Using Time and Space Efficiently in Driverless Cars: Findings of a Co-Design Study

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ABSTRACT

The alternative use of travel time is one of the widely discussed benefits of driverless cars. We therefore conducted 14 co-design sessions to examine how people manage their time, to determine how they perceive the value of time in driverless cars and to derive design implications. Our findings suggest that driverless mobility will affect both people's use of travel time as well as their time management in general. The participants repeatedly stated the desire of completing tasks while traveling to save time for activities that are normally neglected in their everyday life. Using travel time efficiently requires using car space efficiently, too. We found out that the design concept of tiny houses could serve as common design pattern to deal with the limited space within cars and support diverse needs.

CCS CONCEPTS

• Human-centered computing~HCI design and evaluation methods
• Human-centered computing~Interaction design

KEYWORDS: Self-Driving Cars; Value of Time; Car Interior Design; Co-Design; Design-Fiction

ACM Reference format:
Gunnar Stevens, Paul Bossauer, Stephanie Vonholdt, Christina Pakusch. Using Time and Space Efficiently in Driverless Cars: Findings of a Co-Design Study. In *2019 CHI Conference on Human Factors in Computing Systems Proceedings (CHI 2019), May 4–9, 2019, Glasgow, Scotland, UK.* ACM, New York, NY, USA. Paper 405, **11** pages. https://doi.org/10.1145/3290607.3300635 1234567890

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CHI 2019, May 4-9, 2019, Glasgow, Scotland, UK.
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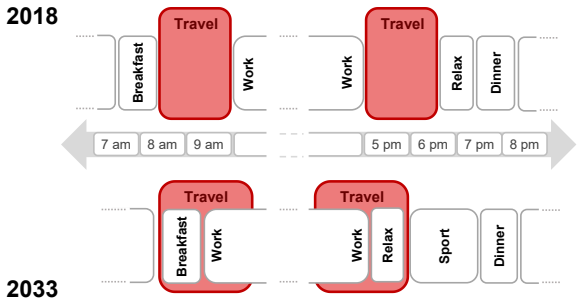
ACM ISBN 978-1-4503-5970-2/19/05...$15.00.
DOI: https://doi.org/10.1145/3290605.3300635

1 INTRODUCTION

Currently we are seeing a global test bed of advanced self-driving functions and driver assistance systems [6]. Although uncertainty on various levels exists, the scenario of driverless cars appears as a possible, close future [47, 48]. Not just an incremental innovation in safety and fuel-efficiency, driverless mobility presents a disruptive, controversially discussed innovation [6, 48, 71, 89]. Some people are afraid of relinquishing control and loss of driving fun and self-reliance [47, 82]. Others welcome the new mode of transportation as the democratization of the luxury of having private chauffeurs [47, 71]. There is growing awareness that the technology progress should be accompanied by a design shift, too: from a driver-centric design to a passenger-centric and service-oriented one [25, 39, 74, 92].

"The boundaries between travel time and activity time are increasingly blurred. Specifically, many people are using travel time itself to undertake activities." [52]

The quote by Lyons and Urry [52] sensitizes us to understand this design paradigm shift from a temporal lens. From the perspective of people's daily routines, the alternative use of travel time is one of the most remarkable benefits of driverless cars [12]. Moreover, this lens uncovers an activity-centric interior car design and does not study travel time in isolation. It bears in mind that travel time and activity time are interdependent in many ways (see Figure 1).



By using a comfortable, fully equipped driverless car in 2033, the daily routine of Mary, a 43-year-old product manager, has changed that some of her daily home and work activities (such as breakfast, office work, relaxation) have been transferred into the travel time to have more time for activities such as sport. In addition, the new driverless car has made her daily commute to work less stressful and more effective, so that she has accepted a longer travel distance and moved with her family to the countryside.

Figure 1. A design fiction [4] about travel and activity time

From this stance, we have conducted an explorative co-design study, where we aim to contribute to following open research questions:

(1) How do people manage their travel time and activity time today?
(2) What are perceived purposeful activities while traveling in self-driving cars in the future?
(3) What visions are there for enabling car interior design to provide a resource and environment for using travel time purposefully taking diversity into account?

2 UNDERSTANDING TIME

Time has a twofold character: it is mechanically measured but coupled with social meanings. Lauer [41] therefore juxtaposes *clock time* in opposition to *social time* – the latter being a temporal reference system constituted by social activities and expressed by the temporal patterns, temporal rules, and temporal symbols that organize and synchronize social life [15]. Temporal concepts are not static or natural but have an evolutionary character shaped by the particular socio-cultural context. Or as stated by Jeremy Rifkin [79]: *"Every culture has its own unique set of temporal fingerprints. To know a people is to know the time values they live by."*

In western societies, the economic view dominates: time is a scarce and valuable commodity that must be optimized [101]. Above all, this view applies to working life, where mechanization of production and the constitution of labor are aligned with a rational use of time aiming to achieve lower costs per unit of production. This attitude has also expressed itself in an increasing temporal control of workers. Delays, for instance, were tracked by the introduction of stamp cards and were penalized by wage deductions [101]. Promoted by the general acceleration of society and increasing time conflicts in everyday life, however, the economic time regimes spread from the economic sector into almost all other areas of life [64]. In particular, personal time has become an entity that must be managed and allocated according to subjective utility functions, whether measured in dollars per hour or pleasure per hour [22].

The increasing significance of clock time in modern life has not replaced social time, but still clock time has become a second nature for individuals. *Wright* [101] coined the word *chronarchy*, where it is not only a temporal pattern that exists but one where people are ruled and regimented by time-keeping. The extensive control of time is expressed by the omnipresence of time-keeping devices in the 20th century such as wristwatches, calendars, timetables, and real-time information systems.

The economic understanding also incorporates various temporal concepts such as *value of time* theories. In essence, these theories value individual's time by the willingness to pay for the time savings or by the opportunity costs measured by the money that could alternatively be earned during this time [2], [16]. This view has been applied to various domains, for instance studying the relative marginal utility of working hours while taking people's time budgets into account [2, 40], studying the housewife's time costs of production of child services [23], or studying time rebound effects substituting, e.g. household work by energy-intensive appliances [5]. Traveling can also be added to this list of domains as is outlined below.

The economic understanding also shapes common *time budget* and *time management* theories [18, 33, 81] that ask how people allocate, plan, und use time as a scarce resource in everyday life. From this stance, various studies regarded what people do with their time, how much time they spend on various activities when they have a low time budget, and how they experience time [34, 81]. The studies' activity categories vary, but working, housekeeping, relaxing, and sleeping were common main categories. Yet, there is the metrological challenge since activities are not mutually exclusive but are connected (e.g., taking care of children while watching TV with them) or done in combination to make the most efficient use of time (e.g., eating while traveling) [52].

A complementary view is provided by temporal concepts that emphasize the various meanings and uses of social time in different cultures and situations [27, 41, 75]. Lauer [41], for instance, mentions the culture of the Navajo, who have traditionally no view of temporality than to act on the basis of an expected future, but the only real time – as the only real space – is that which is the *here and now*. Several social theorists [65, 75, 84, 86] also highlight the nexus between space and time that constitutes the socio-temporal

order where action is taking place. Routinization presents the appropriation of such order, taking it for granted, using it as a resource to act and plan actions in advance [84].

