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Does conducting activities while traveling reduce the value of time? Evidence from a within-subjects choice experiment

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A B S T R A C T

Many studies about conducting activities while traveling start from the hypothesis that conducting onboard activities reduces the value of time (VoT). However, surprisingly limited empirical evidence is provided for this hypothesis. The few studies that aim at providing this evidence face methodological problems in the sense that effects attributed to conducting onboard activities are confounded with differences between groups. This paper further develops and applies a solution for this problem proposed by Wardman and Lyons (2016). In essence, this method includes constructing a within-person choice experiment, which involves that the same respondents make choices in a context that enables conducting activities, as well as in a context that does not enable conducting activities. This method is applied in a study that collected data from 820 train travelers in the Netherlands. The results show that as expected, the VoT in the activity context is significantly lower than the VoT in the non-activity context, which thus supports the hypothesis. Reduction in VoT due to conducting onboard activities is around 30% for commuters, while leisure travelers who prefer to read lose almost half their VoT value. In addition, this paper discusses how the estimated VoT reduction values can be interpreted as the Value of Activity (VoA), which can be used for appraising investments aimed at reducing the disutility of travel other than by means of reducing travel time, such as improving Internet connections.

1. Introduction

Travel time is generally assumed to be valued negatively by travelers because it requires effort and may be tiring (e.g. Mokhtarian et al., 2015) and it is mainly regarded as ‘wasted time’; hence, the time spent on travel cannot be spent on conducting activities at a location from which travelers generally derive more utility. This negative valuation of travel time is consistently found in the literature (e.g., Abrantes and Wardman, 2011; Wardman, 1998; Wardman, 2004). However, Mokhtarian and Salomon (2001) argue that travel time may be valued positively, or at least less negatively, if the activity to be pursued at the destination has a high utility, if

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the trip in itself has intrinsic value, or if activities are conducted during the trip. The latter notion combined with the rapid market penetration of portable ICT devices in the early 2000s, such as mobile phones and laptops, and later smart phones and iPads, has motivated a stream of research that explored activities that are carried out while traveling, in particular traveling by train.

Most of these studies focused on measuring which onboard activities are conducted and explore the factors that influence the engagement in those activities (e.g., Berliner et al., 2015; Frei et al., 2015; Gustafson, 2012; Gripsrud and Hjorthol, 2012; Jain and Lyons, 2008; Kenyon and Lyons, 2007; Lyons and Urry, 2005; Lyons et al., 2007; Ohmori and Harata, 2008; Shaw et al., 2019; Susilo et al., 2012; Tang et al., 2018; van der Waerden et al., 2010; Zhang and Timmermans, 2010). These studies revealed a long list of activities that can be conducted onboard of trains, such as sleeping/snoozing, reading for leisure; working (reading/writing/typing/thinking), talking to other passengers, window gazing/people watching, playing games, cracking a puzzle, listening to music/radio, phone calls/text messages (work), making phone calls/text messages (personal), watching movie, eating/drinking, entertaining children, romancing, and being bored/anxious. Furthermore, a range of factors that influence the engagement in those activities has been found, among others socio-demographic variables, in particular age; trip characteristics, in particular trip purpose; travel duration; travel companion; attitudes, in particular polychronicity (inclination to conduct activities simultaneously); and being equipped, in particular by ICT devices. We refer to Keseru and Macharis (2018) for a comprehensive review of this literature.

Many of these studies are motivated by the unchallenged assumption that travel-based multitasking allows travelers to make more valuable use of their travel time (see Wardman and Lyons, 2016 for a literature review). This is particularly enabled by ICT devices, which allow conducting more productive work while traveling and a range of new recreational onboard activities, such as watching a movie. Consequently, it is argued that conducting onboard activities results in a reduction of the disutility of travel. Furthermore, because travel time is commonly valued negatively, travelers are generally willing to pay a certain amount of money to reduce travel time, which is called the Value of Travel Time. This term is defined by Daly and Hess (2019) as “the amount of money the traveler would pay or need to receive (e.g. in price reduction) to maintain indifference after a time saving or loss (respectively)”. For reasons of brevity, we use the acronym VoT (Value of Time) in this paper. Thus, based on the assumption that conducting onboard activities reduces the disutility of travel, hence reduces the negative valuation of travel time, it is argued that conducting onboard activities also decreases the VoT. While some research has been done on the impact of onboard activities on feelings, satisfaction and pleasantness of a trip (Ettema et al., 2012; Frei et al., 2015; Mokhtarian et al., 2015; Rasouli and Timmermans, 2014; Rhee et al., 2013; Russell, 2012) and on mode choice (Malokin et al., 2019), surprisingly limited empirical research tested the hypothesis that conducting activities while traveling reduces the VoT. This is remarkable, because this is an important value for policy making since it constitutes the basis for calculating the benefits of infrastructure investments aimed at reducing travel time, investments decisions that may involve billions of euros. Furthermore, the hypothesis is suggested as an explanation for decreases in VoT estimates observed in longitudinal VoT studies in the last couple of decades (e.g., Gunn, 2001; Shires and de Jong, 2009), but has not been substantially empirically underpinned.

Only a few papers aimed to find empirical support for the hypothesis. Based on revealed mode choice data, Malokin et al. (2017) find evidence that Millennials have lower VoT than Non-Millenials, which along their higher sensitivity to travel costs is explained by Millennials’ higher propensity to use laptop while traveling that makes traveling for them less onerous. This paper focusses on the propensity to use laptop, and does discriminate between its use for various activities. The latter is done in Ettema and Verschuren (2008), who present the results of a stated choice experiment in which choice alternatives describe travel time, travel costs and the possibility of multitasking. Onboard activities that are typically conducted while traveling by train were interacted with the travel time parameters, which among others and in contrast to expectation, revealed that train travelers who read for work have a higher instead of the hypothesized lower VoT compared to travelers who conduct other activities. As the authors argued, it is likely that self-selection caused this result: travelers who have a job and feel time pressed are more likely to come equipped to conduct work while traveling. In line with the hypothesis, conducting the intended activity might have reduced their VoT but nevertheless, the VoT of this group may still be higher than the VoT of travelers conducting other activities. Also Kouwenhoven and de Jong (2018) refer to the self-selection problem to explain their unexpected finding that travelers who bring a mobile ICT device to their trip, on average have a higher VoT instead of the hypothesized lower VoT. On the other hand, Varghese and Jana (2018) report results based on revealed data gathered in a developing country (India, city of Mumbai) that are largely in line with the hypothesis. However, also this study suffers from the problem that the groups compared have different characteristics. The study reports that the highest income group had the highest proportion of non-activity. It is also likely that the highest income group has a relatively high VoT, which therefore is an important alternative explanation why the VoT of the non-activity group is higher than of the activity group. Thus, although the results are in line with the hypothesis, it is likely that these are also caused by differences between the groups that are compared.

