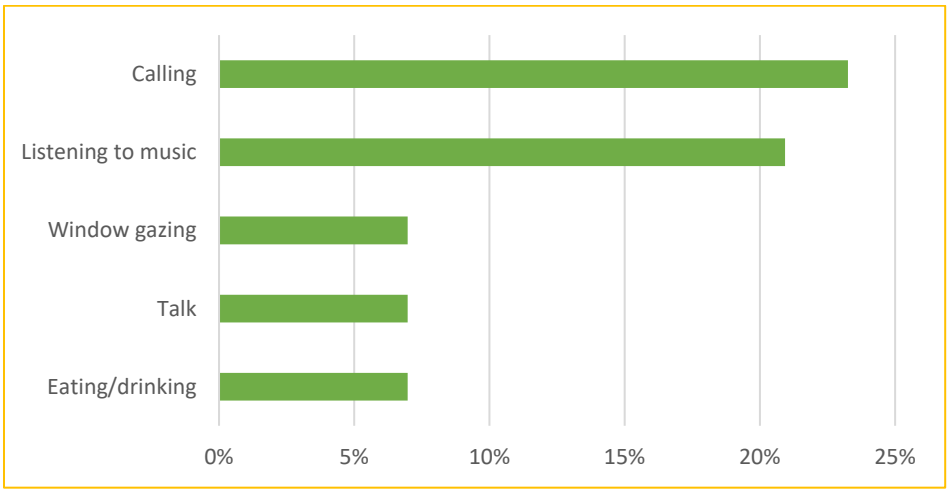
Figure 1: Top 5 of activities during train travel (all passengers).



Source: Authors

Figure 2 shows the results for car users (driver). Based on 12 studies, it is clear that, except for driving, there are two main activities: making phone calls and listening to music. The others are marginal. Contrary to train users, car drivers cannot multitask and doing so quickly becomes illegal when other activities are performed such as reading/sending messages, etc.

Figure 2: Top 5 of activities during car travel (driver).

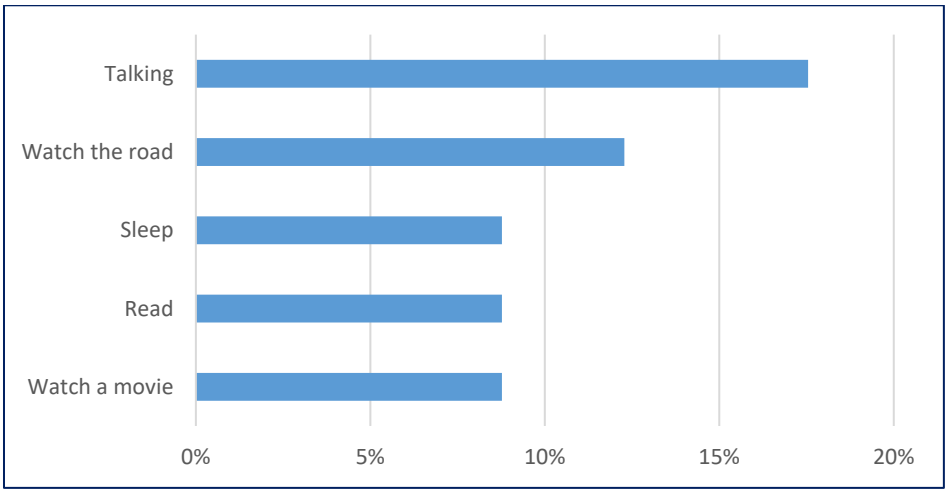


Source: Authors

Finally, figure 3 shows the results for AVs. We use the term projection because the results come from a survey and not from observations or real-life experience because of the absence of access to AVs. First of all, only 6 studies described activities. Secondly, they are projections and not real observations or results from experiments. Thirdly, it seems to be positioned between rail and car modes with two main activities (talking, watching the road) and others. Also, it is interesting to note that the second activity for the AV, in which we could expect to become free of the driving task, remains that of watching the road due to a lack of trust in the system, and the difficulty of considering a car like a train in spite of automation. Finally, the literature could expect AVs to provide an opportunity to become more productive

(Harb *et* al, 2021). The first projections suggest that this would not be the case as future users do not place work in the top five activities.

Figure 3: Top 5 of activities during AV travel.