With regard to this nexus, Torre [94] also speaks of the three qualities of time as being a *resource* for action, an *environment* where (non-)action is encountered that must be adapted to, and a double *horizon,* that enables meaning to be assigned to what has happened, what might be happening, and what is planned to happen.

3 DEALING WITH TRAVEL TIME

In transportation and mobility research, time is a key issue in many ways. The general acceleration of society, for instance, was accompanied by the acceleration of transport means, enabling the transport of countless goods and people over even longer distances and facilitating mobile and flexible forms of life [64, 87, 96].

Moreover, with the emergence of mass traffic, it became increasingly important to plan, coordinate, synchronize, and align the behavior of people, goods, and transport systems [26, 96]. With the advent and spread of the railway, for instance, timetables became necessary [36]. Nowadays advanced real-time transit information systems improve the usability of public transportation [20, 91, 100]. Transportation research has extensively studied activity and travel time as well as (but less extensively) the nexus between them [52]. In particular, *time budget* and *value of time* theories have been adopted to examine the valuation of travel time savings, e.g., with regard to travel mode choices (willingness to pay for travel time savings) [60], individual and national economic impact (time saving leads to more working), as well as impact of commuting on personal time budgets (travel time cutting the remaining time budget).

Transportation engineers and infrastructure planners typically focus on saving travel time, e.g., by increasing the speed of transportation modes [52]. However, there is a controversial debate whether a '*law of constant travel time budget*' [30, 60, 62] exists, which states that the average number of daily trips per person and the time budget allocated to transport show stability. In other words, people reinvest the saved time into the opportunity to travel longer distances.

Complementary to the quantitative view, there is an increasing interest in the quality facets of travel time, understanding traveling as a resource and environment for doing other activities [31]. In particular, various studies confirm the hypothesis from Lyons and Urry [52], demonstrating e.g., that cars are not just places for driving; they are for various activities. The most prominent example might be the use of mobile phones, which is well-studied concerning its effect on driving performance [46]. In addition, Laurent [42] and O'Hara et al. [67] uncovered practices to prepare car travels and use car time as a resource for doing office work. There is also a long tradition of enter- and infotainment design, making car time more enjoyable [29]. Several studies [11, 19, 43] further show that the car is also a place for social interaction in general and family time in particular.

Public transport systems, especially trains, are advanced modes of transportation concerning travel-time use [51]. They are places for various activities such as listening to music, eating, working, relaxing, etc. [51]. Moreover, trains provide various facilities to use travel time productively such as board restaurants, tables, power outlets, quiet zones, night sleepers, family compartments, etc. This feature of trains creates a comparative advantage, where people, for instance, accept longer travel time when using trains instead of cars [52].

Concerning the human factor of self-driving technology [45, 68, 72, 78], takeover interaction [37, 61, 99] and car-to-social environment interaction [6, 7] are unsolved design challenges today. In particular, temporal issues play a critical role in takeover interactions [37, 61, 99], where three phases on the transition event timeline can be defined: a scheduled takeover or the initial event causing an takeover, the handover of control phase and the phase handback control to the vehicle [56]. Concerning this, Mok et al. [61], also take passenger-centric activities such as playing games into account to disengage participants from the takeover task.

There are also a growing number of surveys about user acceptance of self-driving vehicles (e.g., [44, 53, 82]), showing that the acceptance depends on many factors including age, lifestyle, current mobility behavior, technology experience, etc., but also design and technology issues such as autonomy level and car design.

Findings of various studies show that driverless cars should radically break with the 100-year-old driver-centric design tradition [39, 49, 59, 74, 77]. In particular, the Dagstuhl seminar about automotive user interfaces in the age of automation [77] has outlined a possible research agenda, raising new questions as how to design interfaces to promote work and play by utilizing the space without passengers experiencing motion sickness. In a similar vein, Kun et al. [39] stress that the new focus should be on the passenger and the new possibilities of passenger-car interactions, asking what will be appropriate design metaphors [39].

In addition, various car companies have published concept studies on YouTube [1, 24, 57, 58, 63, 80, 83, 95, 97, 98]. Except the passenger-centric concept of Rolls-Royce [98] and Audi [1], the mentioned studies are quite driver-centric and still address the issue of how to use time in driverless car explicitly or implicitly (e.g. for working [80, 98], eating

& drinking [80, 98], sleeping [24], relaxing [80, 83, 98], talking together [57, 57, 63, 80], enjoy the view [63], info- and entertaining and gaming [57, 63, 97, 98], or making party [95]). A closer look further reveals the several car interior design elements such as retractable steering wheels [63, 80, 95, 97, 98], revolving chair [57, 63, 80, 97, 98], movable objects [97], extendable shelves [57, 63, 80, 98], ambient light [80, 95], interactive surfaces [1, 57, 58, 97], living room [1], multi-purpose environments [98] to support the various activities.

So far, only a few studies have studied the questions arising from this new research agenda, shifting the focus from the *active driver* to the *active passenger*. One of them is Pfleging et al. [74], who conducted a survey, what activities can be expected during a highly automated ride. The result was that the most frequently expected ones were talking to passengers, listening to music, and gazing out of the windows. Another study by Fraunhofer IAO and Horváth & Partners [21] focused on the economic value of time. In a web survey, they asked people in Germany, Japan and California about the willingness to pay for added values in highly automated cars. The findings show a general willingness to pay, specifically regarding communication, productivity, and basic needs. However, there are significant differences among the countries and the willingness also depends on the type of trip and how the services are implemented.

Laurier et al. [43] has noted that the interior of the car and its appropriation remain a largely unexamined space. The same holds for driverless cars, too. One of the few design studies comes from Lorsignol [49], where he draws a comparison to the airplane interior and service design in a blog post, concluding that currently passenger-centric features are more of an afterthought. In contrast, he argues that, in the future, the interior design focus will be on the passenger with comfort, customization, entertainment, productivity, and safety as essential goals.

4 METHODOLOGY

To answer the outlined research questions, we use the co-design methodology as an established method to understand future design issues from a user's perspective [85]. To contact and recruit participants, we used a combination of qualitative sampling [10] and snowball sampling [3]. In total, we conducted 14 individual co-design sessions with a broad spectrum of people regarding age, gender, job, and time and mobility management, mapping different perspectives in terms of diversity (cf. Table 1).

We visited the people so that the co-design was conducted in familiar places, such as a café for the elderly or in the participants' living rooms. On average, the interviews took about 40 minutes (min: 32 mins; max: 62 mins). Each session was structured as follows.

