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How will automated vehicles shape users' daily activities? Insights from focus groups with commuters in the Netherlands

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ABSTRACT

Automated Vehicles (AVs) are expected to allow their users to engage in a broad range of non-driving activities while travelling, such as working, sleeping, playing games. The impact of this possibility on the satisfaction with travel and on travel demand has been extensively discussed in the literature. However, it has been hardly recognised that the availability of on-board activities influences the (time-geographic) constraints of daily activities and may alter the selection, location, and sequencing of other activities in the day. This hampers correct representation of travel behaviour in activity-based models aiming to predict the effects of AVs on mobility and environment (e.g., greenhouse gas emissions). To help fill this gap, we gathered and analysed qualitative data from focus groups, in which 27 commuters discussed their expectations concerning on-board activities and daily schedules in the AV-era. Among the core insights are the following three. First, it is useful to separate in modelling the satisfaction with travel and the potential for on-board activities during travel: they have different determinants and different consequences for activity schedules and individual travel demand. Second, on-board activities may be classified in 4 quadrants according to their novelty and priority level: this classification is helpful in understanding the potential re-arrangements of daily activities. Third, performing new activities during travel may lead to complex re-arrangements of daily activity patterns; the re-arrangements may ease or also increase time pressure. These, and other reported insights may facilitate more realistic representation of activity-travel behaviour in future travel behaviour models.

1. Introduction

Fully Automated Vehicles[1] (AVs) are expected to bring many positive effects, such as improved road safety and increased productivity and well-being thanks to more meaningful travel time use and reduced stress from driving. However, due to their increased attractiveness, AVs may also induce car travel and, by doing so, contribute to congestion and negative environmental impacts, which may be fully or partially offset by smoother driving cycles, shorter headways and lighter vehicles. These counteracting effects have been investigated in several recent studies (e.g., Milakis et al., 2017; Wadud et al., 2016; Auld et al., 2017; Chen et al., 2017). To anticipate the up- and downsides of the introduction of AVs, the changes in travel behaviour due to more meaningful travel time-use have been routinely modelled using a lower penalty associated with travel time (e.g., Childress et al., 2015; Gucwa, 2014; Kröger et al., 2018). This is despite the fact that previous studies have called into question this approach when applied to productively used travel time (Lyons et al., 2007; Lyons & Urry, 2005; Gripsrud & Hjorthol, 2012) and indicated that activity patterns in fact influence the travel time penalty (Paleti et al., 2015).

Complementary to these studies, we propose that a simple reduction in the travel time penalty does not fully capture the potential impact of on-board activities on daily activity schedules of travellers. In this regard, it is useful to recall the perspective of time-geography (Hägerstrand, 1970), which suggests that individuals choose their activities, activity locations and times guided by

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[1] We refer throughout the article to so-called level 5 automated vehicles, according to SAE International (2016) standards.

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capability, coupling and authority constraints. Capability constraints relate to the physical ability of the individual to reach locations considering that certain time should be spent for biological needs (sleep, meals) at given places. Coupling constraints relate to the necessary access to tools, materials and other individuals to perform some activities. Authority constraints address mainly the legal boundaries for activities (e.g., in-store shopping is possible only within the shopping hours). From here, it can be observed that the possibility of performing new activities on board of the AV may affect all classes of constraints: activities on board are allowed (authority constraint), possible thanks to undivided attention and potentially some equipment available in the AV (coupling constraint), and potentially enable to reach further locations if some of the biological needs (e.g., meals) can be satisfied in the AV. Therefore, on-board activities can be expected to influence daily activity schedules of travellers, for example, make them more efficient and more relaxed, and this influence is due not only to the changes in travel time penalty, but importantly also to changes in the constraints of activities.

To model changes in daily activity schedules, it is possible to adopt not only time-geographic but also activity-based or time-use perspectives (Arentze & Timmermans, 2004; Kitamura, 1988; Becker, 1965). Steps towards developing such a modelling perspective are being taken in several recent studies where the traveller's ability to engage in on-board activities is explicitly modelled (Pawlak et al., 2015, 2017; Banerjee & Kanafani, 2008; Pudāne et al., 2018). We aim to support such modelling efforts by exploring questions, which have so far received little attention, but are important in developing activity-based, time-use, and time-geographic models for the AV-era. Many such questions relate to the (assumed) interactions between on-board and stationary activities: would activities be *transferred* to an AV from another location and time-of-day (or would they rather be *added* to the traveller's activity-list)? What types of re-arrangements in activity schedules could be expected? What type of re-arrangements will occur due to more pleasant travel (if travel in AVs is indeed more pleasant), and what type of re-arrangements will occur due to interactions between on-board activities and other activities?

Given the uncertainty associated with these crucial questions, we believe that the time has come to take a step back, and to explore them using a qualitative research method – specifically, focus groups. Our goal is to derive qualitative insights which can be used (1) to verify and validate existing formal, mathematical models describing activity schedules in AV-contexts and (2) to help design the next generation of such models. The resulting methodological advancement can be pivotal for the evaluation of policies concerning AV-adoption and -usage. Crucially however, the research presented in this paper aims to serve as a building block for formal modelling efforts, not as an alternative to such models. Our data is not suited for quantitative, statistical, or confirmatory analysis, but aims to help in designing such studies.

We gathered data in a focus group setting, where participants discussed how they expect their travel to change in the AV-era, envisioned on-board activities and their impact on their daily routines. Our study is in line with several qualitative studies who have successfully investigated various aspects of travel behaviour in the AV-era: on-board activities and satisfaction with travel (Trommer et al., 2016), intentions to use AVs (Payre et al., 2014; Silberg et al., 2013), and changes in daily activity schedules with an emphasis on travel demand (Zmud et al., 2016). However, we direct our attention specifically into daily activities of future AV-users, which the current literature, to the best of our knowledge, has not yet addressed in depth. In the following sections, we explain the planning and execution of the focus groups (Section 2), present our findings (Section 3), and discuss the findings in a broader context, as well as suggest directions for modelling (Section 4).

