Discussing the "positive utilities" of autonomous vehicles: Will travellers really use their time productively?

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Abstract

Autonomous vehicles (AVs) are expected to reshape travel behaviour and demand in part by enabling productive uses of travel time—a primary component of the "positive utility of travel" concept—thus reducing subjective values of travel time savings (VOT). Many studies from industry and academia have assumed significant increases in travel time use and reductions in VOT for AVs. In this position paper, I argue that AVs' VOT impacts may be more modest than anticipated and derive from a different source. Vehicle designs and operations may limit activity engagement during travel, with AV users feeling more like car passengers than train riders. Furthermore, shared AVs may attenuate travel time use benefits, and productivity gains could be limited to long-distance trips. Although AV riders will likely have greater activity participation during travel, many in-vehicle activities today may be more about coping with commuting burdens than productively using travel time. Instead, VOT reductions may be more likely to arise from a different "positive utility"—subjective well-being improvements through reduced stresses of driving or the ability to relax and mentally transition. Given high uncertainty, further empirical research on the experiential, time use, and VOT impacts of AVs is needed.

Keywords

Autonomous vehicles; Value of time; Travel-based multitasking; Subjective well-being; Positive utility of travel.

1. Introduction

In 2013, a now-anonymous user posted the following question to AskReddit: "If someone from the 1950s suddenly appeared today, what would be the most difficult thing to explain to them about life today?" (Reddit, 2013). The top voted response was: "I possess a device [a smartphone], in my pocket, that is capable of accessing the entirety of information known to man. I use it to look at pictures of cats and get in arguments with strangers." Hyperbole aside, this commenter's point is that although new technologies hold the potential to dramatically reshape our lives, we do not necessarily put them to productive use, or at least to the full extent that futurists predicted. My objective in this position paper is to argue that this outcome may be true for the next disruptive transportation technology: autonomous vehicles (AVs). People simply may not utilize their travel time as productively as forecasts assume, which has significant implications for the travel behaviour impacts of AVs.

Autonomous vehicles, especially small passenger vehicles or self-driving cars, are expected to have revolutionary effects on the transportation system as well as the design and use of cities and land. Predictions vary, but most assume at least a mixed fleet of human-operated and Level 4 or 5 AVs—where the vehicle performs all driving functions under specific or all conditions (SAE, 2016)—by 2050 or sooner (Bertoncello & Wee, 2015; Milakis, Snelder, van Arem, van Wee, & Correia, 2017; Shanker et al., 2013). Among first-order effects, AVs are anticipated to: improve traffic safety by reducing human error; increase roadway and intersection capacities through platooning and other vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) capabilities; reduce local emissions from more efficient driving and electric vehicles; and (critically, for this paper) reduce the disutility of automobile travel by relieving travellers of the driving task and opening up time for doing other things. Higher-order supposed impacts include: reduced vehicle fleets in the case of shared AVs; decreased demand for parking as AVs can be sent away to park elsewhere; increased urban density from reduced parking needs; increased mobility for children, the elderly, and other people with restricted mobility; and potentially increased urban sprawl as longer-distance driving becomes less onerous (Bahamonde-Birke, Kickhofer, Heinrichs, & Kuhnimhof, 2016; Fagnant & Kockelman, 2015; Milakis, van Arem, & van Wee, 2017; Smith, 2012). Many scenarios predict an overall increase in vehicle distances travelled due to a combination of these factors.

One critical pathway from individual to long-term societal impacts of AVs is through their effects on travel time use and valuation. The subjective value of travel time savings, sometimes shortened to the value of time (VOT) or described as the time cost of travel, is conceptualized as the willingness to pay for a marginal reduction in travel time. VOT has a long history of theoretical and empirical development (Becker, 1965; DeSerpa, 1971; Jara-Díaz, 2002). AVs are expected to decrease in-vehicle values of time by eliminating the burden and stress of driving and allowing former drivers the time to engage in other productive tasks: working, reading, watching entertainment, or even sleeping. This view is consistent with sociological perspectives on mobilities, where cars are private spaces to inhabit, the lines between travel time and activity time blur, and new technologies allow passengers (in particular) to do many things while travelling (Jain & Lyons, 2008; Lyons & Urry, 2005; Watts & Urry, 2008). Lower subjective time costs for automobile travel is one of the driving forces behind predictions of increased trip-making, distances travelled, long-distance car trips, and suburban sprawl: if travellers can make better use of their time in AVs, they may be willing to drive more, farther, and for a longer time.