We started with semi-structured interviews. The questions were mainly formulated openly to create a less restrictive

Table 1. socio-demographic data of study participants

No	Gender	Age	Job	Children*	Regular Trip time**	Disposable Time***
P1	male	36	Expert in strategic projects	-	2 h per day [Car]	2
P2	female	26	Social worker in parental leave	1	20 min. per day [Car]	7
P3	male	80	Pensioner	-	15 km once or twice a week	6
P4	female	77	Pensioner	2 Grand-children	Using the bus for 3 years, no car	5
P5	female	67	Pensioner	-	10 min. per day [Car]	8
P6	male	37	Teacher	-	45 min. per day [Car]	3
P7	male	72	Pensioner, voluntarily active	-	10 – 20 km per day [Car]	5
P8	male	36	Personnel Officer/Recruiter	-	Min. 1.5 h, max. 6 – 9 h per day	1
P9	female	29	Clerk: Organization	-	2,5 h per day [Bike and Train] ca. 30 min. per day [Car]	2
P10	female	32	Product manager	-	1.5 – 2 h per day [Car]	4
P11	male	47	Head of management systems	1	2 h per day [Car]	1
P12	male	68	Civil servant in retirement, additional activity on 450 € basis	-	15 min. per day [Car], 40 min. per day [Train]	4
P13	male	47	Area manager	3	1.5 h per day [Car]	5
P14	male	18	Pupil helps in a drink market	-	1 h per day [Car]	4

[* Children living within the household. ** Most participants did not know their regular trip time exactly but provided a vague estimation (sometimes also in km instead of time). *** Perceived disposable time (1= time is too short, 10 = no perceived lack of time)]

and more explorative environment. We paid attention to leaving enough time to express personal views, unconventional ideas, and new topics. In these interviews, we surveyed basic socio-demographic data such as age, number of children, etc. We further asked about the participants' current use of the perceived time management and mobility behavior. In addition, we asked them to rate their *disposable time* on a 10-point scale where 1 means that time is too short, and 10 means there is no perceived lack of time.

Second, we adopted the concept of inspiration cards workshops [28] to foster reflection, creativity and to empower the participants to envision purposeful time use within the car. We used two card sets: The *Activity Cards* illustrate various passenger activity scenarios including using the car as an office, a gym, a restaurant or café, a kindergarten, a place for relaxing, entertaining, enjoying the view, or just as a place to sleep. The *Trip Cards* visualize common trip categories such as the way to work, the way home, and a business trip between appointments, shopping, and leisure or vacation trips. We asked about the interpretation of these cards and how the participants could imagine these interpretations being implemented. We also asked about possible services that might be used during the journey. Subsequently, the participants were asked to choose their top activity cards and assign them to possible reasons for a journey.

Third, we adopted the concept of interior design configurator as an established tool to empower end users expressing their demands and ideas in a spatial language [66]. They started by selecting a preferred car layout, choosing between a small, medium or upper-class car, SUV, sports car, or van. Then they created their personal interior car design by placing predefined equipment elements (such as a seat, table, or screen). We encouraged them to add their own ideas, too (see Figure 2).

In twelve cases, interviews were recorded and fully transcribed; in the other cases, only field notes were taken, for privacy reasons. We follow the qualitative content analysis guideline to develop a category system that was deductively informed by the previous literature survey and additionally expanded by inductive category development [55].

5 FINDINGS

5.1 Making more time for the beautiful things in life

We were impressed by the manifold, skillful routines for making more time in daily life, e.g., to shorten the time for work at home and have more time for cycling (P3), checking emails in a traffic jam (P8), or to schedule time by strict time management (P4). Still, many of the participants feel a lack of time and would like to have more. The greatest time constraints are experienced by the under 40-year-olds, while the over 60-year-old people in our sample express that they usually have enough time.

Concerning driverless mobility concepts, most of the participants had private cars in mind whereas only one expressed the carsharing concept explicitly. With regard to the general attitude towards driverless cars, various concerns have been voiced that e.g., the technology is neither mature, nor safe, nor affordable. Some also had concerns about giving up control over the car and that one might become sick while driving if not looking forward. The opportunity, however, to win time was positively welcomed by everyone.

Most would like to use the saved time for pleasure activities they miss in daily life today. Here, maintaining social contacts was the most mentioned. Eight of fourteen participants would like to spend more time with their family, their children, other relatives, and their friends. One benefit mentioned in the interviews was to make travel time more social. Even when driving together, travel time was perceived as less enjoyable by the drivers because of the limited interaction with the passengers. In contrast, several participants outlined the new options for socializing such as playing games or talking and listening attentively.

A preference was also stated for using travel time more productively by making more time for other activities outside the car. Here, several examples were given such as meeting friends in a café, visiting relatives, going shopping with the spouse, or bringing the child to sports activities. More time was also desired for leisure activities such as sports (cycling, running, playing badminton), going for a walk, watching movies, learning languages, reading books, or cooking. A few would also like to have more time for basic needs such as sleeping and having breakfast. Three participants wanted to use the time gained to relax and do nothing or use it as a buffer if necessary. Having time for themselves and simply relaxing on the terrace was desirable for them.

Time for creative activities was wished for by three participants, for instance, to do more craftwork such as knitting, carpentry, or crafting a table. Half of the participants also missed time for domestic work including gardening, renovating and repairing as well as housekeeping. Also having time for unpopular tasks such as cleaning up the cellar or completing the tax declaration was mentioned several times. These are tasks that are constantly pushed back.

5.2 The car as a place beyond transportation

Overall, the interviewees express a desire to gain more time. This was also reflected in the visions about the future car, which was not only perceived as a means of transport

from A to B but also as place where travel time could be used meaningfully. In particular, the selection of preferred Activity Cards indicated that the driverless car is both a place for work and a place for relaxing/enjoying. One striking aspect here was a spillover effect that the time use within the car seems related to the trip the car is used for. For instance, the car as a place for work is preferred in business, home-to-work and work-to-home trips. However, the car as a place for relaxing/enjoyment seems to be preferred for non-working related trips.

In the following, we discuss in more detail how these cards inspired our participants to reflect on the future car as a place for purposeful activities.

5.2.1 Office

The car as a place for working is the most frequently selected favorite (6 times topic 1 and 8 times in total). Especially for people under 40 years and mostly for men, it seems to be important that they can use travel time productively.

"If I have to decide I would choose the office activities. That would definitely be a very meaningful activity while using a driverless car" [P6]

Most participants would like to simply have more time for specific tasks such as reading up on topics, reading messages, writing e-mails, creating presentations, sorting documents, and talking with employees. The activities should be supported by the in-car equipment; however, the requirements seem to be strongly influenced by individual preferences and usage practices:

"A table, a chair, so that you can comfortably do office work, that you can put the laptop on the table or it is already available. A network connection would be important and lighting if you travel at night, for example a table lamp that is pleasant for the eyes." [P8]

"Network is definitely necessary. I have a notebook with me anyway. So, I don't need a table. I must be able to sit comfortably. I can place the laptop on my lap and that's fine [laugh]." [P10]

One motivation to use the travel time for work and work-preparation was to start a working day more relaxed and less stressfully. However, for us, it was surprising that even the 18-year-old student had considered the car as an extended workplace for similar reasons – which told us not just about individual preferences but also about the younger generations, too.

"I would actually take the office, because it is immensely time-saving, if you are heading home from school you can do your schoolwork. Therefore, you also need an atmosphere where you can concentrate" [P14]

The office is especially wanted on the way to work. In the morning, the participants may be more productive. After work it is slightly less attractive than, for example, relaxing on the way home. Four people also mentioned that they would like to work on business trips.

5.2.2 Enjoying the View

Enjoying the view was the second most preferred card (6 times topic 1 and 8 overall). However, there were strong differences between the generations. All over 60-year-olds chose this card as one of the top 3, while among the under-40s, only three out of seven did.