As a solution for this methodological problem that results are confounded with group differences, we apply and further develop in this paper a method proposed by Wardman and Lyons (2016). The essence of this method is that a stated choice experiment is conducted in which the same travelers make time and cost trade-offs in two different contexts: an activity context, in which they are able to conduct activities, and a non-activity context, in which they are not able to conduct activities. In line with the hypothesis that the ability to conduct onboard activities reduces the VoT, the VoT is expected to be lower in the activity context than in the non-activity context. Hence, positive and statistically significant different VoT values provide support for the hypothesis. To the best of our knowledge, this is the first application of the proposed method. Furthermore, if indeed the VoT reduces due to conducted onboard activities, we argue in this paper that there is a monetary value in conducting activities while traveling, which can be used to appraise projects that are aimed at reducing disutility of travel other than reducing travel time.

The aim of this paper is threefold. First, to further develop and apply the method proposed by Wardman and Lyons (2016). Second, to find evidence for the hypothesis that conducting onboard activities reduces the VoT. Third, to discuss how the estimated reduction VoT values can be used for appraising investments aimed at increasing the engagement in activities while traveling. Hence, whereas hitherto benefits of investments could only be calculated if they reduce travel time, the method developed in this study allows appraising investments that reduce the disutility of travel other than reducing travel time, i.e. investments that increase the ability to conduct productive or recreational activities. Thus, the third aim of this paper is to expand the toolkit of appraisal methods for investments in public transport services. To achieve these three aims, this paper reports the results obtained from a sample of 820 regular train travelers in the Netherlands.

The remainder of this paper is organized as follows. First, the methodological approach is discussed in more detail, which is followed by a description of the stated choice experiment developed accordingly and the utility function that is estimated from these data. This is followed by a presentation and discussion of the results. Then we discuss in more detail how VoT reduction values may be regarded as value of activities. This paper ends by drawing conclusions and discussing the limitations of this study which lead to suggestions for further research.

2. Methodology

2.1. VoT reduction

The Value of Time (VoT) is typically calculated by taking the ratio of the marginal utility of travel time and the marginal utility of travel costs. Straightforwardly, it is usually calculated by taking the ratio of the travel time parameter (β_T) and the travel cost parameter (β_C), which are estimated by discrete choice models from observed choices that involve time and costs trade-offs.

$$VoT = \frac{\frac{\partial V}{\partial T}}{\frac{\partial V}{\partial C}} = \frac{\beta_T}{\beta_C}$$

As already discussed in the Introduction, the methodological approach followed in this paper involves calculating the VoT for an activity and for a non-activity context. It is hypothesized that the VoT in the activity context, in which travelers are able to conduct activities, is lower than the VoT in the non-activity context, in which travelers are not able to conduct activities. Hence, this difference is expected to have a positive value ($VoT_{NAC(Non-ActivityContext)} - VoT_{AC(ActivityContext)} = \Delta VoT > 0$). Thus, positive and statistically significant VoT reduction values provide evidence for the hypothesis that conducting activities while traveling reduces the value of time. As will be discussed later on in this paper, we argue that the VoT reduction can also be interpreted as the monetary value of conducting onboard activities.

It is important that the ability to conduct activities is the only difference between both contexts, thus that no other circumstances differ. This is a challenge, because not being able to conduct activities while traveling by train is often caused by travel conditions that are typically perceived by travelers as unpleasant, such as not having a seat. Such a condition can virtually only be created in an experiment. Hence, the challenge is to avoid that respondents relate the non-activity context with unpleasant travel conditions, which would confound the reduction of VoT estimates with the impact of other context differences. As a solution for this potential confoundment, we propose to provide respondents with the reason why they cannot conduct the preferred activity in the non-activity context, which comprises that they forgot to bring the equipment they need to conduct the activity. This obviously limits this approach to activities for which travelers need to bring equipment like an ICT device (e.g., laptop, Ipad, smart phone) or paper work (e.g. book, newspaper, document). However, in that respect this study does not differ from many onboard activity studies that focus on activities enabled by ICT devices or being equipped in general.

It may be argued that travelers are always engaged in some activity, if not in an active activity that requires equipment, then in a rather passive one, such as window gazing or sleeping (see also the list of activities included in the Introduction). Consequently, it may be argued that there is no such thing as a non-activity context. We therefore operationalize the activity context more specifically as the context in which travelers are able to conduct their usual activity, which we assume is their preferred activity while traveling (in those circumstances). The non-activity context is then defined as the travel context in which travelers are not able to conduct their preferred activity. We do not specify which kind of activity they do instead nor do we measure which alternative activity they assume they would have performed instead.

2.2. The reference trip

To increase the validity of the choices observed in the stated choice task, we request travelers to make these choices for the trip they normally make while traveling by train, the reference trip, and for the activity they then typically conduct during that trip. To establish this reference trip, the first part of the questionnaire poses the following questions:

- For which *trip purpose* do you most often travel by train? One of the following trip purposes could be chosen: commute, business meeting, school, shopping, private visit, hobby/sports, medical, maintenance/caring task, holiday, day/night out, something else.
- What is the *most important activity* that you conduct when you travel for that purpose? This was further specified as the activity on which respondents spend most of their travel time. One of the following activities could be chosen: reading, talking, relaxing/day dreaming, surfing the Internet, using social media, listening to music, working/studying, gaming, sleeping, telephoning, doing something else.
- Which *device or other item* do you bring in order to conduct that activity? Respondents could specify several options from the following list: telephone/IPad, laptop/pc, headphone/something to listen to, book/newspaper/something to read, something else,

nothing.