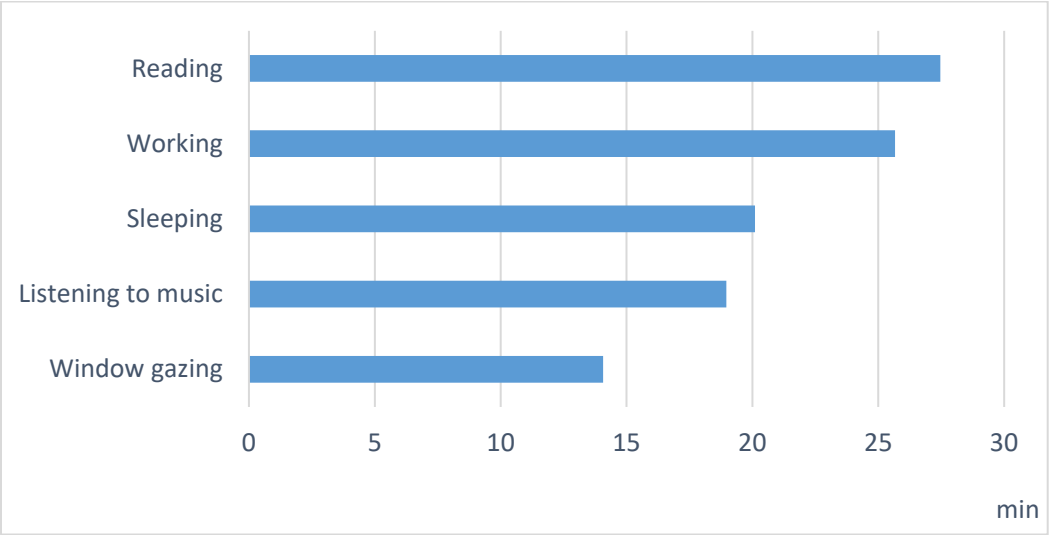


Source: Authors

3.3 Dynamic approach by duration

To complete the overview, figure 4 considers the ranking of main activities according to their duration, declared and observed. It is difficult to consolidate the results because of the small number of studies (only 6) on the question and the considerable heterogeneity observed for the measures of activity duration. Consequently, the results are only for train travellers and give an indication of the time allocated to each activity. Reading appears be the longest activity followed by working. Train users take less time to sleep, listening to music or window gazing. Lyons *et al.* (2013) showed that the activities needing little concentration like listening to music or window gazing are more common on shorter trips than activities like reading or working which require a higher level of concentration. They are longer and preferred for longer trips. The duration of the trip could have a strong effect on the type of activities performed during travelling and its duration.

Figure 4: Top 5 duration (minutes) of main activities during train travel.



Source: Authors

4. Discussion

In this last section we discuss the relevance of the activities and categories proposed by the literature in the context of AV. Subsection 4.1 highlights the limit of the definition of activities in the literature. Subsection 4.2 proposes a new approach based on physical involvement in an activity. Then subsection 4.3 tests the proposed approach on the main results from the literature to highlight new paths for future research.

4.1 Updating the definition of activities for AV

Subsection 3.1 showed that the definition of the activity is not always relevant when considering the characteristics of AVs. Two aspects have to be considered to solve this problem: the definition of the activities and the activity itself. In the economic literature, the main orientations taken to define activities concern the level of productivity (Lyons & Urry, 2005), the level of technology (Tang *et al*., 2018; Singleton, 2018; Varghese *et al*., 2020) or the theme (recreational, work, socializing, etc.) as described by Gripsrud and Hjorthol (2012) and Wadud *et al.* (2021). In each study, the definition given to the activities has a direct consequence on the choice of the activities proposed to the users in the survey. For sample, Varghese *et al.* (2020) defined four categories considering the use of technologies or not (Non ICT passive, Non ICT active, Non ICT work, ICT leisure/work/private). They grouped in the first category (non ICT passive) different activities like sleeping, window gazing or doing nothing. It is clear that in the context of the AV, it is difficult to consider sleeping and window gazing in the same category. For the first one, the driver's eyes are closed and lose contact with the environment and the road which is not the case for window gazing. In the same way, Wadud and Huda (2021) considered activities that could be performed in an AV. They allocated the different activities between five categories: technological, recreational, traditional, productive and maintenance. Each of them was illustrated by different activities. The main limit is to consider categories