Frequently, it was suggested that the travel experience could be enriched by additional information about the current location, e.g., if passengers get information through speakers about places of interest or a visualization with a 360° camera for the landscape on a display that considers age-specific desires such as visual impairments.

"Binoculars would not be bad [...] when something interests you, because vision deteriorates with increasing age" [P12]

When asked about the design, the participants also became enthusiastic.

"What I could think of is very futuristic and would be that the information would be displayed within the car, as there is already the speedometer, [...] information about the environment, or individual information like where is the next supermarket, or when I am on holiday where are interesting places with interesting activities." [P2]

Enjoying the view is especially interesting for leisure and holiday trips. Two interrelated reasons seem to be responsible for this: people are more open to aesthetic experiences and they usually visit unknown regions and places during holidays when they are interested in having extra-ordinary experiences.

"Beautiful view with beautiful scenery would be nice, like in the train. Where you sit and think 'what a beautiful landscape'" [P8]

Because of the link to aesthetic experience, it is not surprising that enjoying the view was often associated with relaxation.

"Relaxation and enjoying the view is similar for me. I can relax well while I look outside and observe the area, so I'm finding it a bit hard to separate this, for me it is a mixture of both." [P8]

5.2.3 Relaxation

The desire for relaxation seems to be a prominent issue, but not in first place (only once topic 1, but 10 times in total). This is also reflected in the fact that it was usually mentioned related to other categories such as eating and drinking, a place to sleep, or a pleasant view while driving.

So, it seems that relaxation is more an *aspect* than an own *category* of driverless car experience.

"Relaxation and a pleasant view while driving belong together for me. I can relax well while I look outside and look at the area, so I have trouble to separate that. For me it's a mixture of these two." [P10]

Most of the participants would like to relax after work on their way home in the evening. Still, a fully equipped relaxation area seems to be popular only for leisure and holiday trips.

"A relaxation bus or train, why not? Then you can start the holiday already on the trip, a bookable relaxation room would be great. It would be nice to have private cabins, or at least a clear demarcation, so that you can really relax there." [P6]

Relaxation was also linked to feeling well and all-round feel-good atmospheres, which also could be created by adaptable mood lighting. Further, the massage chair was often mentioned for a relaxation area.

5.2.4 Restaurant or Café

The car as a restaurant/café was another example of a common, but secondary satisfying issue (only 1-time topic 1, but 8 times in total). This category is usually connected to eating snacks and drinking while traveling. Overall a fast-food style was preferred, where no larger dishes or staff service are needed.

However, it was noticeable that the female participants tended to interpret the restaurant/café as a social place. Four out of five women expressed their desire to drink a coffee with others, sitting opposite each other. For men, this issue did not appear at all. They also do not necessarily need food and café equipment inside the car. They prefer to spend more time outside the car, at home or in a restaurant, and cooking without hassle.

"For cooked dishes, I would prefer a real restaurant, where I can eat and drink without a hassle and enjoy observing my environment." [P12]

The car as a restaurant or café place was most popular for holiday trips but some also liked this idea on leisure trips.

"Basically, I would like the thought of eating or drinking something while using an autonomous car, especially on a long trip and when I forgot to have breakfast." [P5]

5.2.5 Entertainment

Entertainment is appreciated by both genders equally but was mentioned less often (only once topic 1, but 3 times in total). Entertainment equipment such as television, but also community games such as Monopoly or Scrabble, were suggested as social activities while traveling.

"If I use the autonomous car with several people, then I could imagine playing board or card games. What I like to play for example is Scrabble or card games, where you need space to discard something. Therefore, a table would be great for playing games, […]" [P5]

The car as a special place for entertainment was mainly desired for holiday trips.

5.2.6 Sleeping Place

For the participants, sleeping in the car is mostly associated with relaxation, and a place to sleep would therefore promote relaxation. Sleeping as a basic activity also seems to be an important issue, but it was not in first place for autonomous cars (only once topic 1, but 5 times in total). One reason is, that long-distance and over-night travels are exceptional, which does not justify the large space cost of a comfortable place to sleep. Dealing with space as a scarcity, most preferred armchairs for little naps as a good compromise.

"The best thing would be a bed. But if a bed doesn't fit, then certainly a seat that can be brought into a pleasant and almost lying position, so that one can also sleep well." [P9]

Only long-distance trips, as in the case of a holiday trip, a bed was preferred as much more comfortable: "*If it is a long way, I could definitely imagine sleeping in there [the bed]." [P4]*

5.2.7 Sport

Various participants would like to have more time for sports, but do not perceive the car as the right place (zero times topic 1 and only 2 times in total). Moreover, the participants that like sport activities within the car were very skeptical concerning space requirements and safety issue.

"I can hardly imagine sports in a car because of the missing room in which I could place for example a treadmill. I really don't know how exactly this could look." [P9]

5.2.8 Kindergarten

Kindergarten was only selected once (zero times topic 1 and only once in total). The reasons for the poor rating might result from our sample structure, where only one person had a child in kindergarten age. In addition, the category name *Kindergarten* did not inspire our participants to reflect on the car as a place for family work in general. The few responses, however, indicate a problem of space where compromises must be made compared to existing solutions outside the car.

"A small corner with little toys for grandchildren, nothing great, unless you have such a spaceship." [P12]

5.3 Genres and patterns of car interior design

"Every object tells a story... if you know how to read it" - Henry Ford (quoted by [35])

5.3.1 Design Genres

We adopted the concept of design genre from media and design theory to talk about categories of design that are co-constructed by producers and consumers and characterized by recurrent pattern of use expectations, narrative structure, function-material format, and typical design elements and design patterns [50].

Common categories in the car industry, e.g., compact cars, sport cars, SUV, etc., can be seen as design genres in this sense. Or more precisely, they present sub-genres of the overall driver-centric design genre that is taken for granted today. A striking feature of our co-design study is that the created car layouts completely break with this tradition. In contrast to the driver-centeredness of car design today, the layouts express a passenger-centric, or more precisely an activity-centric, interior design making the car a second place to be.

Comparing the various layouts from this stance, we noticed two distinct kinds of interior designs. The first we call designs for specific purposes. In contrast, we also observed designs for diverse kinds of activities. We call these recurrent examples the genre of mobile, tiny house.

5.3.1.1 Interior design for specific purposes

Five of the fourteen layouts were characterized by being clearly for a specific purpose. One layout focuses on taking a snack as a social activity. The narrative structure was the one of a small, French bars, where one sits face to face at a small table drinking coffee together in a cozy atmosphere. Nearby a table with two seats, a coffee machine, a refrigerator, and a kitchenette were placed.

Two other layouts focus on relaxation, but one with a focus on a single person while the other has more people in mind. The narrative structure was one of a living room, inviting a retreat to the comfortable armchair nook for some cozy chat or just watching TV.