2. Methods

2.1. Motivation and limitations of using focus groups

Focus groups, compared to other qualitative research approaches, such as individual interviews, allow participants to learn from, build upon and contrast each other's ideas (Stewart & Shamdasani, 2014). This is desirable for our study, as many participants may not yet have thought about the possible influence of AVs on their daily lives. In addition, focus groups provide a more efficient way of gathering qualitative data compared to individual interviews: less time is needed to complete the interviews. Finally, previous studies show that focus groups can provide valuable insights on new transport technologies; see, for example, Kenyon and Lyons (2003) and Maréchal (2016), including AVs (Trommer et al., 2016; Silberg et al., 2013). Krueger and Casey (2014), Onwuegbuzie et al. (2009), and Morgan (1996) helped to design several aspects of the focus groups, such as an appropriate questioning path and optimal number of participants and groups.

Yet, the focus group approach also has its limitations for studying future phenomena. Since no statements about the future can be made with full certainty, a fully-automated future may still be quite distant, and incentive-alignment is practically unenforceable in a focus group setting, participants occasionally described quite unlikely scenarios, which may have (partially) been intended as entertainment:[2]

> *'I imagine a kitchen inside it (the AV), you can prepare everything, cut vegetables, and when you're home you can eat everything, everything's done.'* (Johanna)

[2] Yet, bold ideas for how to take most advantage of the self-driving mode are abundant and currently seriously explored (MIT Technology Review, 2018).

2.2. Sample description and recruitment

Five focus groups were conducted in the Netherlands between September and November 2017. Each group consisted of 4–7 participants, adding up to 27 participants in total. To ensure that participants have regular daily activity schedules that involve travel, we invited only daily commuters (travelling to work or studies). Furthermore, we recruited mostly current car or public transport users, because those modes are easier to compare with AVs than active modes. Although, in line with the focus group and qualitative studies' methods (Marshall, 1996), the sample was not intended to be representative of the Dutch population in terms of either sociodemographic background nor in terms of travel behaviour, the following are useful statistics to better understand our findings.

Of the 27 participants, slightly more than half (15 participants) were male. Age groups 30–39 (11) and 40–49 (10) were most represented, followed by 20–29 (5) and 60–69 (1). Almost all the participants were employed, except two students and one recent retiree. Most participants were commuters by car (as drivers) or by public transport, but some participants mostly commuted by bike. Those participants who were cycling on a day-to-day basis were in the first group, which consisted of TU Delft students and researchers. However, they were asked to recall past experiences of commuting by car or public transport as a comparison for AV in the discussions. Participants in other groups were selected such that approximately two thirds were car drivers and one third was public transport users. The reported commute travel times ranged from very short (15 min) to rather long (1 h or more one way). Five participants reported making multiple trips a day for work (e.g., visiting clients). Their travel time amounted to several hours every day, and all of them travelled by car.

Of the 27 participants, 21 are cited on an individual basis in this paper. Respecting the privacy of our participants, we replaced their real names with fictive ones. Socio-demographics of participants – their age group, gender, profession, travel mode(s), commuting times – are available in Table 3 in Appendix A. Participants of the first group were invited through posters in TU Delft and through personal networks. Participants of focus groups 2 to 5 were recruited through a marketing company and received an incentive of 40 Euro for participation.

2.3. Focus group sessions

To allow the participants full creativity in considering their daily activity schedules in a future with AVs, the most facilitating scenario for on-board activities was discussed: AVs are fully automated (i.e., level 5 according to the standards of SAE International, 2016), available for private use (i.e., not shared), fully safe and secure, available (i.e., purchase or rental costs were not considered), and permits a range of on-board activities. A general introduction of AVs and these assumptions were presented to the participants in a short animation movie at the start of each session. The possible on-board activities (e.g., working, watching television, sleeping) and some potential re-arrangements were illustrated with examples in the movie.[3]

All focus group sessions lasted 1.5 h. After briefly introducing themselves and the introduction movie, participants discussed 10 questions. The discussions were assisted by a moderator, who was not involved with the research until after the focus groups. This helped to minimise any confirmation bias and, we believe, made participants more comfortable expressing their opinions. The questions relate to their activity and travel behaviour currently or as envisioned in the future, when they will have the access to AVs. See Table 1 for a list of questions used in one focus group. Based on experience and suggestions of the moderator, the questions for every group were slightly adjusted, combined or split, mostly to improve their clarity.

The first questions inquired about the current travel behaviour of participants and their satisfaction with it. Thereafter, participants were asked to broadly reflect on the possibility of travelling in an AV (question 3), in order to become more comfortable with the topic. Questions 4–6 address the core of the study: performing activities in the AV and possible changes in daily routines. Questions 7–9 inquire about potential travel demand changes, including changes in residential location. Finally (question 10), participants could reflect on what they believed were the most crucial points of the discussion.

2.4. Data analysis

The focus group discussions were audio-recorded and transcribed afterwards.[4] The transcripts were coded and analysed following content analysis principles (Elo & Kyngäs, 2008). The analysis was mostly inductive, but some categories during analysis were derived deductively – i.e., based on own hypotheses and literature. The influence of preconceived ideas could be considered a limitation of our method, especially when viewed from fully-inductive perspectives, such as grounded theory (Charmaz, 2006). However, we believe that it is nearly impossible for any researcher to completely isolate oneself from the ideas in the field's literature.

Thus, the following section presents the final storyline, which is a combination of inductive and deductive analyses. We systematise the core outcomes in conceptual maps. The main findings we illustrate with quotes from focus groups as well as contrast them with insights from literature.

[3] The animation movie (in Dutch) is available from the corresponding author upon request.

[4] The complete transcripts are available here: http://doi.org/10.4121/uuid:994f0ab2-0fa2-493f-88ad-fbf4eaaf470e (Pudāne, 2018).

Table 1
Focus group questions - example from the 4th focus group.