These travel behaviour impacts of AVs are founded in "the positive utility of travel" (PUT) concept. Popularized by Mokhtarian and Salomon (2001; Salomon & Mokhtarian, 1998) and recently re-conceptualized (Singleton & Mokhtarian, in progress), the PUT notion suggests that travellers may be motivated by or gain benefits from factors besides simply reaching a destination. For the purposes of this paper, let us assume that a PUT is anything that reduces the disutility of traveling (i.e., decreases VOT), whether or not it actually yields an overall positive utility (i.e., generates travel). One major component of the PUT concept is particularly relevant for understanding AV impacts: travel-based multitasking, or the engagement in activities while traveling. A second PUT component relates to subjective well-being (SWB): finding enjoyment or meaning from the travel experience—e.g., driving a sports car to express social status and feel powerful, or riding a bicycle just for the fun of it (Singleton & Mokhtarian, in progress).

Although many industry accounts and simulation studies involving AVs suggest that the ability to do other things while traveling is one of the major benefits (and pathways to secondary impacts) of this technology, I join Milakis, van Arem, and van Wee (2017) and others to argue that there is emerging evidence to the contrary or that at least should give one pause. Specifically, I suggest that VOT reductions from AVs may be more modest than anticipated and that, if substantial, they may derive more from improvements to travel SWB (such as reduced stress and increased comfort) than from productive uses of travel time. I do not discount the likelihood that AVs will bring dramatic changes to travel behaviour and travel demand; I simply question whether this pathway (through activity participation and VOT) will be as strong as many predict. This paper begins to tackle the literature gap "about the impact of vehicle automation on the values of time" identified by Milakis, van Arem, and van Wee (2017, p. 340).

In the following section, I summarize key perspectives on AVs' potential travel behaviour effects from industry and academia, with a focus on estimates of impacts to travel time valuation, especially among recent published simulation studies. This paper does not intend to be a comprehensive review; rather, it summarizes some of the most recent and commonly cited journal articles and published reports on this subject. The subsequent (and largest) section describes and interprets results from emerging research to support my contention, discussing issues surrounding the experience of riding in an AV, the productivity and usefulness of travel-based multitasking, and the relevance of issues related to subjective well-being. The concluding section summarizes these ideas and offers hypotheses and suggestions for future research investigating AVs, VOT, and the PUT concept.

2. Industry and academic perspectives on AVs and VOT

Industry reports and marketing efforts, frequently cited in popular press (e.g., Thompson, 2016), paint a picture of how AVs will revolutionize our lives by freeing up driving time for doing other sorts of productive or fun activities while we travel. Waymo talks about how "Time spent commuting could be spent doing what you want" (Waymo, 2017). A report by KPMG and CAR (2012) begins by asking readers to "imagine" scenarios where one can work seamlessly from the office to home, catch up on emails, or read many books and watch movies during the commute. The report's authors interviewed dozens of industry leaders and concluded that AVs "offer travelers the opportunity to regain time formerly lost to driving as productive time," declaring that "all or part of this time is recoverable" (p. 29). They even go so far as to suggest that AVs will be customized as "mobile offices, sleep pods, or entertainment centers," without discussing whether laws and regulations will allow this or if the market with support such a diversification of vehicle types. Morgan Stanley estimates that full adoption of AVs could net the US economy over $500 billion per year "from people now being able to work" in the car (Shanker et al., 2013), assuming (perhaps optimistically) that 30% of all travel time could be spent working at 90% productivity.

Globally, AVs could provide travellers up to one billion hours per day of time savings that could be used for working, relaxing, or being entertained, according to estimates (without supporting documentation) by experts interviewed by McKinsey & Company (Bertoncello & Wee, 2015).