according to a theme already used in the literature for other modes of transport but not related to the specificities of the AV. This resulted in them proposing phone calling/messaging as an activity. In the first case, the users are passive as they can be fully concentrated on the road and driving if necessary, especially if they use a hands-free system. In the second case, the users lose concentration and has to use their hands and eyes to text the message. In this situation they are active and less able to drive the car if necessary. Both activities can be added together in the context of rail travel but are less relevant in the context of a car or AV trip. Unfortunately, table 4 shows that these mistakes are ordinary in the literature, even for the studies considering activities in an AV. Cyganski *et al*. (2014) considered relaxing and sleeping as the same activity. However, both are very different in terms of concentration. Kyriakidis et al. (2015) mixed text messages and phone calls as did Shivak and Shoettle (2014), Bansal and Kockelman (2016) and Wadud and Huda (2021). The two most common mistakes are to mix phone calls, text messages and sleeping with doing nothing or window gazing. When considering the activities that could be performed in an AV, the main explanation could be that there has been no change in definitions since the definitions and the list of activities proposed by Lyons and Urry (2005).

4.2 For a definition of activities adapted to AV characteristics

This subsection proposes an adapted definition of activities in the context of AV. Circella *et al.* (2012) produced a key paper on activity definition. Based on the train mode, they proposed a new method on the basis of passive or active involvement. According to them, an active activity "involves the deliberate use of one's physical and/or mental faculties" (p. 83). This definition has the advantage of considering the level of physical involvement to define an activity although it may not be totally appropriate for AVs. The association of mental faculties can lead to considering an activity such as planning one's day or talking as an active activity. Consequently, it is necessary to complete the definition for the AV.

The proposal is to consider only physical involvement in an activity. An activity could be considered active when a physical involvement (at least eyes and hands) is necessary, whether deliberate or not. On the contrary, an activity is passive when no physical involvement is needed. Thus, sleeping becomes an active activity whereas talking is a passive activity. Also, making a phone call is a passive activity and must be distinguished from texting a message, which is an active activity. Table 4 shows that only 30% of the literature is compatible with our definition while none of the studies deals with AV.

Table 4: List of the papers compatible with the definition proposed.

Year	Authors	Compatible	Limit
2001	Mokhtarian & Salomon	No concern	
2004	Laurier	-	
2005	Lyons & Urry	No	Phoning/texting
2007	Ettema & Vershuren	No	Phoning/texting
2007	Lyons *et al.*	Yes	
2008	Timmermans	Yes	
2009	Ohmori & Harata	Yes	
2009	Ferguson	-	
2009	Hislop & Axtell	-	
2010	Ettema et al.	-	
2010	Zhang & Timmermans	No	
2010	White *et al.*	-	
2011	Russell *et al.*	Yes	
2011	Kamp *et al.*	Yes	
2012	Ettema *et al.*	Yes	
2012	Gripsrud & Hjorthol	No	Phoning/texting
2012	Circella *et al.*	-	
2013	Lyons *et al.*	No	Phoning/texting
2013	Rhee *et al.*	No	Sleeping and doing nothing
2013	Hislop	-	
2013	Jamson *et al.*	-	
2014	Groenesteijn *et al.*	No	Staring or sleeping
2014	Cyganski *et al.*	No	I use travelling to relax and sleep
2014	Schoettle & Sivak	No	Texting and talking
2015	Kyriakidis *et al.*	No	Phoning/texting
2015	Guo *et al.*	Yes	
2016	Hagen *et al.*	Yes	
2016	Bansal & Kockelman	No	Text, or talk on phone
2016	Pfleging *et al.*	Yes	
2017	Keseru & Macharis	-	
2018	Tang *et al.*	No	Sleeping and window gazing
2018	Singleton	No	Singing, dancing
2018	Pudane *et al.*	-	
2019	Malokin *et al.*	Yes	
2020	Varghese *et al.*	No	Too aggregated
2021	Wadud & Huda	No	Phoning/texting

Source: Authors

4.3 Application

To make the proposal concrete, we propose to interpret the previous results from subsection 3.1 in the light of the new definition of active/passive. Table 5 gives a sample of the activities that can be classified as active or passive. The main change by contrast to the literature is to consider sleeping as an active activity and calling or talking as passive activities. For calling, the assumption is, of course, that the user is using a hands-free system. There are few changes for the other activities.