1. How do you travel normally?
   – Train/car/…?
   – How long does the trip take?
   – What do you do during the travel?
2. Are you satisfied with how you use your travel time or would you like to use it differently?

Travel time is for you:
   – Time to relax
   – Time to do something
   – Wasted time
   – Time to kill

3. Imagine that you travel with an AV. What are pros and cons in comparison to your normal way of travelling?
4. Imagine that you have an AV and can arrange the interior the way you want. What would you like to do when travelling and why?
5. Would you like to perform such activities in the AV which you normally perform in traditional environment like at home or at work? If so, do you think you can save time for other things which you would like to (or have to) do?
6. Would you change anything in your daily routine if you had an AV?
7. Would you travel further or more frequently to perform activities if you had an AV?
8. Would an AV be a good alternative for trips which you usually perform by a bicycle or public transport?
9. Would you like to move if you had an AV?
   – If yes, where to?
   – If no, imagine you need to move (e.g., because of a job). Would an AV influence your decision?
10. Would an AV make your life better or worse?

3. Findings

The focus groups offered rich information on all questions. The findings are presented roughly according to the questioning path (Table 1) as follows:

1. Pleasure from travelling and feasibility of activities in an AV (questions 3 and 4) – Section 3.1,
2. Types of activities while travelling (questions 4 and 5) – Section 3.2,
3. (Changes in) daily activity schedules (questions 5 and 6) – Section 3.3,
4. Individual's travel demand (questions 7 and 8) – Section 3.4.

Section 3.5 presents a synthesis of the core factors and their relationships.

3.1. Pleasure from travelling and feasibility of activities in an AV

A major part of all focus group discussions was a reflection on the many aspects of travel that will (likely) be different with fully automated vehicles compared to present travel modes. Participants often imagined how many inconveniences of travel in public transport (e.g., having to make interchanges, lack of privacy) and private cars (having to stay focused on the road, limited comfort) would be reduced making the travel more pleasant (or: increasing the intrinsic utility of travel). Furthermore, participants often reasoned that many aspects of travel in AVs would make new non-driving activities possible. These aspects were not always the same as the characteristics enhancing the pleasure from travel. Although clearly both travel pleasure and possibility to conduct on-board activities influence the overall satisfaction with travel (Ettema et al., 2012; Frei et al., 2015), literature recognises that it is useful to separate the two (Mokhtarian & Salomon, 2001; Singleton, 2018).

Table 2 lists all the characteristics of travel in an AV which were mentioned in the focus group discussions, and their perceived influence on both effects. Note that some of the characteristics apply also to conventional cars – for example, travel continuity – yet, their effects (especially on the feasibility of on-board activities) are different due to the cars also being fully automated. Some factors

Table 2
Influence of characteristics of travel in AV on pleasure from travelling and feasibility of on-board activities.

Characteristics of travel in AV	Influence of the characteristics on …	
	Pleasure from travelling in AV	Feasibility of on-board activities
(a) Fully automated driving	mixed	positive
(b) Availability, little planning needed	positive	neutral
(c) Travel continuity	positive	positive
(d) Comfort	positive	positive
(e) Equipment, storage possibilities	neutral	positive
(f) Privacy, isolation	mixed	positive
(g) Predictability, reliability of travel time	mixed	positive
(h) Longitudinal and lateral movement, position of the traveller	negative	negative

received mixed assessment from the participants, when describing their impact on the pleasure of travel. For example, privacy was seen as desirable, but its flipside, isolation from other travellers, was sometimes perceived as undesirable.

Below we discuss each characteristic and illustrate its impact with quotes.

(a) Fully automated driving enables advanced on-board activities. However, automated driving also takes away the driving task from travellers. This was perceived differently by focus group participants (especially current car-drivers):

'Continuously you must pay attention (while driving a car): in case of congestion, traffic jams cars can suddenly come from everywhere. (…) If you can fully rely on the equipment of the car (AV) in terms of safety, then you are very relaxed in the car. Then you can do a lot of other things.' (Pieter)
'I'm afraid it (the AV) is too slow. If you're in such a thing you're out of control, I'm afraid that I just get stressed.' (Gabrielle)

The latter sentiment relates to the literature of mode-specific preferences and motivations for travel, such as independence, curiosity and status (Ory & Mokhtarian, 2005; Anable & Gatersleben, 2005; Steg, 2005). Automated driving might alter these affective characteristics of car travel (Haboucha et al., 2017; Nordhoff et al., 2018).

(b) Availability at any time and a limited need for planning was appreciated by many participants, especially current public transport users:

'You have the freedom: I get into the AV when it suits me, and that AV is ready for me at the front of my door.' (Linda)

(c) Travel continuity was appreciated both for allowing the traveller to engage in advanced on-board activities and for its own sake:

'What would be nice: now, I often have to wait because I have to transfer, that would be gone.' (Norbert)
'The fact that I have to switch (to different modes) means that I cannot really do anything, prepare for work or whatever.' (Linda)

(d) In a similar fashion, comfort was also appreciated on its own as well as for facilitating on-board activities (including sleeping):

'(In an AV) You are in your own cocoon which does the work for you, maybe it will take longer (than a plane for a long-distance trip), but you will travel in a very relaxing way to your destination.' (Pieter)
'If I am able to sleep in the AV, I would do the travel at night. (…) I would arrive at my destination in a much better shape than when I have to sleep on a chair in a bus.' (Bart)

(e) Participants recognised that equipment and storage possibilities enable many more advanced on-board activities:

'*- (You could hold) A kind of work consultation (in an AV). Your colleagues are also on their way home, you can just do it on the way.*
- In your AV, Skype.
- (You would need) A good screen and a good sound system.' (Elisabeth and others)

(f) Privacy was appreciated for allowing more on-board activities. At the same time, it was recognised that complete privacy (or complete isolation from other travellers who are not one's travel companions) would mean foregoing positive experiences that sometimes result from travelling with others. In the latter regard, te Brömmelstroet et al. (2017) lead an interesting discussion into how different travel modes influence the feeling of being connected to places and communities.