In recent years, a growing number of simulation studies have investigated the potential impacts of AVs on travel demand. Several of these—shown in Table 1—made assumptions (or at least tested various scenarios) about travel time valuations for AVs. Many of these studies modified existing travel demand forecasting models, creating a new AV mode and assigning travellers a VOT associated with that mode. As the table illustrates, some studies assumed relatively modest VOT reductions of 5–25% from current VOTs for passenger vehicles, especially for Level 1–3 AVs (in which a human must be ready to assume driving control at all times (SAE, 2016)). In the long run, many scenarios assumed much more substantial reductions, cutting AV VOTs to half or 25% of current levels. Two studies (Gucwa, 2014; Kockelman et al, 2017) even tested scenarios in which AV VOTs were set to zero, demonstrating a potential upper bound on travel behaviour impacts.

Table 1. Autonomous vehicle value of time (VOT) assumptions in simulation studies

Study	*Area*	*AV VOT Assumptions*
Gucwa, 2014	San Francisco Bay Area, CA	100% of high-quality rail VOT; 50% of car driver VOT; zero
Speiser, Treleaven, Zhang, Frazzoli, Morton, & Pavone, 2014	Singapore	30% of car driver VOT
Childress, Nichols, Charlton, & Coe, 2015	Seattle, WA	65% of car driver VOT (for high-income travelers only)
Davidson & Spinoulas, 2015	Brisbane, Australia	95–75% of car driver VOT (for lower level AVs); 90–50% of car driver VOT (for higher level AVs)
Kim, Rousseau, Freedman, & Nicholson, 2015	Atlanta, GA	50% of car driver VOT
van den Berg & Verhoef, 2016	United States, the Netherlands	100–61% of car driver VOT
La Mondia, Fagnant, Qu, Barrett, & Kockelman, 2016	Michigan	75% of car driver VOT
Wadud, MacKenzie, & Leiby, 2016	(none)	95% of car driver VOT (for lower level AVs); 50–20% of car driver VOT (for higher level AVs)
Auld, Sokolov, & Stephens, 2017	Chicago, IL	100%, 75%, 50%, 25% of car driver VOT
Kockelman et al, 2017	Austin, TX	100% of transit VOT; 50% of car driver VOT; zero

Beyond the development of simulations for scenario analysis or sensitivity testing, what do non-industry "experts" think about these issues? Two recent studies asked researchers and professionals with travel behaviour and modelling expertise to give their assessments of changes in VOT from AVs due to increases in comfort and in-vehicle activity engagement; both found more modest reductions than are typically analysed in simulation studies. Using a Delphi poll of 45 modelling "experts" from around the world, Willumsen and Kohli (2016) found that respondents assumed AVs would yield an average 10% reduction in VOT, although responses ranged from a 50% reduction to a 50% increase. Milakis, Snelder, et al. (2017) asked 20 transportation professionals and researchers with AV knowledge in the Netherlands to estimate the VOT reduction for AV users under various 15- & 35-year deployment scenarios. In the most aggressive scenario, respondents thought VOTs would be reduced by 18% in 2030 and 31% by 2050, on average. Other scenarios were much more modestly assessed (3% reduction by 2030 and 16–21% reduction by 2050). Again, estimates were highly varied, with large standard deviations, indicating considerable disagreement and uncertainty. In a poll of 109 travel survey researchers and practitioners at a fall 2017 conference, only 45% were "certain" that commuters would tolerate longer travel times in AVs; 39% responded "perhaps" while 16% said "no, never" (personal communication, September 2017). It appears that "experts," at least in the travel surveying/modelling/forecasting arena, are more sceptical in their AV forecasts.

Perspectives on AV futures from academia appear to be drawing from similar behavioural motivations and expectations of increases in productivity and comfort as proposed by industry. For instance, Childress et al. (2015) described how AVs may be "less stressful" than driving, enabling travellers to "spend time relaxing or working" (p. 100); Wadud et al. (2016) suggested that "vehicle automation will relieve…driving related stresses and demands on attention" and "permit productive use of in-vehicle time" (p. 8). Not surprisingly, academics' guesses on the VOT impacts of AVs (and the source of those impacts) appear to be more restrained—and perhaps more realistic—than those of industry advocates. Both sets of perspectives do acknowledge the high degree of uncertainty involved with forecasting such impacts. In the following section, I present empirical research findings and discuss indications that support more modest estimates of VOT reductions from AVs.

3. Discussion of empirical research related to potential VOT impacts of AVs

There are emerging signs that the VOT impacts of AVs and productive uses of travel time in AVs may be smaller than proponents suppose and many simulation studies assume. In the following sections, I discuss empirical research findings that draw upon multiple areas of inquiry, none of which are conclusive alone but which together begin to paint a slightly different picture.