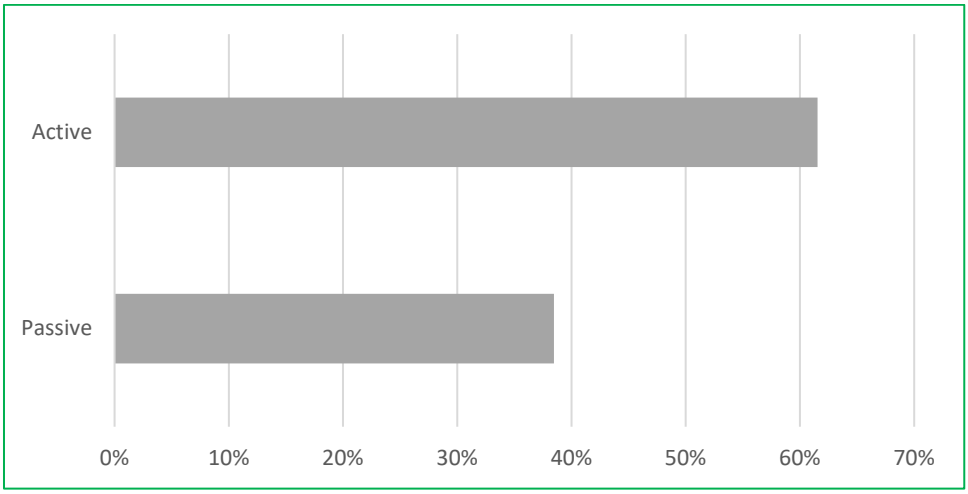
Table 5: Application of the new categorization to the main activities.

Category	Activities
Passive	Listening to music; talking; calling; window gazing
Active	Reading; eating/drinking; working/studying; sleeping; playing games; text message

Source: Authors

Figure 5 illustrates the main activities (top 5) identified in each study in the literature for train users. It shows that the largest share of the activities practised in trains are active.

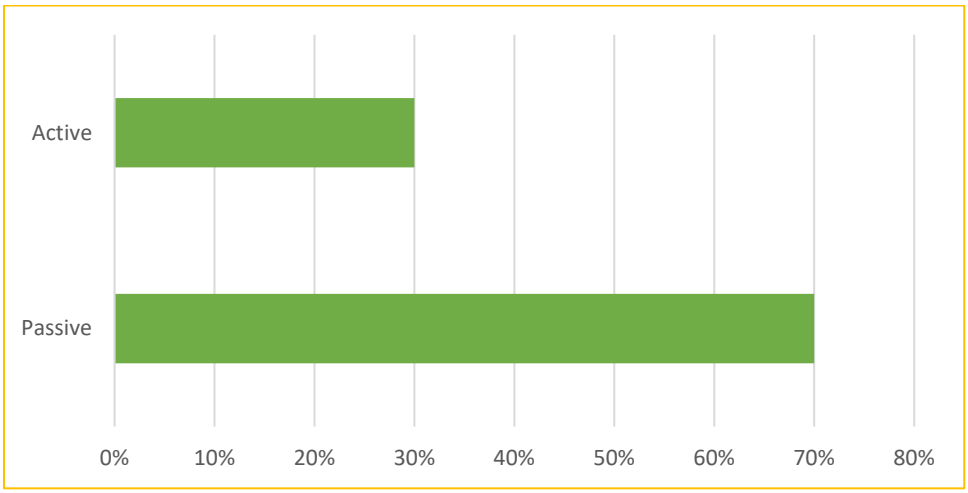
Figure 5: Share of active/passive activities for the train travellers.



Source: Authors

By contrast, figure 6 shows that car drivers are mainly involved in passive activities such as talking, calling or listening to music. Active activities are less important than for rail travel because of the concentration required by the primary activity (driving).

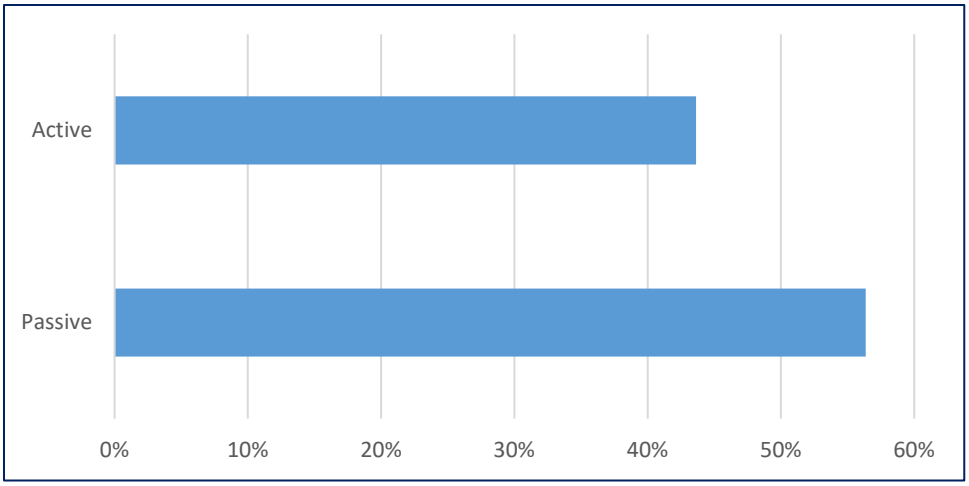
Figure 6: Share of active/passive activities for car drivers.