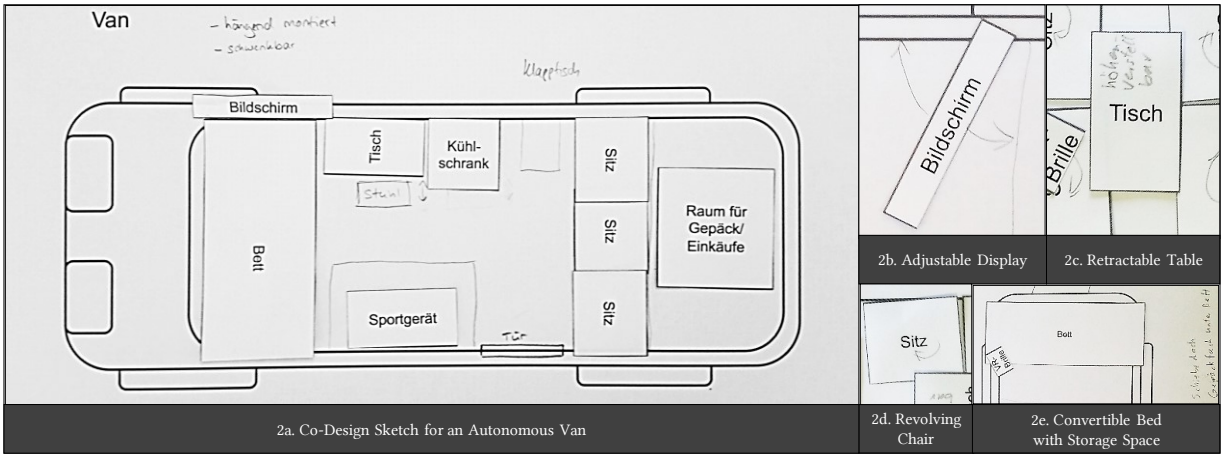
Two layouts are passenger-centric concepts that also could be interpreted as the future interior designs of premium or business class ride services. Both layouts include two seats, a snack area (coffee maker or refrigerator) and a luggage area. They differ with respect to providing either a working place or a place to take a shower.

5.3.1.2 Mobile, Tiny Houses

Nine of the fourteen layouts do not have a clear focus on one specific activity. They are rather designed to support diversity as micro-apartments that cover a wide range of domestic and working activities such as doing sport or office work, relaxing, cocooning together, and taking a snack (Figure 2a presents an example of this design genre). In their narrative structure, they are reminiscent of mobile and tiny houses, in which the furniture is very space-saving and functionally arranged due to spatial constraints [9]. In most sketches, everything looks very crowded, similar to campers used for holiday trips.

We identified two sub-types of the tiny house genre. The first one combines a bedroom, a kitchen, a living room, and a bathroom within one zone, whereas in the second type zones were separated for different activities such as working and relaxing. This second one mirrors today's flat architectures separating living room from bedroom or office room.

Typically, the sketched solutions express a kind of multi-functional architecture, making use of various patterns and making the interior space-saving and flexible. Still this design concept allows the residents of such mobile, tiny houses a wide variety of activities during travel time. They all look very compact, partially crowded and express a need for more space.



2a. Co-Design Sketch for an Autonomous Van | 2b. Adjustable Display | 2c. Retractable Table | 2d. Revolving Chair | 2e. Convertible Bed with Storage Space

Figure 2. Co-design sketches of an autonomous car

5.3.2 Design Patterns

In this paper, we understand design patterns as repeated socio-spatial configurations that are used to cope with common design problems [13]. To identify such patterns, we pinned all sketches together on a board, comparing them and studying similarities and salience. We further analyzed what might be the underlying design problem where the sketched configuration presents a possible solution.

In the next step, we describe the most common and notable ones we identified.

5.3.2.1 Needing space to make use of travel time

It was noticeable that the majority chose a large car layout. In total, five participants chose a van, three a SUV, five a medium-sized car, and only one a compact car layout. The medium-sized cars were mostly chosen to remain realistic. The small one was deliberately chosen for energy efficiency reasons and the vision that cars in the future will become small capsules. Vans and SUVs were mostly chosen to have as much space as possible. The additional space provided by vans and SUVs, however, does not lead to more free area but was used for a quite crowded interior design similar to tiny houses that support a wide range of activities.

5.3.2.2 Basic Equipment

A common pattern was to provide basic equipment in the car such as a refrigerator (12 times), a coffee machine (10 times), chairs (in every sketch), a table (in every sketch) and displays (11 times) into the autonomous vehicle. This reflects a basic need for relaxing, eating a snack, drinking a coffee, working or watching a movie on a trip.

The fridge and coffee bar were always placed close to each other, if both were desired. They should be accessible from the seats. Sometimes even a freezer was desired, which can be placed in the trunk. Good sound equipment was also desired as a general interior design element.

5.3.2.3 Revolving Chair

A pattern in the placement of the seats was to look forward during the ride. However, adaptable seats were repeatedly sketched, allowing users to turn the orientation (this was often indicated by arrows as shown in Figure 2d). This adaptable design provides more freedom for use. For instance, changing the orientation of the seats, one can sit in front of other passengers to talk, play, or share food and drink. Also, changing the backrest from a normal to a comfort position was desired to support activities, working, and relaxing. Sometimes seats were also sketched as optional, to remove them if space for other items or equipment was needed.

5.3.2.4 Retractable Furniture

Another repeated pattern was to sketch various forms of retractable furniture. In particular, tables were often sketched foldable, slidable, retractable, or height-adjustable (this was often indicated by arrows and annotations as shown in Figure 2c). Tables were always placed near the seats. Regarding this, we identified two main functions: Firstly, tables can serve as social objects placed between opposing or adjacent seats. Second, tables can be placed in front of a seat to work.

Commonly, screens and information displays were sketched flexible, foldable, and, if necessary, scalable, too (see Figure 2b). They were often positioned opposite seats or beds. Some participants also placed them in front of the windshield. Still, they were always sketched as flexible ones, so that they would not permanently block the front view. In addition, various forms of small screens were sketched that could be folded out from a table or from the ceiling.

Sports equipment occurred only as an exception in the sketches. If people sketched them, they were flexible (either optional accessories or scalable in size), so that they only occupy space when used. We found a similar pattern for beds that were sketched as a convertible solution, sharing the space with the luggage area (see Figure 2e). Space for luggage was always placed behind, at the very least supplemented by small shelves in the interior. Some supplemented their designs by a transport option at the rear to carry bicycles.

5.3.2.5 Adaptable Light Atmosphere

Some of the participants mentioned adjustable light settings within the car to customize the light atmosphere depending on the mood. One person expressed the idea of mood lighting with changing colors and intensity depending on the activities they were carrying out, e.g., specific colors for working and relaxing.

"Mood lighting, you already have it in cars today, but if you don't have to drive yourself, you can of course play a lot more, with light, color or whatever, I would just like to feel good in the car, like at home in the living room too, different settings for working or relaxing. "[P2]

5.3.2.6 Dynamic Privacy Boundary Regulation

Chassis are not just functional but present a boundary between the car as a private place and the street as a public space. In car design, this boundary is realized by doors and windows regulating the transition of information, people, and goods between inside and outside. Regarding this, the layouts express a wide variety of individual privacy preferences. Most of our participants wanted windows as large as possible, bright, with a panorama view. Some participants wished for a panoramic roof or a panoramic lounge in the front part. Others, however, wanted darkened

windows for their privacy. Bringing this demand in line with a private, but also ample and spacious room at the same time, a common pattern was to provide a dynamic boundary regulation. Often the desire was expressed to darken or blur windows, e.g., for sleeping and for other intimate moments.