'I will take the AV as a mini office space and do office-work that does not need any interaction with people. It is different (than public transport) because it is a confined environment where I can concentrate.' (Bart)
'I am afraid that if we use AVs all the time, we will find ourselves in bubbles. We go from point A to B in an isolated way. So, there may be not much room left for interaction and unpredictable things.' (Bart)

(g) Respondents imagined that travel times with AVs, especially if everyone is using AVs, would be perfectly predictable and reliable. This would allow to arrive at the desired time and to also better plan on-board activities. Also literature widely acknowledges that reliable travel times are desirable (e.g., Bates et al., 2001) and that unpredictability causes stress (Evans et al., 2002).

'If someone (now) looks at his phone and causes a head tail collision, then the highway is stuck. (…) (With AVs) it takes away a bit of uncertainty, adding a bit of peace. You can say much better, if I have to go to work, it takes me 20 minutes, and there is little variation in that.' (Maarten)
'If the car would drive itself and stop at the right points, I could watch Game of Thrones.' (Felix)

However, a perfect predictability of commute routine (in a broader sense than reliable travel times) was sometimes dreaded for potentially making days too monotonous:

'If you have to travel by public transport, like me, sometimes you encounter unexpected moments, right? But if you have the same trip every day in that AV, then every day is the same. (…) It becomes monotonous.' (Norbert)

(h) Some participants expressed a concern that they may experience motion sickness in an AV, which would not allow performing activities while travelling. It was also mentioned that movement itself could be an obstacle for some activities while travelling:

'I cannot actually read a book inside the car, because I will get sick.' (Renate)
'You are playing a game inside the car and then the car suddenly brakes. How does that work?' (Paulien)

Several studies confirm that longitudinal and lateral movements of AVs, as well as new positions of travellers in the AV (e.g., not facing forward) can cause motion sickness for future AV users (Diels & Bos, 2016; Le Vine et al., 2015). As such, the impact of AV movements may be underestimated in the present study, where participants imagined an on-board environment where many activities are feasible (limited only by the necessary space and equipment).

3.2. Types of activities desired for travel in AV

A core part of the focus group discussions related to the envisioned (type of) non-driving activities to be performed during travel in AV. Clearly, not all activities are feasible in AVs:

'Ideally, you could do everything in such a car. Brushing your teeth, putting on your lenses, everything. You cannot take a shower, that's a little over-enthusiastic.' (Norbert)

Feasibility is therefore a pre-requisite. Nevertheless, even if new activities are feasible in an AV, participants did not always express a desire to make full use of that feasibility. Their current time-use might be optimal, or, in other cases, this might be due to general resistance to adopting a new travel mode (König & Neumayr, 2017) or response lag (Chen & Chen, 2009). The potential unwillingness of travellers to change their travel time-use is also a core insight of Singleton (2018) and Fraedrich et al. (2016).

'Well, if I compare with public transport or a bus, I would do the same thing (in an AV). I would listen to a podcast or read a book.' (Dennis)

In addition to the choice to engage in new activities during travel in an AV (versus continuing to pursue current on-board activities), an important dimension is the priority level of selected activities. Some participants imagined performing activities of high priority that need to be performed during the day (e.g., work, sleep, meals, personal care, scheduled appointments and commitments). Other participants thought that AVs would provide a good opportunity for optional, medium to low-priority activities – activities that are performed only if there is extra time available for them (e.g., hobbies without appointments, time to contemplate – if those have medium to low priority for the individual).

Building on these two dimensions (new or current and high-priority or optional activities) we can classify on-board activities into four types, see Fig. 1: new high-priority activities (I), current high-priority activities (II), current optional activities (III), new optional

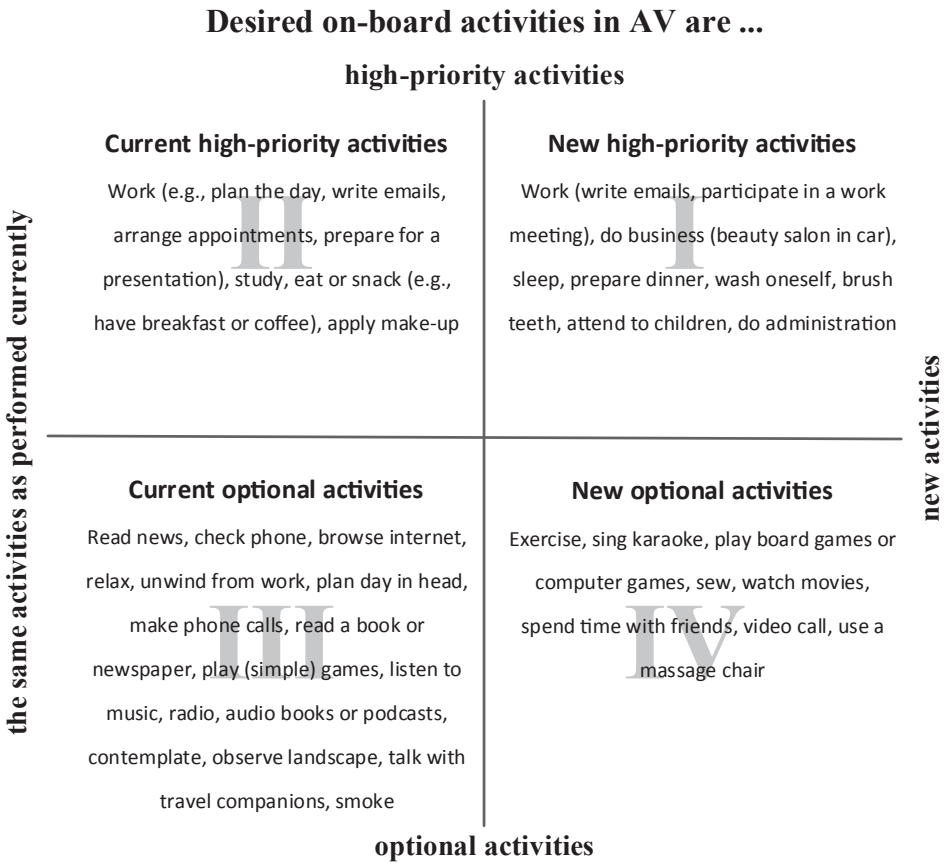

Fig. 1. Classification of desired activities in AV considering their priority level and difference from current on-board activities.

activities (IV). Note that some activities could be classified in different types by different individuals – for example, writing emails could be a type II activity for current public transport users, but a type I activity for current car drivers.