Source: Authors

Finally, figure 7 gives the results for AV users (projection). It is interesting to observe that passive and active activities are almost at equilibrium with an advantage for the passive ones. Firstly, it shows that users still have difficulties in considering AV like a train service. Secondly, according to the literature, a large share of the users are not ready to trust an automated driving system (Sivak & Shoettle, 2014; Harb *et al.*, 2021). Last but not least, the advantage taken by passive activities suggests that the behaviour of car drivers in AVs will be closer to their current behaviour as car drivers rather than reflect that of train passengers.

Figure 7: Share of active/passive activities for AV users (projection).



Source: Authors

5. Conclusion

The objective of the study was to synthetize the literature about the activities performed during travelling by train, car and AV. The study proposed a wide ranging and original literature review to compare the results and modes with each other. 36 papers published from 2000 to 2021were analysed and compiled in this study.

The main results are as follows. Firstly, the literature on trains was voluminous but narrower for cars and AVs. More studies on AVs should be conducted, especially in situations of real on-road experiments to compensate for the lack of knowledge gained from users. The second finding concerned the type of activities practised during travel according to the different modes of transport. For trains, we saw that users multitask with little production except for business travellers. Most of the travellers practise relaxing or leisure activities. Car drivers multitask less and practise two main activities: calling and listening to music. The projection for AV highlights an intermediate stage between cars and trains, with talking being the main activity followed by watching the road. Finally, the literature analysis showed the need to adapt the definition of activities to the AV context. We proposed an approach based on the physical involvement, deliberate or not, of users in an activity in addition to the definition proposed by Circella *et al.* (2012). It allows solving several recurrent mistakes made in the literature such as the association of the action of making a call with texting a message. They both have different levels of physical involvement involving eyes and hands; also, for sleeping and doing nothing, usually associated by the literature, in the same activity. According to this definition, we found that activities practised during train travel are mainly active whereas they are passive during car trips, as expected. The interesting result is for AVs in which activities could be mainly passive, thereby reducing the benefit in terms of productivity and the interest for the value of time. Users would be more in the position of car drivers than train passengers, also reducing the substitutability of trains by AV.

To conclude, this study is interesting from the academic standpoint for at least two reasons. Firstly, it proposed a wide-ranging overview and synthesis of 20 years of research on activities performed during train and car travel. To our knowledge, this work has not yet been performed. Secondly, it highlights the need to question the notion and definition of an activity in the context of AV in which the primary task of driving could become progressively less decisive during the journey. The development of observations in situ is necessary to improve our knowledge. Also, the application of tools from other fields of research such as neuroscience could provide better understanding of what constitutes an activity and its implications for the traveller's behaviour through the analysis of eye movements, heartbeat and others (Souche-Le Corvec & Zhao, 2020).

This paper can also have policy implications. It is interesting to observe that AVs do not seem able to fully replace trains on the basis of activity analysis. Consequently, the waiting benefits in terms of VoT could be less considerable than expected. The second findings highlighted the progressive transition from the manual car to the AV, with the possibility of increasing the number of active activities. An extension to this paper could be to consider the degree of involvement in these different activities. Certainly, some active activities such as texting messages will be faster and easier to perform in an AV than sleeping because they need

less physical involvement. The question for the authorities is to determine the level of involvement from the driver and the level of the autonomous system to take into consideration and determine whether the driver can shift from the primary activity to an active secondary task. Currently, driving while holding a mobile phone is still forbidden in many countries in the world. What would be the relevance of this prohibition in case of the development of hybrid autonomous systems or other such systems? Undoubtedly, there is a need to improve our knowledge regarding activities performed during travelling in order to better regulate the use of future AVs.

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