In the literature, VoT estimates have consistently been found to differ among different travel purposes and consequently it is of interest to explore whether this also applies to VoT reduction. For Netherlands Railways (NS) the most relevant groups to distinguish are commuters and leisure travelers, because they typically travel in peak hours and in non-peak hours respectively, which may influence the possibility and the valuation of conducting activities. Commute (34%) and leisure (41%) are the two most common trip purposes of train travelers in the Netherlands (NS, 2015). Furthermore, Ettema and Verschuren (2008) report different VoT estimates for groups of travelers that conduct different activities, more specifically, those who read for work while traveling are found to have a considerably higher VoT than those who listen to music. Hence, it is of interest to explore whether this also applies to VoT reductions. According to Ettema and Verschuren (2008) the three most often conducted activities by public transport travelers for which equipment is required involve reading for leisure, reading for work and listening to music, which are regularly or often performed by 80%, 67% and 48% of their respondents respectively. Consequently, in this study we focus on the following six combinations of traveler groups: commuters and leisure travelers, who prefer to work/study, read or listen to music while traveling by train and who bring equipment to conduct this activity. Hence, only respondents who belong to any of these 6 groups are invited to participate in the stated choice part of the questionnaire.

2.3. The stated choice experiment

As mentioned before, a stated choice experiment is constructed to observe choices in an activity context and in a non-activity context. A within-subjects experimental design was applied, which involves that every respondent makes choices both in the activity and in the non-activity context. This is opposed to a between-subjects design, in which each context is presented to a different response group. A disadvantage of the latter design is that observed differences between the contexts may be confounded with the differences between the groups assigned to the different contexts. The applied within-person design avoids this because the choices in both contexts are observed for the same group of persons.

To observe train travelers' time and costs trade-offs, choice sets are constructed consisting of two generic alternatives, each described by travel time and travels costs. We were interested in exploring choices made for a wide range in travel times and travel costs. To avoid combining unrealistic time and cost values, for example, presenting very long travel times for very low costs, we constructed three time-class experiments that each lead to realistic time-cost combinations: a short (10,20,30 min, €3,4.5,6), a medium (35,50,65 min, €6,8,10) and a long (80,100,120 min, €8,12,16) travel duration class.

Choice sets are constructed by applying the D-efficient design approach, which aims at obtaining parameter estimates with the smallest possible standard errors (e.g., Rose and Bliemer, 2009). This involves balancing the utilities of the alternatives in each choice set, which requires priors, hence, the best possible preliminary estimates of the parameter values. These were obtained from an extensive pilot research, in which a preliminary version of the stated choice experiment developed in this paper was tested. Based on the choices made by 531 train travelers, the following parameter values were found by estimating a Multinomial Logit (MNL) Model: travel time = −0.0957, travel costs = −0.432, resulting in an average VoT value of 13.65 €/hour (Kingsley and de Bruyn, 2017). These prior parameter values were used to construct the designs for all three time classes. In this way, 6 choice sets were constructed per time-class by using experimental design software Ngene (ChoiceMetrics, 2018). We used the Ngene feature to check for dominant alternatives, with the result that none of the choice sets contained an alternative that is both cheaper and faster than the other alternative.

Because the choice alternatives are relatively simple as they are described by two attributes only, there is a possibility that respondents remember the choices they made during the course of conducting the experiment. To avoid these memory effects that would result in underestimation of the effect of the activity contexts, respondents were randomly assigned to one of the three time-classes per activity context. Hence, they never encountered the same choice sets twice. Furthermore, it is randomly determined whether a respondent first completes the activity or the non-activity context.

Fig. 1 presents an example of a choice set displayed to respondents who prefer to read while travelling and who indicated that they typically bring a paper document for this purpose. The latter is customized for each respondent based on their responses to the reference trip questions. Above each choice set, the respondent's profile is presented which summarizes their own answers to the reference trip questions to emphasize for respondents that they have to make choices for that particular trip. More specifically, the travel purpose, the chosen activity and the required equipment to perform that activity are presented. Then the two choice alternatives are described in terms of travel time and travel costs. In addition, the activity context is included in the choice set, which looks like an attribute, but its levels are always the same for both alternatives. The non-activity context level explicitly stated that the respondent forgot to bring the required equipment, while the activity context level explicitly stated that the respondent brought the required equipment for conducting their activity.

2.4. The estimated utility function

The estimated models presented in this study are rooted in utility maximization theory, hence, we assume that in each choice set, a traveler chooses the alternative i from which she derives the highest utility, hence, $U_i > U_j \ (i \neq j)$. It is further assumed that utility U_i is composed of two parts: structural utility V_i that can be determined by the model and random utility ε_i, which cannot be determined by the model, hence, $U_i = V_i + \varepsilon_i$. Structural utility V_i of the alternatives in our experiment could most straightforwardly determined by the following linear additive utility function: $V_i = \beta_T \cdot T_i + \beta_C \cdot C_i$, in which T and C are the time and costs attributes

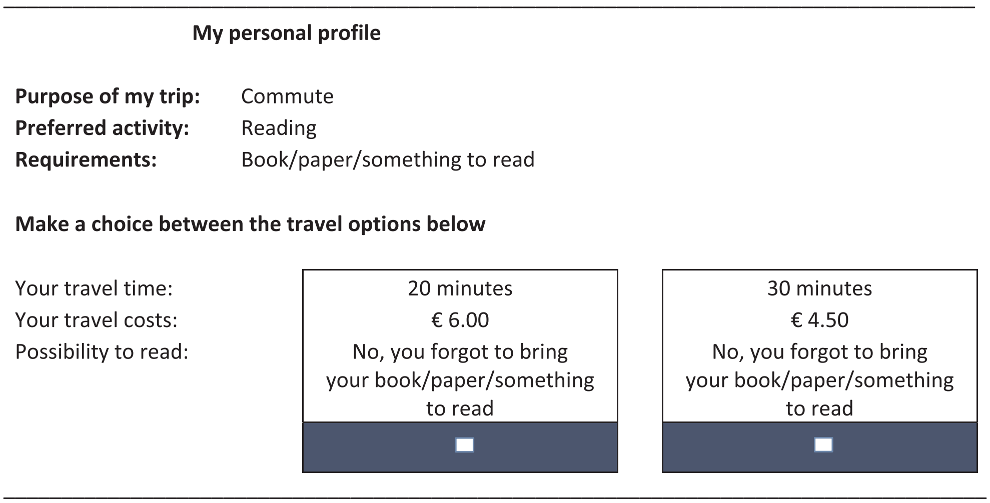

Fig. 1. Example choice task.

varied in the stated choice experiment and β_T and β_C are the time and the costs parameters to be estimated.