Type I or **Type II** (high-priority) activities were most often desired or already performed during travel by participants who experience time pressure (a result also of Ettema & Verschuren, 2007), which could be either chronic or acute (as defined by Gunthorpe & Lyons, 2004). This is not surprising, since multitasking is a known strategy to reduce time pressure (Kaufman-Scarborough & Lindquist, 1999). Furthermore, some high-priority activities are time-inflexible (e.g., important phone calls), which means that they may need to be performed during travel:

'I'm currently experiencing a structural sleep shortage of 1 to 1.5 hours a day. I would really use it (the AV) for that.' (Eric)
'On my way I make calls, I try to put it on Bluetooth, with calls I usually do. Often my boss sends a WhatsApp to me, that's the only time I have contact with that man. (…) The most immediate effect, if I had such an AV tomorrow, would be less stress, because the work pressure is less.' (Jelmer)
'Now, someone is driving a car, a mother or a father – you often look backwards at your child who wants something. These are dangerous situations. (…) With AV, you can feed a baby; you don't have to stop (…).' (Niek)

Having to perform high-priority activities during travel can create tension between the existing and necessary conditions to perform the activity. The above statements suggest that (some participants believe that) AVs could resolve that tension.

At other times, participants desired to perform high-priority activities during travel in order to free time for *other* activities within the day. They reported having insufficient private time, which is related, but not equivalent to time pressure:

'I feel that people do not spend time, which is essential, for casual interaction, not about work. (…) Spending some time to work in the car will liberate, make available some time for this kind of interaction.' (Bart)

Type III activities – primarily transition or time-out activities using the words of Jain and Lyons (2008) – were mentioned by participants whose travel is too short for more substantial activities. This accords with several studies, as summarised by Keseru and Macharis (2018), and potentially explains the preference for AVs for long-distance trips (Yap et al., 2016; Fraedrich et al., 2016; LaMondia et al., 2016):

'If you have 2 hours then it (possibility to perform activities while travelling) really matters. (…) But, within a short time there is nothing to do.' (Laurens)

Passive on-board activities (like transition, time-out) were often also selected seemingly for no reason. But, as described by Holley et al. (2008), such anti-activity may 'assist creativity by providing "incubation" time':

'- Sometimes (in public transport) I was just looking at the landscape.
- Just relax?
- Yeah, looking around. (…) Sometimes an idea may come up.' (Bart)

Type IV activities were selected by participants who desire leisure (or other optional) activities, which at present do not have a suitable time or place in their schedules:

'I think in my AV I would do something that I never have time for. For example, maybe use the car as karaoke salon.' (Caroline)

Another interesting reason (offered by participants) for selecting activities of **any type** was their perfect compatibility with the on-board environment (or with the fact of being in motion):

'In public transport I used to read quite a lot, more than when I am at home. (…) We are changing places, so we change environment and it gives the will, I think, to see differences, different experiences. Traveling is an experience. Reading is an experience as well. It is a kind of travelling.' (Bart)
'-I always have to go to the customer with my suitcase (to perform pedicure), that is quite a heavy thing. (…)
-You can make a studio in your (automated) car. (…)
- Yes, just a collapsible treatment chair, and you have everything with you. That would be ideal!
- The car gets a completely different function.
- I do not have to do anything; I do not even have to drive to the next client.
- No, of course, that will save time.
- Meanwhile, I can clean up my things for the next client.' (Paulien and others)

The above-mentioned reasons for selecting different types of on-board activities can be summarised as an attempt to re-balance activity needs and wishes with their constraints, once a new location (on board) is available. The new location not only relaxes the constraints for activities, but may also create new activity wishes and needs, which in turn could create new constraints.

Finally, we observed that some participants appreciate the *possibility* to use the travel time for activities, which can be chosen flexibly or even spontaneously, even if they currently do not desire specific activities. In modelling terms, the activities seem to have an option-value (Laird et al., 2009), which may matter for their decision utility, but not necessarily experienced utility (Kahneman et al., 1997; Chorus & De Jong, 2011; De Vos et al., 2016).[5]

[5] Decision utility refers to the weight of outcomes and attributes in the process of making decisions. Experienced utility is the actual, subjective

'For me personally it (activities in the AV) would not matter much (for the daily habits) because I don't have a partner. (…) I have a lot of time, and I occasionally get bored. (…)
The nice thing is that you can do something active or something passive (in the AV), that you can make the choice.' (Petra)

3.3. AVs' impact on travellers' daily activity schedules

After contemplating their desired activities during travel in AVs, participants were asked to think about the impact of those activities on their daily activity schedules. With 'impact on travellers' daily activity schedules' we refer to changes in activities performed outside travel time, as well as changes in travel and activity timings. This excludes changes in activities performed during travel, which are discussed in the previous subsection.