3.1. Will riding in an AV feel more like being a passenger on a train or in a car?

VOT estimates are often assumed to vary across modes, accounting for dissimilarities in the experience, comfort, and characteristics of traveling by different modes. In the absence of real-world data, it would be reasonable to suppose that the experience of riding in an AV might be close to what it is like being a rail, bus, or auto passenger today. Indeed, several simulation studies have assumed that the AV experience (operationalized by VOT) might be closest to the experience using rail-based public transit systems, designed for comfort and productivity (Childress et al., 2015; Gucwa, 2014; Kockelman et al, 2017). On the other hand, there are convincing reasons why today's car passenger might be a closer analogue for tomorrow's AV user.

Foremost, the physical design and operation of AVs may be more like a car than a train, the result of trade-offs between comfort and productivity on the one hand and safety and operational efficiency on the other. Humans only feel comfortable moving within limited ranges of acceleration/deceleration, lateral motion, and jerk (e.g., Hoberock, 1977). Rail-based transit tends to involve more gradual speed and direction changes than car travel, which helps to explain why people find it easier to read or work while on trains than on buses or in cars. While the autonomous vehicles themselves are being designed with some of these limits of human comfort in mind (Elbanhawi, Simic, & Jazar, 2015), simulation studies demonstrating the operational and capacity efficiencies of AVs typically do not take them into account. In fact, one study that limited AV acceleration rates to those experienced on light-rail transit and high-speed rail found that such operations adversely affected the intersection capacity advantages of AVs (Le Vine, Zolfaghari, & Polak, 2015). In short, the personal productivity benefits and the system-level operational efficiencies of AVs may be fundamentally at odds.

Given these trade-offs, it seems plausible that AVs may operate more like today's cars than today's trains, thus diminishing the potential for productive time use for several additional reasons. First, upwards of two-thirds of the population currently exhibits motion sickness while riding in a car (Diels & Bos, 2016), so it may be unrealistic to expect them to feel much more comfortable riding in an AV (Nelson, 2017). Additionally, car passengers tend to feel discomfort at lower acceleration levels than do car drivers (Le Vine et al., 2015). AVs may actually increase carsickness—due to diminished anticipation of motion and acceleration rates and profiles—thus inhibiting task performance (Diels & Bos, 2016). Finally, the design of motor vehicle occupant safety mechanisms might continue (at least until the majority of the fleet consists of Level 4–5 self-driving cars) to restrict the arrangement and alignment of seats and other in-vehicle objects, further limiting multitaskability (Sivak & Schoettle, 2016). As a result, VOT reductions may be more modest for car-like AVs.

3.2. Will most AVs be privately owned, shared but privately used, or operated as shared-ride vehicles?

There may also be trade-offs between AVs that are conducive for productive time use and those supported under various business models or promoted by public policies. A key tenet of the "Shared Mobility Principles for Liveable Cities" (Chase, 2017)—signed by many governments and by mobility providers like Uber— is that "autonomous vehicles (AVs) in dense urban areas should be operated only in shared fleets." This model of shared and shared-ride AVs could be in conflict with studies showing people would prefer to own their own AVs (Zmud, Sener, & Wagner, 2016). Stated choice experiments investigating AV ownership have found that, on average, people would be willing to pay in the range of $3,000 for partially-automated and $5,000–7,000 for fully-automated features (Bansal, Kockelman, & Singh, 2016; Daziano, Sarrias, & Leard, 2017). Although intriguing, these studies cannot tell us *why* a portion of the population would prefer owning AVs: it could be due to perceived safety improvements as much as the potential for being productive while traveling.

Public preferences for owned (and against shared and shared-ride) AVs also show up in VOT results from stated preference studies. Krueger, Rashidi, and Rose (2016) surveyed 435 Australians about a choice between using their current mode on a reference trip or a shared AV either with or without dynamic ride-sharing. Although in-vehicle VOT estimates did decrease (to about 65% of current mode) for the ride-alone shared AV, the shared-ride AV option saw much smaller VOT reductions (to about 90% of current mode). These findings were corroborated by a

German stated preference mode choice study (Steck, Kolarova, Bahamonde-Birke, Trommer, & Lenz, 2018), which also found that a shared AV option reduced auto VOT much less (10% reduction) than privately-owned AVs (31% reduction). A stated preference experiment in the Netherlands looked at the use of AVs as an egress mode for train trips (Yap, Correia, & van Arem, 2016). The authors found that in-vehicle VOT for the AV option was unexpectedly higher than for a manually-driven car-sharing option in this instance; one potential explanation was the inability to do much during short-duration transit egress trips.