6 DISCUSSION

There is more than a 100 year tradition of driver-centric car design; but there is also a long tradition in envisioning self-driving cars [76]. A prominent example in popular culture is Johnny Cab from the movie Total Recall, a chauffeur-like robot close to the steering mechanism and passenger seats in the back [54]. There is a growing awareness of wanting to overcome this driver centricity [39, 49, 59, 74, 77], but still dealing with the steering wheel seems to be the common issue in many professional concept studies [24, 57, 58, 63, 80, 95, 97].

6.1 From driver-centric to activity-centric design

To prevent misunderstanding, the aim of our study was not to predict or prescribe that future cars will exactly look like the sketched interior designs. First, the sketches created do not appear to be implementable and do not take several design constraints into account, e.g., safety, security, and motion sickness issues. Second, the sketches are not based on first-hand experience traveling with driverless cars, so they are highly tentative and speculative. Instead they complement professional concept studies published on YouTube [1, 24, 57, 58, 63, 80, 83, 95, 97, 98] by design fictions [4] made by ordinary users to provoke common ways of design thinking and inspiring designers to transcend conventional concepts.

Previous studies showed that cars are places to perform various activities such as working, socializing, or relaxing [11, 43, 52, 67, 74]. Driverless cars therefore offer new possibilities in two dimensions. First, using cars instead of driving them creates more time for other in-car activities. Second, saving the driver's place makes more space for other interior design features, enabling new in-car activities, making them easier and more comfortable. Despite the various concerns about giving up control, the effect of having more time was welcomed by all participants.

The findings suggest that, in a driverless age, the current design paradigm will be replaced by a new paradigm characterized by a differentiation of various post-driver centric design genres. Like we could see by some professional concept studies [1, 83] the interior design concepts might focus on a specific purpose such as relaxation, working, passaging, etc. In addition, solutions seem to be attractive that integrate as many opportunities as possible to support diversity and that result in the design genre of mobile, tiny houses. This issue is partly addressed by the multi-functional environments idea of the Volvo concept study [98].

The findings further demonstrate that in-car space is a scarce resource. Using it efficiently will become a huge design challenge in the future. A repeatedly expressed pattern for coping with this challenge was to provide flexible in-car equipment that can be swiveled, rotated, or folded, or be an optional element. Several of the ideas sketched by the users can also be found in the professional concept studies. This confirms the importance of the issue. Our user study shows that the efficient use of space is a real user need. Regarding this, the pattern of adaptable and multifunctional interior design indicates remarkable solutions for making better use of the scarce space. Our study further suggest learning from existing tiny and mobile home design concepts, where there is considerable experience in creating a place to dwell and inhabit in the tightest of spaces [88]. In particular, Buckminster's experimental prototypes of the Dymaxion car from 1933 [35] look like visionary design studies about the new challenge of doing more with less space.

Some of the sketched concepts such as the folding table show a similarity with design solutions established in trains and airplanes. Hence, it seems useful to analyze the socio-material interior design of these transportation modes systematically to benefit from their long tradition of passenger- and service-centric design [8]. The metaphor of cars as tiny houses encourage studying the interaction concepts of Smart Homes research, adopting common concepts such as smart furniture, ambient light, or home experience design [32, 73, 93] so that people feel at home within their cars.

The activity-centric car design has important implications for the engineering of driving algorithms, too. So far, speed was a key factor [52]. Focusing on the productive value of traveling time, however, slower, but more defensive driving becomes equally important in increasing the satisfaction of in-car activities and reducing motion sickness [14].

6.2 Designing with people's daily time management in mind

The ongoing acceleration of the rhythm of life presents the unique temporal fingerprint of modern societies [79]. In our study, most people, especially the younger ones, did not feel comfortable with their current time budget. The workload leaves too little time for the beautiful things in life. This lack of time is a key driver in searching for new opportunities to combine and compress activities. Travel time and activity time are thus not detached from each other but entwined in many respects [52]. Regarding this, direct effects are those that influence travel time as resource for actions [94]. In trains, for instance, it is common that people are not just transported from A to B

but use travel time productively. Here, our study confirms previous findings that this also holds for cars [43, 52, 67], especially that using travel time productively presents one of the most valuable feature of driverless cars [12, 21, 74]. This view also corrects the partly false image that the emerging technology will disempower the human as the role of the *active driver* switches to *passive passenger* [76]. However, our study suggests that *passengers* are and will be quite *active.* Hence, we expect that driverless cars will lead more to a shifting of power rather than a one-sided deprivation of power.

The indirect effects are those on the overall time management and the socio-temporal organizations of daily routines. It is reasonable that, e.g., working time, will be shifted to travel time and the saved time will be used for leisure and domestic activities (e.g., by heading for home earlier). Bearing in mind previous research on constant and mode specific time travel budgets [30, 52, 62], it is also plausible that savings will be (partially) reinvested in travel time – so that the net-effect of driverless cars will be not just having more time but more traffic, too.

6.3 Owning or sharing cars in future

Some researchers assume that, in the future, private cars will be replaced more and more by driverless mobility services [17, 38, 71, 90]. Our findings on this topic suggest that ownership and usership scenarios are likely to co-exist in the medium to long term.

First of all, robo-cabs will get cheaper because of saved wage costs [48], making mobility services more attractive for everybody. In addition, saving the driver-space, more comfortable cabs can be built to use travel time effectively. For the luxury segment, the concept study of Rolls-Royce [83] and Audi [1] are good examples of this trend. They were supplemented by sketched passenger-centric layouts of our participants which seem to be more suitable for the mass market. So, an increased market share can be reasonably expected – also at the expense of other mobility services such as public transportation and traditional carsharing [69, 70].

However, our study indicates that private cars will not become obsolete for various reasons: In contrast to shared mobility services, the private car facilitates a domestic mode of dwelling, where car-owners like home-owners can control which person can visit their home at which time [52]. The sketched layouts of cozy bars or living rooms demonstrate that the desire for a domestic mode of dwelling will not become obsolete in the future; the opposite is true. In addition, the observed diversity of lifestyles and individual demands indicate that future cars will be furnished as personal as homes are today.

Last, but not least, using travel time as a resource demands that it has a stable socio-material order for the user [84]. Therefore it is important that everything has its place and that work and leisure materials can be left in the car, minimizing the effort required to carry them from place to place as well as the set-up times the next time the car is used as a place for play and work [39, 52]. Owning driverless mobile homes and offices instead of using shared mobility services increases the availability, predictability, and planning certainty of using travel time as a resource for activity time.

7 CONCLUSION

This paper has outlined a temporal lens that understands in-car time as a resource and environment for action. This view aims to inform and inspire design researchers to overcome the traditional way of thinking of in-car interior design. It highlights the notable feature that drivers become active passengers, which affects people's use of time within and outside the car. Therefore, it is important to consider the user's perspective when designing driverless cars, especially for reasons of diversity.

Under the dominating circumstances, however, it is unclear if this feature presents a desired utopia or a nightmarish dystopia. On the one hand, driverless mobility might lead to a deceleration of life enabling more time for the beautiful things in life and fostering the pro-environmental shared mobility [38], too. The chronarchy of western societies today [102], however, abet development paths where the saved time might be re-invested in working longer and traveling longer distances [52] alone in heavy-weight, big-size tiny house cars while using enormous amounts of fuel and space.