From the statements of focus group participants, we infer that AVs may lead to changes in daily activity schedules primarily via what can be named a 'saved time' effect. Time may be saved by transferring new high-priority activities to the travel episode (Type I activities, according to Fig. 1). This may result in various changes in daily activity schedules: new activities might be scheduled in the freed time, activities or travel might be extended, activities might also be swapped or reshuffled. Participants usually did not know or did not specify the exact form of re-arrangements, but agreed that in general there would be substantial changes in their daily activity schedules – which depend on activity needs, wishes and constraints. Note that this notion is at the basis of time geography (Hägerstrand, 1970):

'It can go two ways. On the one hand, I sometimes stay late at my work, but then I am working on something and then I want to finish it. (…) I could catch up on the way home. But, of course, that can also occur when I get up: I have to do things for another hour, so I will be able to prepare some things in advance. (Maarten)

In addition, some participants imagined dispatching an empty AV to perform some activities, if such a possibility would become available (e.g., to pick up groceries from a supermarket, a guest from train station, or to send children to some activity locations).[6] Such 'outsourcing' of activities was popular also in a real-world chauffeur experiment, intended to resemble AVs (Harb et al., 2018). Similarly as transferring high-priority activities to the travel episode, the outsourcing creates a 'saved time' effect. However, trust is necessary for the travellers to make use of this possibility (especially to allow their children to use the AV alone):

'We have to bring my daughter to her internship two evenings a week. (…) Now, she can get in that car and the car will take her there. And that car comes back to us, so that would save time. So, that would be nice, if I trusted it. But I have to trust that thing first.' (Nora)

Furthermore, the 'saved time' effect was appreciated by many participants for making their schedules 'more efficient' and relieving their time pressure:

'For me, it would be more efficient use of time, your working time starts as soon as you get out of the door. On the other hand, your free time starts again when you step out of the door at work, or that last bit of work you can do on your way home. So, that ultimately gives you more free time, so you can be more relaxed in it.' (Linda)

However, and this was an unexpected but prominent insight from the focus groups, some participants noticed a potential downside of the saved time effect. They imagined that the possibility to be productive (work) in the AV would rise the expectations at the work places either formally (their manager would request that) or informally (their co-workers would set the norm). Higher expectations increase the time pressure and stress (see Fig. 2):

'Immediately you would think: I drive across the country, I have a two hour ride, this means a workload because you have a two hour drive. (…) The expectation pattern is there, you cannot choose anymore.' (Eric)

The perception of increased time pressure could also be due to the availability of a wider choice of activities. If more activities are feasible in a day, it may create an illusion that more activities *should* also be performed in the AV-era, which leads to time pressure (Ackerman & Gross, 2003). The effect also resembles the more general impact of ICT, which has been called 'technostress' (Ayyagari et al., 2011) – the feeling that the ever higher pace of communication and availability enabled by ICT should be matched by their users. This also relates to blurred boundaries between work and life afforded by ICT, and perhaps also AVs (Wheatley & Bickerton, 2016; Gustafson, 2012).

A middle path of the two options (as illustrated in Fig. 2) would be a modest increase in amount of activities and also expectations, such that the same level of time pressure is maintained. That would make the perceived time savings disappear, changing little in how individuals experience their days:

'You get used to it (extra time) very fast, so you do not even appreciate having that extra time.' (Elisabeth)

Finally, discussion in all focus groups at some point deviated from daily activity schedules to non-daily and holiday activity

(*footnote continued*)
hedonic experience – 'the pleasure and pain' – resulting from the choice ex post. (Kahneman et al., 1997).

[6] The possibility to dispatch empty AV may be available for fully automated vehicles, but that would also be determined by other factors, such as legislation. In the focus groups, sending an empty AV was assumed to be possible.

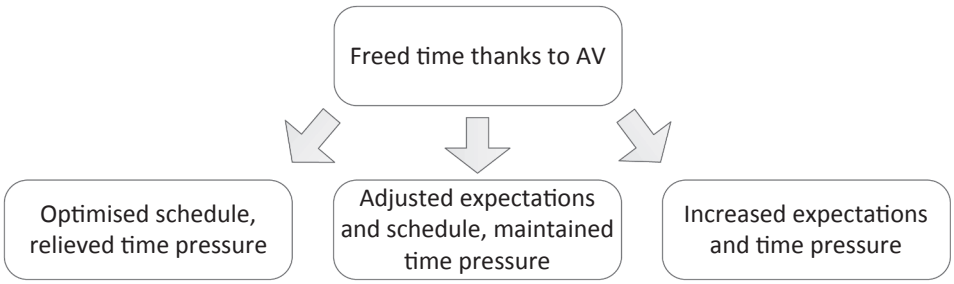

Fig. 2. Possible adjustments of daily activity schedule and expectations given freed time thanks to AV.

schedules. Almost unanimously, participants agreed that AVs would offer major gains for these non-regular and often long-distance trips: transferring long activities (such as sleep) to a long journey done with an AV, would let the traveller arrive at the (holiday) destination while barely noticing the trip. This would likely influence activity schedules, because the traveller would not need as much time to rest and recover from the long journey.

'-Yes, you are less tired. You do not have to account for a return trip. If I go far away, I want to eat and drink, but that's not possible, because you have to go back in the evening. In this way, you can easily go to Brussels or Paris.
- To have dinner there?
- Yes, nice, right? Eat there and then go back and sleep in your car.' (Gabrielle)

3.4. AVs' impact on demand for travel

The final insight from the focus groups relates to the expected changes in an individual's demand for travel. Participants had varied opinions about whether their *daily* travel demand would increase, remain unchanged, or even decrease. However, many participants indicated that their *non-daily* travel demand might increase, either by accepting further locations for activities, by performing long trips more often, or by switching their travel mode from plane or train to AV for long-distance trips. The following paragraphs briefly discuss these findings.