Overall, these findings suggest that the AV business models that public policies may try to encourage—ride-sharing, or at least shared AVs operated by mobility providers—would have more modest VOT impacts than a system built upon privately owned AVs. It seems likely that having to (or having the potential to) share the vehicle with a stranger is perceived as a deterrent to in-vehicle activity participation. Further complicating the shared-AV vision is the suggestion that AVs could be tailored to facilitate various activities—working, sleeping, partying, etc.—while traveling (KPMG & CAR, 2012). Such specialization of vehicle types might result in decreased levels-of-service for passengers and diminished efficiencies for fleet operators.

3.3. How productive and useful is travel-based multitasking anyway?

Even if the future AV riding experience merges the "best" attributes of train travel and privately-owned automobile use—a smoother ride in a personal and private space—a fundamental question remains: Will travellers take advantage of an increased ability to engage in a variety of activities while traveling (provided by AVs) and make productive use of travel time? Some insights into this question can be gained by investigating activity participation and the self-reported usefulness of travel-based multitasking for public transit and auto passengers today.

Although research on travel-based multitasking used to focus on public transit passengers (e.g., Guo, Derian, & Zhao, 2015; Lyons, Jain, & Weir, 2016), multimodal studies are increasing (Keseru & Macharis, 2018). Naturally, modal differences in activity participation appear, likely due to differences in required levels of operation and attention (Circella, Mokhtarian, & Poff, 2012). According to recent reviews, train travellers tend to be the most likely to read, write, rest, sleep, or do some sort of multitasking; although, other passengers in buses and cars also do more things than car drivers (Keseru & Macharis, 2018; Singleton, in progress). This would seem to support assertions that AV riders might engage in productive tasks while traveling, especially if AVs feel more like trains.

However, investigating the specific activities travellers conduct suggests caution. In surveys of rail passengers in Great Britain, a sizable share of train riders reported spending most of their time window gazing/people watching (19%) or even "being bored" (2%) (Lyons et al., 2016). In a recent U.S.-based study of commuters in Portland, Oregon, the most common activities among transit and auto passengers were not traditionally productive activities: thinking or daydreaming, viewing scenery or watching people, talking with other people, listening to music, and texting/emailing (Singleton, in progress). These findings could reflect effects of trip lengths: activity participation is more common on longer journeys (Keseru & Macharis, 2018). Overall, instances of multitasking that are productive enough to substantially reduce VOT for AVs may only occur in very limited circumstances: e.g., long-distance travel on limited access facilities. Indeed, several simulation and stated preference studies (Bansal et al., 2016; La Mondia et al., 2016; Wadud et al., 2016; Zmud et al., 2016) have suggested that these situations may be where AVs are the most attractive.

These findings are corroborated in studies asking about the subjective usefulness or productivity of in-vehicle activity engagement. Studies tend to find that transit passengers do report more useful trips than car drivers, which supports the idea that AVs may make travel time more productive; although, walk and bicycle commutes tend to be viewed as even more useful (Singleton, in press). However, the specific activities conducted have varying impacts on how useful travellers perceive their time spent travelling (which affects values of time). In the Great Britain and Portland studies mentioned above, engaging in common passive activities (window-gazing, people watching, thinking, daydreaming, sleeping, or snoozing) was associated with perceiving more wasted time and less useful commutes (Susilo, Lyons, Jain, & Atkins, 2012; Singleton, in press). Among Portland commuters, most other reported activities were not associated with self-assessments of travel usefulness (Singleton, in press). It seems that, in many instances, the things passengers do while travelling many be more about passing the time than about being productive.