Which future scenarios will become reality is an open question. Still with this closing remark, we want to raise awareness that we should not consider only the direct design context but reflect also on the specific socio-material context we design for [87] and the time values people live by [79].

REFERENCES

[1] Audi Audi Aicon Concept INTERIOR (High Tech Living Room on Wheels) LUXURY SUV | LEVEL 5 Autonomous Car.

[2] Becker, G.S. 1965. A Theory of the Allocation of Time. The economic journal. (1965), 493–517.

[3] Biernacki, P. and Waldorf, D. 1981. Snowball sampling: Problems and techniques of chain referral sampling. Sociological methods & research. 10, 2 (1981), 141–163.

[4] Blythe, M. 2014. Research through design fiction: narrative in real and imaginary abstracts. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (2014), 703–712.

[5] Brenčič, V. and Young, D. 2009. Time-saving innovations, time allocation, and energy use: Evidence from Canadian households. Ecological Economics. 68, 11 (2009), 2859–2867.

[6] Brown, B. 2017. The Social Life of Autonomous Cars. Computer. 50, 2 (2017), 92–96.
[7] Brown, B. and Laurier, E. 2017. The Trouble with Autopilots: Assisted and Autonomous Driving on the Social Road. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (2017), 416–429.
[8] Camacho, T.D. et al. 2013. Pervasive technology and public transport: Opportunities beyond telematics. IEEE Pervasive Computing. 12, 1 (2013), 18–25.
[9] Carlin, T. 2014. Tiny homes: Improving carbon footprint and the American lifestyle on a large scale. Celebrating Scholarship & Creativity Day. (Apr. 2014).
[10] Coyne, I.T. 1997. Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries? Journal of advanced nursing. 26, 3 (1997), 623–630.
[11] Cycil, C. et al. 2014. Designing for frustration and disputes in the family car. (2014).
[12] Cyganski, R. et al. 2015. Travel-time valuation for automated driving: A use-case-driven study. Proceedings of the 94th Annual Meeting of the TRB (2015).
[13] Denef, S. et al. 2011. Designing for social configurations: Pattern languages to inform the design of ubiquitous computing. International Journal of Design. 5, 3 (2011).
[14] Diels, C. 2014. Will autonomous vehicles make us sick. Contemporary Ergonomics and Human Factors. (2014), 301–307.
[15] Elias, N. 1994. The civilizing process, trans. Edmund Jephcott. Oxford: Blackwell. 65, (1994), 1.
[16] Evans, A.W. 1972. On the theory of the valuation and allocation of time. Scottish Journal of Political Economy. 19, 1 (1972), 1–17.
[17] Fagnant, D.J. and Kockelman, K.M. 2014. The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. Transportation Research Part C: Emerging Technologies. 40, (2014), 1–13.
[18] Feldman, L.P. and Hornik, J. 1981. The use of time: An integrated conceptual model. Journal of consumer research. 7, 4 (1981), 407–419.
[19] Ferguson, H. 2009. Driven to care: The car, automobility and social work. Mobilities. 4, 2 (2009), 275–293.
[20] Ferris, B. et al. 2010. OneBusAway: results from providing real-time arrival information for public transit. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (2010), 1807–1816.
[21] Fraunhofer IAO and Horváth & Partners 2016. »The Value of Time« Nutzerbezogene Service-Potenziale durch autonomes Fahren.
[22] Goodchild, M.F. and Janelle, D.G. 2004. Spatially integrated social science. Oxford University Press.
[23] Gronau, R. 1973. The effect of children on the housewife's value of time. Journal of Political Economy. 81, 2, Part 2 (1973), S168–S199.
[24] Groupe PSA 2016. OpenLab Design - le véhicule autonome et connecté vu par la génération Y.
[25] Guenes, E.B. et al. 2018. The Digital Driver of the Future—User Experience Research on Generation Z in Germany. Road Vehicle Automation 4. Springer. 57–68.
[26] Hägerstrand, T. 1985. Time-geography: focus on the corporeality of man, society and environment. The science and praxis of complexity. (1985), 193–216.
[27] Hall, E.T. 1984. The dance of life: The other dimension of time. (1984).
[28] Halskov, K. and Dalsgård, P. 2006. Inspiration card workshops. Proceedings of the 6th conference on Designing Interactive systems (2006), 2–11.
[29] Heikkinen, J. et al. 2013. Mobile devices as infotainment user interfaces in the car: contextual study and design implications. Proceedings of the 15th international conference on Human-computer interaction with mobile devices and services (2013), 137–146.
[30] Hupkes, G. 1982. The law of constant travel time and trip-rates. Futures. 14, 1 (1982), 38–46.
[31] Jain, J. and Lyons, G. 2008. The gift of travel time. Journal of transport geography. 16, 2 (2008), 81–89.
[32] Jakobi, T. et al. 2017. The Catch (es) with Smart Home: Experiences of a Living Lab Field Study. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (2017), 1620–1633.
[33] Johnson, M.B. 1966. Travel time and the price of leisure. Economic Inquiry. 4, 2 (1966), 135–145.
[34] Kahneman, D. et al. 2004. A survey method for characterizing daily life experience: The day reconstruction method. Science. 306, 5702 (2004), 1776–1780.
[35] Kennedy, R. 2015. Looking back to move forward: the Dymaxion revisited. Procedia Technology. 20, (2015), 46–53.
[36] Keyes, R. 1991. Timelock: How life got so hectic and what you can do about it. Harpercollins.
[37] Koo, J. et al. 2015. Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust, and performance. International Journal on Interactive Design and Manufacturing (IJIDeM). 9, 4 (2015), 269–275.
[38] Krueger, R. et al. 2016. Preferences for shared autonomous vehicles. Transportation research part C: emerging technologies. 69, (2016), 343–355.
[39] Kun, A.L. et al. 2016. Shifting gears: User interfaces in the age of autonomous driving. IEEE Pervasive Computing. 15, 1 (2016), 32–38.
[40] Lancaster, K.J. 1966. A new approach to consumer theory. Journal of political economy. 74, 2 (1966), 132–157.
[41] Lauer, R.H. 1981. Temporal man: The meaning and uses of social time. (1981).
[42] Laurier, E. 2004. Doing office work on the motorway. Theory, Culture & Society. 21, 4–5 (2004), 261–277.
[43] Laurier, E. et al. 2008. Driving and 'passengering': Notes on the ordinary organization of car travel. Mobilities. 3, 1 (2008), 1–23.
[44] Lee, C. et al. 2017. Age Differences in Acceptance of Self-driving Cars: A Survey of Perceptions and Attitudes. International Conference on Human Aspects of IT for the Aged Population (2017), 3–13.
[45] Lee, K.J. et al. 2014. Partially intelligent automobiles and driving experience at the moment of system transition. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (2014), 3631–3634.
[46] Lipovac, K. et al. 2017. Mobile phone use while driving-literary review. Transportation research part F: traffic psychology and behaviour. 47, (2017), 132–142.
[47] Lipson, H. and Kurman, M. 2016. Driverless: Intelligent Cars and the Road Ahead. MIT Press.
[48] Litman, T. 2014. Autonomous vehicle implementation predictions. Victoria Transport Policy Institute. 28, (2014).