Some participants imagined accepting longer travel distances daily because of the higher pleasure from travelling in an AV:

'I would meet with my customers more easily outside the office. If I want to meet outside the office now, (…) then I have to sit in a car for an hour and a half there and back. Then I think: I am not going to do that.' (Paulien)

However, other participants found that more comfortable travel alone should not make them travel more, because compared to the AV there are still better places to spend their time:

'We should not spend more time in the car just because the car is comfortable. My home is also comfortable, so why not spend time there?' (Caroline)

Furthermore, several participants noted that they would not like to extend their travel time indefinitely, because they would still be 'locked up':

'However, I still think I will get bored at a certain moment, you are still locked up. You get some more degrees of freedom, but you're still trapped.' (Linda)

These contrary opinions point at a need for further research into whether the ease or pleasure of travelling could lead to accepting longer travel distances, a suggestion which has been often been made in the literature (e.g., Singleton, 2018). Participants were also rather ambiguous when considering changed travel distances due to changed daily activity schedules (a finding also of Zmud et al., 2016):

'My routine, how it will look like, I do not know, but my pattern will really change. (…) I do not think I would travel a lot of extra kilometres or travel more.' (Linda)

Some said they would even travel less because of 'outsourcing' some activities – but the resulting change in vehicle-kilometres-travelled is unknown in this case:

'I would travel less – I will send the vehicle to pick up children, if I would have, or friends from airports. Or help somebody to deliver something. Usually you ask the person who has a car. (…) I prefer to do something more useful.' (Daniel)

Compared to the varied expectations regarding daily travel demand, participants were rather certain about the benefits of AVs for long distance and holiday travels (as discussed also by LaMondia et al., 2016). The first four factors contributing to increased pleasure of travelling (Section3.1, Table 2) were most often mentioned in the context of long distance travels: automated driving (and therefore relieved burden and spared energy for the activities at the destinations), availability and less planning needed (compared to travelling by air or public transport), travel continuity, and comfort. The possibility to engage in long activities, such as sleep, was

also recognised as beneficial (see the quote of Gabrielle at the end of Section 3.3). Thanks to these factors, several participants indicated that they would travel longer or more often both for work, as well as leisure:

> *'(The biggest change in my life with AVs would be that I would) travel more, visit friends and family. My parents live in Brabant, which is quite far. I could go there more often. Now it is doable in public transport, but you have to cycle to the station, to the train. And with an AV, if money is not an issue, I would also go climbing.'* (André)

Therefore, considering irregular trips, our findings align with the often-feared impact of induced travel (Haboucha et al., 2017; Fagnant & Kockelman, 2015; Harb et al., 2018) or its positive counterpart of increased accessibility (Meyer et al., 2017; Milakis et al., 2018). Some participants also indicated that they may perform long-distance trips with AVs and not with airplanes or trains. However, other participants preserved their preference for air and train travel for long distances.

3.5. All factors in a nutshell

The most important findings of the focus groups can be summarised as follows:

- AVs will influence the pleasure of travel as well as feasibility of activities on board. But the causes of both influences differ – Section 3.1;
- Travellers do not always desire to perform the feasible activities on board – the choice of activity type is influenced by activity needs, wishes and constraints, and aspects of the existing activity schedule. The desired on-board activities may be classified in four types based on their novelty and priority level – Section 3.2;
- Activity needs, wishes and constraints determine travellers' daily activity schedules, but schedules will also be influenced by the selected activities during travel in AV (and vice versa – certain on-board activities may be selected because of their impact on activity schedule). Schedules with new on-board activities may become more relaxed, thanks to newly freed time. However, freed time may also create new activity needs and wishes and increase the (feeling of) time pressure – Section 3.3;
- More pleasant travel in AV may influence daily travel demand directly or via the daily activity schedule. But, opinions differed across participants when considering increased/ decreased/ unchanged daily travel demand. More evidence is found for an expected increase in non-daily travel demand – Section 3.4.

Fig. 3 visualises a summary of all the influencing links (represented by the arrows). Numbers at the bottom right corners of the boxes refer to the subsections that explain their content.

4. Conclusions and suggestions for further research

4.1. Conclusions

This paper offers qualitative insights, obtained in focus groups, into potential changes in daily activity schedules of future AV users. It aims to facilitate verification and validation of existing models and to help design behaviourally realistic representations of activity-travel behaviour in future models. To this end, our focus group data offer several insights. We find that – in the eyes of focus group participants – the expected adjustments in daily activities in the AV-era result from the AVs offering more pleasant travel and a wider selection of feasible on-board activities than present modes. More pleasant travel has clearest impact on participants' acceptance of more frequent or longer non-daily travels. The feasibility of new on-board activities may cause re-arrangements in daily activity schedules. However, as also pointed out by Singleton (2018), we find that the availability of more activities while travelling

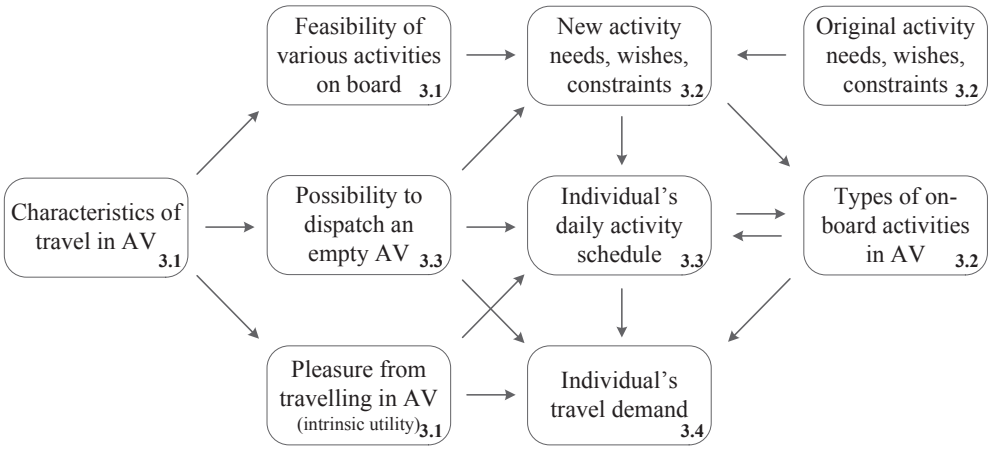

Fig. 3. Synthesis of the main factors and their relationships.