As earlier described, the VoT is calculated by the ratio β_T/β_C, which is used to rewrite the utility function in value of time space: $V_i = \beta_C \cdot C_i + \beta_C \cdot \beta_{VoT} \cdot T_i$. Hence, this function allows estimating the VoT parameter (β_{VoT}) directly, which has the advantage that we can directly test this parameter for statistical significance and it allows easily testing to what extent it is related to personal characteristics by including interaction effects with this parameter. Finally, as argued before, $\beta_{VoT_{NAC}} - \beta_{VoT_{AC}} = \Delta\beta_{VoT}$, which can be also written as: $\beta_{VoT_{AC}} + \Delta\beta_{VoT} = \beta_{VoT_{NAC}}$. This results in the following utility function that is estimated from the observed choices:

$$V_i = \beta_C \cdot C_i + \beta_C \cdot \beta_{VoT} \cdot T_i + \beta_C \cdot \Delta\beta_{VoT} \cdot T_i \cdot NAC$$

This utility function is estimated from a pooled data set that contains both the choices observed in the activity and in the non-activity context. The context is represented by a dummy variable NAC, which takes on the value 1 if the choice is made in the non-activity context and 0 if the choice is made in the activity context. Hence, this utility function allows estimating directly a VoT parameter in the activity context ($\beta_{VoT_{AC}}$) as well as a parameter for the difference in VoT between the activity and the non-activity contexts ($\Delta\beta_{VoT}$), which has the advantage that these parameters can be tested for statistical significance. As explained above, the VoT in the non-activity context (VoT_{NAC}) is completely confounded with VoT_{AC} and ΔVoT and therefore no parameter can be estimated for this variable simultaneously. However, once the model is estimated, VoT in the non-activity context (VoT_{NAC}) can be calculated by simply summing the VoT_{AC} and ΔVoT estimates as discussed before.

To test the central hypothesis and to explore differences among the six purpose-activity groups, first MNL (Multinomial Logit) models are estimated separately for each of the six distinguished groups. After this, we explore to what extent the three main parameters β_C, $\beta_{VoT_{AC}}$ and $\beta_{\Delta VoT}$ differ among categories of socio-demographic variables and trip characteristics. To that effect, we estimate a single MNL model across the observations from all six travel purpose-activity groups. The six groups are effects coded and interacted with the main parameters β_C, $\beta_{VoT_{AC}}$ and $\beta_{\Delta VoT}$. The main parameters can then be regarded as the average values across the entire sample. The interaction parameters express to what extent a travel purpose-activity group differs from these main parameters, thus from the average values. By estimating this single model, the values of β_C, $\beta_{VoT_{AC}}$ and $\beta_{\Delta VoT}$ estimates of every single group as presented in the previous section can be perfectly reproduced.

To explore the relationships with socio-demographic variables and with trip characteristics, we next pool the data from all six purpose-activity groups. We add to the utility function the interactions of the three main parameters (β_C, $\beta_{VoT_{AC}}$ and $\beta_{\Delta VoT}$) with the characteristics as presented in Table 1. These variables are all effects coded, except for reference trip duration, which is standardized and treated as a continuous variable. In addition, we included the effects coded activity context in order to test whether making choices in the activity context first influenced the results. In order to keep results comparable with the MNL results per trip-purpose-activity groups, the interaction effects with the 6 purpose-activity groups are all included in the model, irrespective of statistical significance. The interactions with background variables (socio-demographics, trip characteristics, and activity order) are only kept if they are statistically significant.

3. Results

3.1. Characteristics of the six purpose-activity groups

Respondents were randomly sampled from the Netherlands Railways own travelers' panel, which includes around 40.000 train travelers. About 6000 panel members were invited by email to fill out the questionnaire. In response to this, 1558 train travelers filled out the questionnaire, of which 820 persons were either a commuter or a leisure traveler who normally conducts any of the three

Table 1
Characteristics of the six distinguished trip-purpose-activity groups.

	Commuters			Leisure travelers			Overall	Valid N
	Work	Read	Music	Work	Read	Music		
N	118	211	55	28	352	56		
Socio-demographics								
Male	56%	53%	44%	50%	35%	43%	43%	725
45 + years	40%	48%	33%	40%	80%	36%	58%	741
Above modal income	62%	55%	30%	28%	43%	24%	46%	734
High education	72%	56%	24%	85%	41%	33%	77%	749
Reference trip								
Duration > 1 h	42%	17%	24%	82%	67%	64%	48%	820
Pay self for train ticket	15%	20%	16%	82%	97%	86%	59%	820
Usually crowded	56%	58%	65%	36%	33%	34%	45%	820
Usually seat available	81%	78%	75%	92%	93%	80%	85%	820
Makes a transfer	49%	37%	40%	68%	67%	64%	55%	820
Frequency ≥ 1 per week	98%	96%	95%	29%	14%	23%	54%	820

selected activities and who brings equipment to conduct that activity. As discussed before, only the latter group was invited to complete the experiment and forms the basis of the results presented in this paper.

Table 1 presents the characteristics of each of the six distinguished purpose-activity groups. It should be noted that the socio-demographic variables were not measured in our questionnaire but abstracted from the NS panel database. It turned out that these variables were not measured at a high level of detail, for example income was registered in five broad categories only. Furthermore, each of these variables had about 9% missing values.

The sample consists of slightly more leisure travelers (436) than commuters (384). The most distinguished differences between those two groups involve the reference trip. Compared to commuters, the leisure travelers: (i) tend to make longer trips and consequently make more transfers during their trip, (ii) travel less often, (iii) largely pay themselves for the ticket (e.g. travelers whose travel costs are not reimbursed by their employer), and (iv) largely travel in non-crowded conditions.