Further insights can be gleaned from the few studies that have investigated multitasking in the context of mode choice. A stated preference study in the Netherlands found no association with mode choice for the train's perceived advantages over the car (seats, tables, internet, and quiet compartments) (van der Waerden, Kemperman, Timmermans, & van Hulle, 2010). The same survey of Portland commuters actually found several negative associations with mode choice for technology-related (e.g., smartphone) activities, passive activities, and talking on the phone (Singleton, 2017). A study of Northern California commuters (Malokin, Circella, & Mokhtarian, 2015) analysed the productive use of travel time on the commute and developed a score for the propensity to multitask (mostly associated with using a laptop, reading/writing electronically, or writing on paper) via different modes. Although this "multitasking propensity" score was positively associated with choosing commuter rail and shared car modes, an application to models of AV scenarios (assuming similar multitaskability to that of commuter rail) found modest shifts of around two percentage points towards auto modes.

One study of travellers' perceptions of the advantages of AVs validates these findings that travel-based multitasking now (and in the future) may be more about coping with the burden or boredom of traveling. Cyganski, Fraedrich, and Lenz (2015) asked 1,000 Germans about the perceived benefits of AVs under different use cases. Overall, the biggest stated advantages were "enjoy[ing] the trip and the landscape" and "talk[ing] to companions or other passengers;" only about 13% of respondents thought they would use an AV to "work during the trip." The authors conclude that "the underlying assumption of people wanting to spend their time 'productively' while traveling, if only they could, has to be regarded with caution" (p. 15). I concur.

3.4. What about other "positive utilities" of travel, especially subjective well-being?

As mentioned in the introduction, travel-based multitasking is but one of two components of the positive utility of travel concept. The other, subjective well-being, also has relevance for understanding relationships between AVs and values of time. As I explain in the following paragraphs, SWB may be an even stronger pathway through which AVs could affect travel behaviour.

Indeed, research suggests that subjective well-being concerns may influence travel behaviours (Singleton & Mokhtarian, in progress). "Liking" travel in general or by certain modes has been positively associated with total or mode-specific travel distances, durations, or frequencies (De Vos & Witlox, 2016; Schwanen & Mokhtarian, 2005; Xing, Handy, & Mokhtarian, 2010), although this relationship may not hold for all trip purposes (Ory &

Mokhtarian, 2009). If this is true, perhaps people consider expected SWB when choosing a travel mode; preliminary research suggests this may be the case. In the study of Portland commuters, a multi-item measure of hedonic SWB—a variant of the Satisfaction with Travel Scale (STS), created by Ettema and colleagues (Ettema et al., 2011)—was a significant and positive factor on mode choice. In fact, SWB measures were more strongly and consistently associated with commute mode choice than measures of travel-based multitasking (Singleton, 2017). Therefore, if further research corroborates these findings, we might expect SWB improvements to be a stronger pathway to VOT reductions of AVs than through productive uses of travel time.

Other more qualitative research findings about the meaning and purpose of traveling—and the motivations for automobile use, in particular—support the notion that traveling is about more than just getting to a destination, informing the relevance of SWB in the context of AV mobility. Several scholars have demonstrated the importance of intrinsic motivations (Mokhtarian, Salomon, & Singer, 2015) and non-instrumental factors in traveling and car use (e.g., Anable & Gatersleben, 2005; Steg, 2005). These factors can be related to emotions (affect): driving fast may be fun and exciting; riding the train might make the trip home from work more comfortable and relaxing. Traveling can also involve symbolic motives that evoke eudaimonic SWB: fast driving might help one express control, freedom, and social status, or it might fulfil a desire for variety and adventure. Jain and Lyons (2008) discuss how traveling can be viewed by some as a gift, providing both "transition time" and "time out" for travellers to experience distance, prepare for performing destination activities, escape from home and work obligations, or simply spend some time alone with oneself. It seems reasonable to expect that these psychological and sociological aspects of personal mobility will not disappear, and may even increase in importance, in an AV dominant future.

Nevertheless, there are good reasons not to overestimate the effect that AVs might have on VOT through the pathway of well-being improvements. First, since these non-instrumental motives for and benefits of driving are present today, they may already (to some extent) be "priced in" to existing VOT estimates. Any impact of AVs on VOT would have to come from some differential between the positive experiences of AV use and current modal experiences, such as an increase in stress relief or ability for "carcooning" (Lyons & Urry, 2005; Mokhtarian & Salomon, 2001).