[49] Lorsignol, F. 2016. The next big paradigm shift in automotive design. Felix Lorsignol.
[50] Löwgren, J. 2006. Articulating the use qualities of digital designs. Aesthetic computing. (2006), 383–403.
[51] Lyons, G. et al. 2007. The use of travel time by rail passengers in Great Britain. Transportation Research Part A: Policy and Practice. 41, 1 (2007), 107–120.
[52] Lyons, G. and Urry, J. 2005. Travel time use in the information age. Transportation Research Part A: Policy and Practice. 39, 2 (2005), 257–276.
[53] Madigan, R. et al. 2016. Acceptance of automated road transport systems (ARTS): an adaptation of the UTAUT model. Transportation Research Procedia. 14, (2016), 2217–2226.
[54] Matt Rollins Total Recall - Johnny Cab.
[55] Mayring, P. 2014. Qualitative content analysis: theoretical foundation, basic procedures and software solution. (2014).
[56] McCall, R. et al. 2016. Towards a taxonomy of autonomous vehicle handover situations. Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (2016), 193–200.
[57] Mercedes-Benz 2015. Mercedes-Benz F 015 Concept Car.
[58] Mercedes-Benz The F 015 Luxury in Motion Future City - Mercedes-Benz original.
[59] Meschtscherjakov, A. et al. 2015. Experiencing Autonomous Vehicles: Crossing the Boundaries between a Drive and a Ride. Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (2015), 2413–2416.
[60] Metz, D. 2008. The myth of travel time saving. Transport reviews. 28, 3 (2008), 321–336.
[61] Mok, B. et al. 2017. Tunneled in: Drivers with active secondary tasks need more time to transition from automation. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (2017), 2840–2844.
[62] Mokhtarian, P.L. and Chen, C. 2004. TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets. Transportation Research Part A: Policy and Practice. 38, 9 (2004), 643–675.
[63] Nissan 2015. Together We Ride.
[64] Nowotny, H. 2015. Time: The modern and postmodern experience. John Wiley & Sons.
[65] Oevermann, U. 1981. Fallrekonstruktionen und Strukturgeneralisierung als Beitrag der objektiven Hermeneutik zur soziologisch-strukturtheoretischen Analyse. (1981).
[66] Oh, H. et al. 2004. What virtual reality can offer to the furniture industry. Journal of Textile and Apparel, Technology and Management. 4, 1 (2004), 1–17.
[67] O'Hara, K. et al. 2002. Exploring the relationship between mobile phone and document activity during business travel. Wireless world. Springer. 180–194.
[68] Ohn-Bar, E. and Trivedi, M.M. 2016. Looking at humans in the age of self-driving and highly automated vehicles. IEEE Transactions on Intelligent Vehicles. 1, 1 (2016), 90–104.
[69] Pakusch, C. et al. 2018. Shared Autonomous Vehicles: Potentials for a Sustainable Mobility and Risks of Unintended Effects. (2018).
[70] Pakusch, C. et al. 2018. Unintended Effects of Autonomous Driving: A Study on Mobility Preferences in the Future. Sustainability. 10, 7 (Jul. 2018), 2404. DOI:https://doi.org/10.3390/su10072404.
[71] Pakusch, C. et al. 2016. Using, Sharing, and Owning Smart Cars-A Future Scenario Analysis Taking General Socio-Technical Trends into Account. Proceedings of the 13th International Joint Conference on e - Business and Telecommunications (ICETE 2016) (2016).
[72] Paredes, P.E. et al. 2018. Fast & Furious: Detecting Stress with a Car Steering Wheel. Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (2018), 665.
[73] Petermans, A. and Pohlmeyer, A. 2014. Design for subjective well-being in interior architecture. (2014).
[74] Pfleging, B. et al. 2016. Investigating user needs for non-driving-related activities during automated driving. Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia (2016), 91–99.
[75] Rawls, A.W. 2005. Garfinkel's conception of time. Time & Society. 14, 2–3 (2005), 163–190.
[76] Regtop, K. 2016. The self-driving vehicle in video advertisements.
[77] Riener, A. et al. 2016. Automotive User Interfaces in the Age of Automation (Dagstuhl Seminar 16262). Dagstuhl Reports (2016).
[78] Riener, A. et al. 2016. Workshop Automotive HMI. Mensch und Computer 2016–Workshopband. (2016).
[79] Rifkin, J. 1987. Time wars: The primary conflict in human history. Henry Holt and Co.
[80] Rinspeed 2014. Rinspeed XchangE concept video presentation.
[81] Robinson, J. and Godbey, G. 2010. Time for life: The surprising ways Americans use their time. Penn State Press.
[82] Rödel, C. et al. 2014. Towards autonomous cars: the effect of autonomy levels on acceptance and user experience. Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (2014), 1–8.
[83] Rolls-Royce Motor Cars 2016. The visionary Rolls-Royce 103EX. Journey into the future of luxury.
[84] Ryan, D. 2005. Time and social theory. Encyclopedia of Social Theory ,. Thousand Oaks, CA: Sage.
[85] Sanders, E.B.-N. and Stappers, P.J. 2008. Co-creation and the new landscapes of design. Co-design. 4, 1 (2008), 5–18.
[86] Schutz, A. 1967. The phenomenology of the social world. Northwestern University Press.
[87] Sennett, R. 2011. The corrosion of character: The personal consequences of work in the new capitalism. WW Norton & Company.
[88] Slavid, R. 2009. Micro: Very Small Buildings. Laurence King Publishing.
[89] Smolnicki, P.M. and Sołtys, J. 2016. Driverless Mobility: The Impact on Metropolitan Spatial Structures. Procedia Engineering. 161, (2016), 2184–2190.
[90] Spieser, K. et al. 2014. Toward a systematic approach to the design and evaluation of automated mobility-on-demand systems: A case study in Singapore. Road Vehicle Automation. Springer. 229–245.
[91] Stein, M. et al. 2017. Mobility in later life: Appropriation of an integrated transportation platform. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (2017), 5716–5729.

[92] Stevens, G. et al. 2016. From a Driver-centric towards a Service-centric lens on Driverless Cars. Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (2016).
[93] Streitz, N.A. et al. 2005. Designing smart artifacts for smart environments. Computer. 38, 3 (2005), 41–49.
[94] Torre, R.R. 2007. Time's social metaphors: An empirical research. Time & society. 16, 2–3 (2007), 157–187.
[95] Toyota UK 2011. Toyota FUN-Vii: Future mobility in 20XX - 42nd Tokyo Motor Show 2011.
[96] Urry, J. 2012. Sociology beyond societies: Mobilities for the twenty-first century. Routledge.
[97] Volkswagen Group Research 2016. Italdesign Gira Concept – Autonomous Car Interior.
[98] Volvo Cars 2016. Volvo Cars: The Future Of Excellence.
[99] Walch, M. et al. 2015. Autonomous driving: investigating the feasibility of car-driver handover assistance. Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (2015), 11–18.
[100] Watkins, K.E. et al. 2011. Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. Transportation Research Part A: Policy and Practice. 45, 8 (2011), 839–848.
[101] Wright, L. 1968. Clockwork man: The story of time, its origins, its uses, its tyranny. Horizon Press.