It is clear that most respondents read (69%) while traveling, which is even more the case for leisure travelers (81%) than for commuters (55%). *Leisure travelers who work or study while traveling* constitute the smallest group, which is not surprising. This seems to be a rather specific group: relatively young, low income but highly educated travelers, which largely may be labeled as *young professionals and students*. *Leisure travelers who read* form the largest group, which largely may be characterized as *older females*. Both commuters and leisure travelers *who listen to music* are fairly young, low income, low educated travelers, probably mostly students (It should be noted that in the Netherland students are given a public transport card that allows them to travel by public transport for free, either during week days or weekend days). The other differences between both groups reflect the general differences between commuters and leisure travelers. Finally, the *commuters' work/study* and *read groups* have fairly similar characteristics, except that the *work/study group* consist of relatively more high income and highly educated persons and they make longer trips. These results corroborate the argument made in the introduction that travelers who conduct different activities have different characteristics.

3.2. Value of time reduction estimates of six travel-purpose-activity groups

Table 2 presents the parameters of the MNL models for each of the six travel purpose-activity groups estimated according to the utility function specification discussed in Section 2.4. All of the six estimated ΔVoT's have the expected positive value. Moreover, four of the six estimated ΔVoT parameters are statistically significant. More specifically, all three commuter groups have significant ΔVoT estimates, while only one of the three leisure travel groups has statistically significant estimates: those who prefer to *read*. Hence, the leisure groups who prefer to *work/study* and *listen to music*, have ΔVoT estimates that are not statistically significant, however, these two groups together constitute no more than 10% of the respondents. The result that ΔVoT estimates are positive and statistically significant for the vast majority of travelers, provides evidence for the hypotheses that conducting activities while traveling reduces the VoT.

To ease interpretation, Table 3 presents the VoT estimates in euro per hour (estimates of Table 2 multiplied by 60). The results suggest that the magnitudes of VoT reduction differs among the 6 purpose-activity groups as expected. In absolute terms, the VoT reductions of all commuter groups are higher than of any of the leisure travel groups. The *work/study* commuters have the highest VoT reduction values, followed by the *read group* and finally the *listen to music group.* Of the three leisure groups, the *readers* have the highest reduction values followed by the *work/study group* and *listen to music group,* who have considerably lower (and non-significant) values.

The results further show that both VoT_{AC} and VoT_{NAC} values are higher for commuters than for leisure travels. This is in line with previous literature. In addition, this was expected based on our earlier reported finding that most leisure travelers pay themselves for the train tickets, while this is not the case for most commuters. Furthermore, also in line with this is the finding that the travel costs parameters (β_C, see Table 2) have a higher magnitude in all leisure traveler groups, suggesting a higher sensitivity to travel costs of leisure travelers compared to commuters. These results give confidence in the results estimated from our experiment.

Table 2
Estimates per purpose-activity group.

	Commuters					
	Working/studying		Reading		Listening to music	
	Est.	*t-value*	*Est.*	*t-value*	*Est.*	*t-value*
β_{VoT_AC}	0.207	13.59	0.187	19.04	0.171	10.56
$\beta_{\Delta VoT}$	0.106	4.37	0.083	5.60	0.061	2.25
β_C	−0.263	−9.51	−0.305	−14.25	−0.333	−7.66
# Observations		1416		2532		660
Rho-square		0.122		0.120		0.108
	Leisure travelers					
	Working/studying		Reading		Listening to music	
	Est.	*t-value*	*Est.*	*t-value*	*Est.*	*t-value*
β_{VoT_AC}	0.109	8.99	0.063	10.53	0.097	7.49
$\beta_{\Delta VoT}$	0.019	1.05	0.057	7.31	0.012	0.66
β_C	−0.616	−6.12	−0.425	−20.91	−0.430	−7.57
# Observations		336		4224		672
Rho-square		0.186		0.141		0.122

Table 3
Value of time reductions per purpose-activity group (in Euros per hour).

	Commuters			Leisure travelers		
	Work	Read	Music	Work	Read	Music
VoT_{AC}	12.42	11.22	10.26	6.54	3.77	5.74
ΔVoT	6.36	4.98	3.63	1.16	3.39	0.69
VoT_{NAC}	18.78	16.20	13.89	7.70	7.16	6.43
% VoT reduction[#]	−33.9%	−30.7%	−26.1%	−15.1%	−47.1%	−10.7%

[#] % VoT reduction = $\Delta VoT/VoT_{NAC}$ * 100%.

Because the VoT estimates differ among the groups, the relative reduction in VoT provides slightly different insights. In line with previous research that calculated the percentage reduction in VoT associated with conducting activities (or due to being equipped by ICT devices) with the non-activity condition as a basis, we divide the ΔVoT by the VoT_{NAC} to arrive at the percentage reduction in VoT. For commuters this is about 30%, which is slightly higher for those who work (33.9%), and slightly lower for those who listen to music (26.1%), while those who read (30.7%) take a middle position. The differences are in plausible directions, although the magnitude of the differences is rather limited. In contrast, the differences between the three leisure traveler groups are relatively large: the percentage reduction in the *read group* is by far the largest (47.1%), while for the *work group* (15.1%) and for the *listing to music group* (10.7%) this is considerably lower. To summarize, the ability to conduct the preferred activity, reduces the VoT of the *leisure group who reads* to almost half its value, while the VoT of the three commuter groups looses a quarter to a third of its value, and the reduction is at most one sixth for the two remaining leisure groups.

3.3. Impacts of socio-demographics and trip characteristics

In this subsection, we discuss to what extent the estimates of the three main parameters (β_C, $\beta_{VoT_{AC}}$ and $\beta_{\Delta VoT}$) differ among the various categories of the respondents' socio-demographic variables and reference trip characteristics (see Section 2.4 for the estimation procedure). Results are presented in Table 4. As already mentioned in Section 3.1, each of the socio-demographic variables contains about 9% missing values. In total 28.2% of the respondents has one or more missing values on the four socio-demographic variables, which means that these respondents are not included in the analysis once these variables are included in the model. Alternatively, missing values could be replaced by average values to retain more respondents. We applied both ways of treating missing values and carefully compared their results. We found that the magnitudes and the significance levels of the parameters were very similar to each other. Because the first method, hence including only respondents that have no missing values, involves the least data manipulation, we adopted this approach.