Second, the benefits to travel-related SWB from the reduced physical and cognitive burdens of navigating a vehicle in traffic may come with other costs. True, if we assume AV riders will feel more like today's auto or transit passengers, then we would expect them to feel significantly less distressed (less upset, frustrated, angry, stressed, and hostile) than drivers, according to recent research (Singleton, in press). Yet, without the ability to spontaneously choose a route or feel mentally engaged and physically in control, AV riders may also have diminished assessments of autonomy (freedom, independence, and control), as do current passengers (Singleton, 2018). (On the other hand, AVs may enhance autonomy for mobility-limited populations (Milakis, van Arem, & van Wee, 2017).) Autonomy is an important component of eudaimonic SWB, and these emotional and symbolic aspects related to the independence, allure, and enjoyment of driving (or "car pride") seem to be closely tied to automobile ownership and use (Steg, 2005; Zhao & Zhao, 2015). These factors may have the potential to moderately diminish incentives for owning and choosing AVs.

4. Summary, hypotheses, and future work

4.1. Summary and hypotheses

To summarize, I presented emerging research findings contrary to the popular narrative that autonomous vehicles will enable much more productive uses of travel time (for working, reading, being entertained, sleeping, etc.), thus dramatically reducing subjective values of travel time savings. In contrast, I echo a small but growing chorus of scholars (e.g., Cyganski et al., 2015; Milakis, van Arem, & van Wee, 2017; Sivak & Schoettle, 2016) who argue that AV users may not necessarily use their newly available travel time for productive in-vehicle activities and thus that VOT impacts of AVs may be more modest than anticipated. This is one major pathway by which AVs could affect travel behaviour and increase auto travel demand and vehicle distances travelled, so understanding the motivations and mechanisms of these potential effects is important.

The reasons for asserting a more modest VOT impact are multifaceted. The experience of riding in an AV will likely be closer to that of a car passenger than a train passenger today, due to conflicts between vehicle acceleration and other motion tolerances designed for comfort and productive work and those necessary for AVs to enable operational efficiencies and capacity enhancements (LeVine et al., 2015). As a result, the types of activities AV users would feel comfortable doing (and the number of potential multitaskers given the prevalence of carsickness (Diels & Bos, 2016)) could be restricted. Similar trade-offs may arise over various AV business models. Local governments and mobility-as-a-service providers prefer business models centred on providing short-distance urban trips via shared and re-deployable AV fleets (Chase, 2017), but it is difficult to be productive on short-duration trips due to start-up loss times and minimum task durations. Additionally, people prefer riding in their own vehicles or riding alone to sharing rides with strangers (Zmud et al., 2016), so discomfort (and VOT) may be higher or could even increase for shared AVs with dynamic ride-sharing (Steck et al., 2018; Krueger et al., 2016; Yap et al., 2016).

While car passengers today do engage in more activities than car drivers, they still perform fewer and less varied kinds of activities than transit riders (Keseru & Macharis, 2018; Singleton, in progress). Even transit passengers (perhaps with the exception of long-distance train travellers) do not appear to be putting their travel time to very productive use. Instead, common instances of travel-based multitasking—watching scenery or people, daydreaming, talking with others, listening to music—seem to be more about coping with boredom or simply passing the time (Singleton, in progress, in press) and do not appear to be a significant driver of mode choice (Singleton, 2017). Indeed, survey respondents have suggested these common passive activities are the most apparent advantages of AVs, not the ability to work during the trip (Cyganski et al., 2015). It seems unlikely to expect a dramatic change in travel time use behaviour and travel motivations simply with the development of a variant on an existing mode.

Instead, if AVs do moderately or substantially reduce VOT, I expect this reduction to come more (or at least more than is typically acknowledged) from a different kind of positive utility: improvements to subjective well-being. Aspects related to SWB—including intrinsic motives for traveling (Mokhtarian et al., 2015) and non-instrumental affective and symbolic factors (Steg, 2005)—have been found to influence travel behaviours (De Vos & Witlox, 2016). Recent research suggests that expectations about SWB during travel may affect mode choices (Singleton, 2017), so it would be reasonable to assume that travellers might prefer an AV for the reductions in the stresses of driving (less negative emotion or affect) or to provide a time to transition between roles or a private space to be alone (Jain & Lyons, 2008). However, even in this area, there is reason to be cautious. These considerations may already be "priced in" to existing VOT estimates.