does not always lead to those activities being desired – some travellers are most happy to use the travel time for simple activities (which do not require much facilities) such as relaxation or 'transition' activities or are not willing to change their current travel time-use. Notwithstanding this, in some cases – for participants under time pressure, participants whose schedules include inflexible high-priority activities or who have unfulfilled wishes for other activities – the possibility to engage in new on-board activities may lead to activity re-arrangements, such as activity transfers to the AV, 'outsourcing' some pick-up or drop-off activities to the fully automated vehicles, and other re-arrangements that make schedules more efficient. The expectation that AVs may substantially influence activity schedules (**e.g.**, make them more efficient), which was grounded in a reflection on the time-geographic constraints of activities and the activity-centric perspective of activity-based models at the start of our work, has been supported for this group of respondents. However, an interesting and somewhat unexpected finding is the mixed attitude towards the prospect of more efficient schedules. Whereas some participants think that clever use of AVs will ease time pressure, others envision that the possibility to be productive during travel would in fact increase time pressure. The relaxation of the time-geographic constraints may make the schedules more relaxed or more intense due to a rebound-like effect for activity demand. Asked directly about possible changes in their daily travel distances and frequency, participants gave mixed answers. This affirms that the travel time penalty approach, which invariably predicts more (daily) travel in the AV-era, should be rethought. Advances in methodology, that is, a more subtle and realistic treatment of time-use effects brought about by the advent of AVs, will impact the assessment of benefits and – primarily environmental (e.g., greenhouse gas emissions) – threats of AVs and will influence policies concerning AV-adoption and -usage.

4.2. Suggestions for modelling

Faced with the challenging task of modelling travel adjustments due to the disruptive innovation of AVs, modellers have arguably too often resorted to the convenient (but rough) travel time penalty (or value of time) as the sole predictor for changes in travel patterns in the AV-era. The results from our focus group study in contrast echo at every step that a variety of sometimes contradictory adjustments are possible, resulting from the subtle interplay between activity needs, wishes and constraints. Yet, note again that our findings should be considered as an input for further empirical research and modelling efforts, rather than as stand-alone or final conclusions about activity-travel behaviour in the AV-era. Therefore, we formulate several questions as suggestions for future work:

- What share of travellers would transfer new activities (type I in Fig. 1) to be performed in the AV?
- What are the psychological reasons behind a preference for different activity types during travel? Is there a deeper ground, perhaps related to timestyles (Cotte et al., 2004), that leads people to desire 'time savings' (primarily type I) as opposed to 'time spending' (other types)?
- What is the option-value of activities while travelling (in the AV) – the value of being able to engage in new on-board activities, even if this opportunity is not used?
- How does freed time affect daily activity schedules of travellers and the (individual) travel demand?
- How does freed time influence activity needs, wishes and constraints? Who will experience increased time pressure (and in which contexts) due to newly available activities during travel?
- What is the impact of 'outsourcing' activities to the AV on the (individual) travel demand?
- To what extent does pleasure of travel and availability of on-board activities influence the acceptance (and desire) of further travel?
- How large is the untapped demand for long-distance and holiday travel that might be served by AVs?
- Under which conditions and in which contexts are AVs a viable alternative for overnight travels (where all passengers sleep while travelling)?

4.3. A final remark

The interesting finding of the possibly increasing time pressure due to freed time in AVs deserves a final revisit. It was observed that some participants prefer to use travel time passively (e.g., as a time to transition as in Jain & Lyons, 2008) now, as well as in the AV-era. However, whereas in present modes the passive time-use could be motivated out of necessity – travel time may not be suitable for performing productive activities – in the hypothetical AV scenarios with perfect facilities for a wide range of activities, (the traveller may feel that) being unproductive is no longer justified. This seems to generate a new conflict between maximising productivity and maximising the satisfaction with daily activities schedules (including a proper work-life balance), where the two objectives now need to be traded-off.

In this way, AVs are simultaneously expected to lead to increased levels of productivity and wellbeing, and decreased levels of rest and wellbeing. Although this seems paradoxical, similar contradictions have already been observed in the context of ICT psychological impact on their users. Jarvenpaa and Lang (2005) masterfully recognise eight paradoxes there: mobile technology leads to both empowerment and enslavement, independence and dependence, competence and incompetence, planning and improvisation, illusion and disillusion; it is both engaging and disengaging, public and private, and fulfils needs as well as create them. Will AVs add to these modern-day challenges? That remains to be seen.

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Appendix A

See Table 3.

Table 3
Details of the participants who are quoted in the paper.

No	Name (replaced)	Age range	Gender	Profession	Dominating travel mode(s)	Commute time
1	André	20–29	M	Student	Bicycle, PT*	Short**
2	Bart	30–39	M	Researcher	PT	Short
3	Caroline	30–39	F	Researcher	Bicycle, PT	Short
4	Daniel	30–39	M	Researcher	PT	Short, sometimes long
5	Dennis	30–39	M	Researcher, consultant	Bicycle, PT	30 min
6	Elisabeth	40–49	F	Consultant	PT	40–75 min
7	Eric	30–39	M	Company owner	PT	30 min
8	Felix	30–39	M	Sales agent	Car, PT	20–40 min
9	Gabrielle	60–69	F	Teacher (recently retired)	Car	40 min
10	Jelmer	40–49	M	Contractor	Car	Travel throughout the day for work
11	Johanna	20–29	F	Catering assistant	Car	20 min
12	Laurens	40–49	M	Credit controller	Car, PT	30–60 min
13	Linda	40–49	F	Researcher	Bicycle, PT	60 min
14	Maarten	20–29	M	Software developer	Bicycle, car	25–45 min
15	Niek	30–39	M	Teacher and student	Bicycle, car	30 min
16	Nora	40–49	F	Customer service employee	Car	15 min
17	Norbert	30–39	M	Content manager	PT	45–60 min
18	Paulien	40–49	F	Pedicure specialist	Car	Travel throughout the day for work
19	Petra	20–29	F	Mortician	Car	20 min
20	Pieter	40–49	M	Sales agent	Car	30–45 min, sometimes 2 h
21	Renate	40–49	F	Coordinator	Car	30 min

* Public transport.
** Exact duration not specified.

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2018.11.014.

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