With respect to socio-demographic variables, only a limited number of interaction effects are found to be statistically significant. As expected, higher incomes have a higher VoT, which is a result that is consistent with previous research. In addition, older train travelers have a lower VoT. Because the older age group typically has more modal options to choose from, possibly this result

Table 4
Pooled MNL models: estimates of three main parameter and their interactions.

	Purpose-activity only		Extended	
	Est.	t-value	Est.	t-value
β_C (cost)[#]	**−0.395**	**−18.11**	**−0.407**	**−15.78**
Commute work	0.133	4.22	0.071	1.88
Commute read	0.091	3.24	0.048	1.39
Commute music	0.062	1.45	0.006	0.10
Leisure work	−0.221	−2.60	0.038	0.95
Leisure read	−0.030	−1.01	−0.231	−2.23
Leisure music	*−0.035*		*0.068*	
Pay self for ticket			−0.063	−2.42
Male			0.030	2.34
β_{VoT_AC} (VoT activity context)	**0.139**	**27.20**	**0.154**	**24.19**
Commute work	0.069	5.10	0.007	0.50
Commute read	0.048	5.04	0.024	2.14
Commute music	0.032	2.28	0.017	0.94
Leisure work	−0.030	−2.70	−0.028	−2.87
Leisure read	−0.076	−10.73	0.004	0.31
Leisure music	*−0.043*		*−0.025*	
Pay self for ticket			−0.044	−5.85
Above modal income			0.032	8.91
Travel time reference trip			−0.014	−3.80
Activity context first			0.014	2.92
45 + years			−0.011	−3.09
$\beta_{\Delta VoT}$ (VoT reduction)	**0.056**	**7.12**	**0.051**	**5.83**
Commute work	0.050	2.33	0.046	2.08
Commute read	*0.027*	*1.86*	*0.033*	*1.98*
Commute music	0.004	0.19	0.015	0.60
Leisure work	−0.037	−2.15	0.017	1.45
Leisure read	0.000	0.04	−0.038	−1.93
Leisure music	*−0.045*		*−0.072*	
Activity context first			0.014	2.15
Rho-square	0.131		0.150	
[#] Observations	9840		7068	

[#] In bold the three main parameters; all other parameters are interactions with the main parameter; parameters in italics are not estimated but added for sake of completeness.

indicates that lower costs of train travel compared to car travel is one of the reason why this group travels by train. Finally, we find that males are somewhat less sensitive to costs. This is remarkable finding, because in a model that does not control for any of the other variables and thus only includes the interactions of gender with the three main parameters, we find the reverse effect, hence, that males are more sensitive to costs. In addition, we found many more significant effects when we added only a single socio-demographic variable to the model with the three main parameters only, hence, if we do not control for any of the other variables. Possibly, the effects of the socio-demographic variables on the three main parameters are indirect, running via the membership of the six purpose-activity groups. Recall that the six travel purpose-activity groups are included in the model, and that we have earlier shown that they differ in background variables.

With respect to trip characteristics, no significant interaction effects were found for *making transfers*, *travel frequency*, *perceived crowdedness* and *seat availability*. That the latter two variables have no significant impact is probably caused by the fact that we only included in our sample those respondents that usually conduct activities during their reference trip, hence, they usually have a seat available (see Table 1). We did find significant interaction effects for the trip characteristics *who pays* and *trip duration*. As may be expected, travelers who pay for their own ticket are more sensitive to travel costs and have a lower VoT, however, their ΔVoT estimate does not differ. Furthermore, the VoT is found to decrease with duration of the reference trip. The latter may be explained by the random assignment of respondents to trip duration class: travelers with a short reference trip who are faced with longer trips in the experiment may be more willing to pay to reduce travel time, while on the other hand, travelers with a long reference trip may be less willing to pay to reduce travel time in case the travel time in the experiment is shorter than their reference trip.

In summary, relations of the three main parameters with socio-demographic variables and trip characteristics are limited, but most effects that are significant are in plausible directions. None of the background variables is significantly related to estimates of VoT reduction due to conducting onboard activities.

3.4. Activity order

In this section, we examine the impact of activity order. More specifically, we compare the results of the respondents who first

Table 5
Activity order results (in Euro per hour).

First context	Second context	Difference
Activity	Non-Activity	
VoT_{AC} 10.08	VoT_{NAC} 13.98	ΔVoT 3.90
Non Activity	Activity	
VoT_{NAC} 10.62	VoT_{AC} 8.40	ΔVoT 2.22

made choices in the activity context with respondents who first made choices in the non-activity context. The estimates are presented in Table 4. The table makes clear that the interaction of activity order with both VoT and ΔVoT parameters is statistically significant, while the interaction with the cost parameter is not statistically significant (and therefore not included in the model).

The interaction with ΔVoT has a positive value, which means that the ΔVoT is larger for the group who first makes choices in the activity context compared to the group who first makes choices in the non-activity context. An explanation for this difference can be found in the endowment effect (e.g. Thaler, 1980; Kahneman et al., 1990), which predicts that consumers attach more value to something they own than to something they do not own, even if the situation of ownership is created only minutes before. Applied to our case, it may be argued that if travelers first make choices in the activity context, they 'own' that situation. Consequently, they are willing to pay more to retain that situation than that they are willing to obtain the same situation if they previously did not 'own' it. A comparable theoretical explanation for the endowment effect can be found in prospect theory, which suggests that losses with respect to a certain reference situation weigh more heavily than gains (Kahneman and Tversky, 1979). Applied to our case, this would mean that by making choices in the activity context first, the activity context becomes their reference. When they are no longer able to conduct their preferred activity, this may be regarded as a loss. In contrast, for the respondents who first make choices in the non-activity context, the added possibility to conduct an activity in their next series of choices may be regarded as a gain, which has a lower value.