Furthermore, not everyone wants to cede control and vehicle operations over to a computer; some people enjoy the autonomy of driving a motor vehicle (Singleton, 2018; Zmud et al., 2016). What will these people do if not allowed to drive?

Certainly, the value of travel time—if we could give this abstract concept sentience—does not care about the source of the valuation, i.e., whether it comes from a productive use of travel time or from enjoyment, relaxation time, decreased stress, or increased comfort from the travel experience. A change in VOT from either source will yield a behavioural response that may not be able to be easily distinguished via observation alone. Nevertheless, transportation modellers, planners, and policy-makers should be interested in the source of VOT impacts, because it will affect the speed with which and situations in which these impacts occur as well as the actions that could be taken to encourage more sustainable or socially-desirable outcomes.

Of course, these discussions remain mostly speculative. The many ways in which the transition to a partially- or fully-autonomous future could take place affect VOT impacts differently. There may or may not be large, generational shifts in preferences and attitudes regarding automobility (McDonald, 2015), work–life boundaries (Duxbury, Higgins, Smart, & Stevenson, 2014), and the sharing economy (Cohen & Kietzmann, 2014) that we cannot account for by looking towards the recent past. Cost is the elephant in the room and will likely be a major factor in travellers' decision-making and the business models that emerge and survive. Public policies on future mobility (e.g., Chase, 2017) will also like play a major role. Additionally, the VOT concept accounts for the opportunity costs of time spent traveling, so it will be sensitive to changes in time use and productivity in other areas of life. (Values of travel time savings could even conceivably rise if technology enables the quality of leisure time to increase faster than the quality of traveling in AVs.) Spatial-temporal constraints (*a la* Hägerstrand, 1970)—such as the scheduling of activities and other requirements of co-presence—also influence VOT and will likely remain relevant into the future.

Nevertheless, I respectfully offer some hypotheses—based on the emerging research findings discussed earlier—about VOT impacts of various AV scenarios, acknowledging that other knowledgeable scholars may disagree and that I may (likely) be proven wrong as AV technologies see wider adoption. First, early AVs that require some human control in certain situations will see little to no VOT reduction; the same thing will occur if laws require a human occupant to be attentive and ready to assume control in case of emergency. Second, sharing AVs with strangers will be less comfortable (and have higher VOT) than privately owned AVs, but this may be counteracted if shared AVs are used by more cost-conscious customers (with lower VOT). Third, the impact of AVs on VOT will vary with trip distance, as longer-distance trips will see a larger VOT reduction (from a greater ability to multitask) than shorter-distance trips. Fourth and finally, if studies are able to empirically distinguish the sources or causes of VOT reductions, factors related to SWB will play a significant role (and maybe even a stronger one than that of productive in-vehicle time use) in these changes.

4.2. Future work

Given significant uncertainties about the future, how should the transportation research community approach these issues? First, future simulations could consider testing the sensitivity of their results to a wider range of VOT values, including more modest VOT reductions (0–25%) than have historically been analysed. They could model various AV operational strategies that account for the limits of comfortable human motion and in-vehicle activity participation. VOTs could also be varied in these simulations according to the assumptions of the previous paragraph (depending on the level of sharing and on trip distances). Furthermore, some potential counteracting forces could be examined with sensitivity testing. For instance, shared AVs will likely have lower monetary costs but higher time costs than private AVs. Also, AVs may be most attractive to longer-distance commuters, but AV-supportive infrastructure could be more costly and be installed more slowly in suburban/exurban areas, and shared AV fleets may not serve such lower density communities.

Second, I join Milakis, van Arem, and van Wee (2017) in calling for "more empirical studies of first-order implications of autonomous vehicles" (p. 343) using a variety of quantitative and qualitative methods. Combining revealed preference studies on travel-based multitasking with stated choice experiments about AVs that pivot off of existing trips could be of interest. The falling cost and increasing detail of wearable technology and virtual reality systems could be used to potentially yield more accurate stated preference responses regarding this hypothetical mode. Additionally, as I suspect a greater role for SWB enhancements from AVs, more research to improve the measurement of travel SWB and its behavioural impacts would also be valuable. Overall, as with any fast-changing and potentially transformative technology, the best strategy may be to remain nimble and continue doing such research as the situation evolves. We may not be able to predict the specifics of an autonomous future, but we may be able to monitor it and at least explain how and why it happened.

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