In Table 5 the main effects and the interaction effects are combined to calculate the VoT and ΔVoT values separately for the group who first made choices in the activity context and for the group who first made choices in the non-activity context (under the assumption that everything else is equal). This table makes clear that if we only take the first set of 6 choices into account, and compare the results obtained from different groups, we find that the VoT_{AC} (10.08) is lower than the VoT_{NAC} (10.62). This is in line with the hypothesis, however, this difference is relatively small: only 0.54. This is the result we would have found if we would have applied a between-subjects experiment. If we now compare the results within each group, hence we compare the results of the different contexts for the same group of persons, we observe considerable larger differences in VoT between the activity and the non-activity context: ΔVoT is 2.22 and 3.90 respectively. These results indicate that a between-subjects experiment would have underestimated the impact of conducting onboard activities. Or in other words, it illustrates the importance of applying a within-subjects design.

From Table 5 it can also be calculated that the percentage reduction in VoT of the group that first makes choices in the activity context is 27.9%, while the percentage reduction of the group that first makes choices in the non-activity context is 26.4%. This relative small difference puts the role of the activity order into perspective: it may be less important than earlier suggested. Finally, the activity order does not have an effect on the cost parameter. This is a plausible finding, because intuitively one would expect that whether or not having the opportunity to conduct an activity is only time related and not cost related. Hence, this result enhances our trust in the outcomes of our experimental approach.

4. The value of activities

The results of this study indicate that conducting onboard activities reduces the VoT. This suggests that there is monetary value involved in conducting onboard activities. We therefore argue that VoT reduction estimates (ΔVoT) can also be regarded as the monetary value of conducting activities while traveling, which alternatively and in analogy with Value of Time could be termed the Value of Activity (VoA). Such VoA estimates may be used by train companies and policy makers to appraise investments aimed at reducing the disutility of travel other than those aimed at reducing travel time. More specifically, the VoA can be used to calculate the benefits of investments aimed at improving the ability to engage in activities while traveling, such as providing more comfortable seats, electricity sockets, improved Internet connections, better lighting, and silence wagons. Hitherto no such values were available which are much needed for making better informed policy decisions. For example, VoA values could be used in a case described by Tang et al. (2018), which involves the policy choice between increasing the speed of high speed trains in China or providing reliable Internet connections instead.

However, such appraisal requires additional information beyond the estimates presented in this paper, as it is not clear yet to what extent the mentioned facilities increase the ability to conduct activities. Unless one is willing to make bold assumptions about these effects, further research is required to examine to what extent improving facilities increases the number of travelers that are engaged in the activities that are facilitated by the investment. Multiplication of this number with VoA values would result in the benefits of the investment. Alternatively, the methodological approach presented in this paper could be generalized to examine the monetary effects of improving facilities more directly. Instead of defining the different contexts only as an activity and a non-activity context, the contexts may be defined as the current travel context and the one after an investment is made. For example, a situation in which no Wi-Fi is available and a situation in which high speed Wi-Fi is available. Moreover, it is not necessary to limit the context to a variation in a single situation (context) variable, but one may define multiple contexts, and observe choices for multi-variable context descriptions. In that case constructing an additional experimental design is needed to systematically vary the context situation variables, under which all choice sets are nested in a balanced way.

It should be stressed that the VoA estimates as presented in this paper do not represent the intrinsic values of conducting particular activities. The reason is that these values are found for groups of travelers that have different characteristics and thus the VoA estimates are confounded with these differences in characteristics. In particular, low values were found for listening to music, which was also found in previous research (e.g. Ettema and Verschuren, 2008). This activity is particularly conducted by relatively young and low income travelers, characteristics shared with the *leisure traveler work group* for which also low VoA estimates are found. Income probably has a direct effect as it is partly responsible for a lower VoT, which somewhat limits the values of VoA. But income is likely also to have an indirect effect as it affects mode choice. As discussed by Molin et al. (2016), a considerable part of the young, low income train travelers do not have a positive attitude towards train travel, hence, many of those travelers prefer traveling by car but cannot (yet) afford it because of their low incomes. In addition, the students' free public transport card reduces their train travel costs to zero for most trips, which largely determines their mode choice. Probably, this group of travelers has a low polychronic attitude, that is, a low inclination to multi-task. In other words, the disutility of travel of this traveler group cannot be mitigated by conducting activities. In contrast, older, higher income train travelers often have alternative travel modes available to choose from and this group largely travels by train by choice, in which probably the ability to conduct activities while traveling plays an important role. Finally, listening to music is the only one of the selected activities that can be combined with driving a car.

This discussion illuminates that the selection of activity while traveling, mode preferences, polychronicity attitudes and valuation of activities and travel time is rather complex, which is outside the scope of this paper. An interesting avenue for further research therefore is to disentangle these direct and indirect relationships. It should be noted that such research requires also insight in complete activity programs because this may influence the choice of onboard activity (e.g. Pudane et al., 2018). For example, a time pressured commuter may choose to relax in the train and thus not engage in an active activity after a day's work in order to be refreshed to conduct some work-related activities in the evening. More suggestions for further research are discussed in the next section.

5. Conclusions and discussion

In this paper, we have further developed and applied a method proposed by Wardman and Lyons (2016) to test the hypothesis that the ability to conduct activities while traveling reduces the value of time (VoT). This method involves conducting a within-subjects choice experiment that observes travel time and travel cost trade-offs in two different contexts: travelers are either able to conduct their preferred activity while traveling or they are not. To create two contexts that only differ in the ability to conduct activities, it is essential to avoid that respondents assume that the non-activity context is caused by unpleasant travel conditions, such as not having a seat. To that effect, respondents are told to assume that they cannot conduct the activity because they forgot to bring the equipment they need for conducting the activity. This method was applied in a study among 820 regular train travelers in the Netherlands.

The modeling results show that as hypothesized, the VoT in the activity context is lower than the VoT in the non-activity context. These results provide an empirical basis for the unchallenged, but also largely untested hypothesis that onboard activities decrease the value of time. Moreover, it also provides evidence for the explanation provided in the literature for the observed long term decrease in VoT that is observed in longitudinal VoT studies in the last couple of decades (e.g. Gunn, 2001; Shires and de Jong, 2009). More in detail, the results suggest that if we take the VoT in the non-activity context as a base, then the ability to conduct activities while traveling reduces the VoT by about 30% for commuters. This is a little higher for commuters who work or study and a little lower for commuters who listen to music, while commuters who read take a middle position. For leisure travelers who read the percentage VoT reduction is considerably higher: it almost halves. On the other hand, reduction is considerably lower for leisure travelers who work or study (about 15%) and even lower for leisure travelers who listen to music (about 10%).

To the best of our knowledge, this is the first study that provides evidence for the hypothesis that conducting onboard activities reduces the VoT that excludes the possibility that estimated effects are confounded with group characteristics. This is due to the applied within-subjects research design while previous studies were all based on between-subjects designs. From this study it can be concluded that the developed within-subjects designed choice experiment proposed by Wardman and Lyons (2016) 'works' in the sense that it produces statistically significant effects, which are all in expected directions, and the estimated values seem reasonable.

However, our approach concerns a stated choice experiment and consequently the results are under suspicion of hypothetical bias. Preferably the results should be validated by revealed data. Arguably, collecting revealed data that are comparable with those collected in a choice experiment as developed in this paper will be very hard if not impossible to find due to the following reasons. First, it will be hard to find activity and non-activity contexts that only differ in the ability to conduct activities while all other circumstances are the same. As argued before, the reason is that non-activity contexts are likely to be correlated with unpleasant travel conditions. Second, it will be hard to collect data according to a within-subjects design. One probably has to rely on between-subjects designs, hence, comparing data observed from different persons, which likely leads to problems related to self-selection or more generally to comparing groups that have different characteristics as earlier discussed. Third, choices probably cannot be observed for both contexts for the same persons at the same moment in time, because at any particular moment in time a particular person can travel only in a single activity context. Hence, if data are collected at one moment in time, for example by means of a standard survey questionnaire, responses may be biased by unequal memory effects, as one of the trips is always further back in time. To avoid this, such a research would require multiple measurements in time, which adds to the difficulty of collecting proper revealed data to validate the results. To conclude, validating the results by revealed data is virtually impossible and replicating the results of this study by applying similar designed stated choice experiments is probably the best we can do to enhance our trust in the results.

Now that this study has found that conducting onboard activities reduced VoT for the vast majority of travelers who typically conduct activities while traveling by train, a logical next step in this line of research seems to be to examine heterogeneity. We took a first step in this study by showing that the VoT reductions differ to some extent between the 6 purpose-activity groups. We also tested whether socio-demographic variables and trip characteristics could explain additional variability in VoT reduction values on top of six travel-purpose groups. We could not find any significant relations of background variables and VoT reduction values. We did find a limited number of statistically significant interaction effects with the cost and VoT parameters of which most were in plausible directions. We discussed that the impacts of background effects may be indirect and run via membership of purpose-activity groups. We also discussed that the socio-demographic variables were not optimally represented in our data, hence, our database is not optimally suited to fully investigate heterogeneity. Hence, future research should better measure socio-demographic variables and on top of that estimate mixed logit models or latent class models to explore unobserved heterogeneity.

This study has several other limitations, which give rise to interesting directions for further research. First, because we intended to avoid memory affects, we randomly assigned respondents to a time class per activity context. The consequence of this random assignment is that in about two thirds of all choice sets, respondents are shown travel times and travel cost values that are substantially different from what they experience in their own reference trip, which may have affected the results. From hindsight we should have dealt with this in another way, in particular, we should have shown respondents only time and costs values from their own time class. We could have constructed more choice sets than strictly needed and block these into two sets and randomly assign each respondent to one block for the activity context and the other block for the non-activity context. Hence, in this way, respondents are never shown the same choice set twice, which also would have avoided memory effects. This procedure is advised for future research. To make the choice set even more tailormade, one may consider constructing pivot designs with the reference trip as a basis.

A second limitation is related to the way the respondents are selected. Although for good reasons as earlier explained, we selected for participation in the stated choice experiment only those train travelers who typically conduct any of the three selected activities while traveling by train. Hence, this resulted in a sample of respondents for whom the activity context is the reference in real life. The activity order effect as found in this study suggests that having the activity context as a reference results in VoT reduction values that are higher compared to having the non-activity context as the reference. As the latter group for whom this is the reference in real life is not selected in our sample, there is a possibility that this study might have overestimated the VoT reduction values. Hence, an interesting question for further research is therefore to examine if this indeed is the case by selecting travelers for whom in real life the non-activity context is the reference. This group is harder to identify as this involves travelers that typically do not conduct activities while traveling now, for example because it is too crowded, but wish to do so.

A third limitation is the limited set of activities considered in our study. First, our methodological approach is limited to the valuation of activities for which travelers need to be equipped, which thus excludes activities such as sleeping, window gazing and talking with people. An interesting challenge for further research is therefore finding ways to measure the value of activities for which no equipment is needed. Somewhat related to this point is that the examined activities were limited to working, reading and listening to music, the most often conducted activities found in previous research. However, these all concern traditional activities while modern ICT devices such as smart phones, laptops and tablets together with improved Internet connections make a whole range of new activities possible, such as watching movies and using social media, which seem to be conducted relatively more often nowadays. It would be worthwhile including more of these activities in future research. Yet another somewhat related point is that travelers were only told that they cannot conduct their preferred activity, which implies any other activity for which they need equipment, while we did not specify an alternative activity nor did we measure what other activity respondents assumed doing instead. Hence, different travelers may have assumed different alternative activities which may have affected the results. Measuring the assumed alternative activity and testing whether this affected results, may therefore be an interesting avenue for further research. Also somewhat related is that we did not control for the direction of the trip, hence whether the trip was activity- or home-bound. The literature suggests that the direction may affect activity choice and consequently may affect valuation of time. Investigating whether this indeed is the case, seems therefore to be an interesting topic for further research.

Notwithstanding these limitations and the notion that various research questions still need to be answered, we believe that our results are valuable for policymakers, transport providers and scholars alike. Although our study focuses on train travel, similar research questions may be addressed in the context of (partially) Automated Vehicles (AVs), as AV's also allow to perform non-travel related activities that may affect car-drivers' VoT. If indeed as expected, the VoT of car drivers will decrease due to the ability to conduct in car activities, this will have repercussions for infrastructural investment appraisal in the future. We believe that the methodological approach as developed and applied in this paper is also suitable to examine the likely VoT reductions in the automated vehicle era.

Declaration of Competing Interest

None.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tra.2019.10.017.

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