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Rules for aggregated satisfaction with work commutes

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Abstract In general trips frequently entail several stages varying in mode, duration, and other factors. In some way travelers aggregate their satisfaction with the stages to satisfaction with the whole trip. In this paper we address the question of how this aggregation is made. We use data from a Swedish survey measuring satisfaction with commutes to and from work and with the stages of the commutes. We test several aggregation rules for their goodness of fit to the observations. Our results show that a normatively correct averaging rule that takes into account the relative durations of the stages out-perform heuristic aggregation rules such as the peak-end, summation, and equal-weight averaging rules. We note that this does not exclude that the heuristic aggregation rules apply to other trips than repetitive commute trips.

Keywords Satisfaction with travel · Work commuting · Aggregation rule · Heuristic

Introduction

Utility maximization theory (McFadden 2001) dominates travel behavior analysis and modeling. In this theory it is assumed that choices people make that maximize (random)

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utility result in satisfaction with the outcomes of the choices. However, this assumed correspondence between utility and satisfaction has been challenged. In recent conceptualizations (Ettema et al. 2010; Kahneman et al. 1997) a distinction is made between experienced utility and decision utility. Experienced utility is the satisfaction with the outcome of a choice (i.e., the degree to which it is liked or disliked), whereas decision utility is the degree to which the outcome is desired when the choice is made. Empirical research (e.g. Kahneman 2000; Kahneman and Sugden 2005) has convincingly shown that due to lack of information and prevalence of cognitive distortions, experienced utility frequently differs from decision utility.

Experienced utility appears theoretically to directly reflect satisfaction with the service level of transport. If experienced utility differs from decision utility, in transport planning aiming at improving the service level it is therefore advisable to measure experienced utility as a complement to decision utility inferred from choices. Such an argument is made by Carse (2011) in an analysis of transport policy. It is also recognized in some recent travel behavior research. For instance, Jakobsson Bergstad et al. (2011a) developed the Satisfaction with Travel Scale (STS) to measure the satisfaction with daily travel. Measures of satisfaction commonly entail both cognitive evaluations (e.g. quality) and affective appraisals, that is evaluations based on feelings of good or bad (Oliver 2010). A drawback is that the originally developed STS did not measure affective appraisals. Therefore, Ettema et al. (2011) proposed a revised STS that also assesses affective components. Abou-Zeid and Ben-Akiva (2011, 2012) and Abou-Zeid et al. (2012) have likewise developed methods of measuring affective components of satisfaction with travel (referred to as travel happiness) as well as how such measures can be integrated in a discrete-choice modeling framework.

The commute trip from home to work (and the reverse) frequently entails several stages varying in mode, duration, and other factors. An example of a four-stage trip is (1) walking to the car port (2) driving to a parking lot at the commuter train station (3) riding the commuter train, and (4) walking from the train station to work. In some way travelers aggregate their satisfaction with the stages to satisfaction with the work commute trip as a whole (Friman and Gärling 2001; Friman et al. 2001). Our aim in this paper is to investigate and model how this aggregation is made.

Another distinction due to Kahneman et al. (1997) is that between instantly experienced utility (instant utility) and remembered utility. Instant utility is the smallest unit that is aggregated across time to a total utility. Assuming there are no interaction effects and no time discounting, a normative rule of aggregating is the sum of the instant utility (or disutility) units. In which order stages are encountered in a multi-stage trip is assumed to not matter. These assumptions would be fulfilled if aggregation is made for instant utilities that are measured in such a way that possible position and order effects are captured by the measure (i.e. if measurements are made in the same context). A measure of instant utility would then, for instance, reflect that an otherwise identical stage has a different instant utility depending on its order in the sequence.

Several previous studies in different contexts have shown that aggregation is made according to a peak-end rule that differs from the normatively correct aggregation rule (for reviews, see Fredricksen 2000; Kahneman 2000). For instance, the peak-end rule was demonstrated by Diener et al. (2001); Fredricksen and Kahneman (1993); Redelmeier et al. (2003) by showing that remembered utility of an event sequence corresponds to the average of the peak experience in the sequence and the experience of the end of the sequence. Kahneman (2000) notes that the peak-end rule implies that the duration of a sequence has no effect. This observation, referred to as duration neglect, lead to violation of transitivity of choices. In the controlled experiment conducted by Redelmeier et al. (2003) participants experienced either a shorter sequence of painful stimuli or a longer sequence identical to the first except that the last stimulus was less painful. When asked to choose which sequence they would prefer to experience again, a majority of the participants chose the longer sequence with the less painful end.

The issue that we address in the present paper is how satisfaction with the stages of a work commute is aggregated to satisfaction with the work commute as a whole. We draw an approximate parallel to the relation between remembered utility (satisfaction with the work trip as a whole) and instant utility (satisfaction with the stages of the trip), while recognizing that also experienced utility of the stage is a remembered utility because stages themselves consist of several components. Furthermore, in our empirical study we obtain retrospective measures of satisfaction with the work commute trip and with the stages of the work commute trip. For work commutes consisting of discrete stages varying in duration, weighing satisfaction with each stage with its duration and then summing would be the normatively correct aggregation rule. The peak-end rule is a violation of this rule since it does not take into account the satisfaction with all stages, nor that the stages vary in duration. Summing the satisfaction with each stage is another aggregation rule that takes into account the satisfaction with all stages but not their duration. Averaging the satisfaction with each stage is still another aggregation rule also taking into account satisfaction with all stages but not their duration.

It should be noted that our analysis is limited to the aggregation of the satisfaction with stages into an overall satisfaction with the trip. The analysis is however not applicable to the evaluation of tours, which can be defined as a sequence of trips starting and ending at the same location. For example, a commute tour would consist of a trip from home to work, being at work, and the trip from work back home. Satisfaction with such a commute tour would not only depend on the trips made (consisting of consecutive stages), but also on the satisfaction with the work activity (which consists of many subtasks). This aggregation process is beyond the scope of our study. In a survey of Swedish work commuters that we have conducted, participants are only asked to report their satisfaction with each stage of their commute to work and from work, respectively, as well as their satisfaction with the commute to work as a whole and the commute from work as a whole, respectively. Satisfaction is in both cases measured by the STS (Ettema et al. 2012). Friman et al. (2012) showed by means of confirmatory factor analyses that the STS consists of a cognitive evaluation, an affect dimension (positive activation) varying from excited to bored, and another affect dimension (positive deactivation) varying from relaxed to stressed. The results will be analyzed for all three dimensions of STS and for both the commutes to and from work. In the analyses of the results the peak-end rule will be compared to the summing rule, the equal-weight averaging rule, and the duration-weighted averaging rule.

The remaining paper is organized as follows. In the next section a description is given of how the survey data were collected. Then, the aggregation rules are specified mathematically. The estimation results are reported in the fourth section. The results and their implications are discussed in the fifth and final section.

Survey

Sample

A random sample of 4,430 individuals obtained from the Swedish tax register was mailed a questionnaire to be answered. Usable answers were obtained from 996 of those who were

Table 1 Background characteristic for participants in Stockholm, Göteborg, and Malmö

	Stockholm (pop. 850,000)	Göteborg (pop. 510,000)	Malmö (pop. 395,000)
Sample size	338	350	308
Response rate (%)	22.9	23.7	20.8
Women (%)	56.8	61.1	60.7
Non-response (%)	1.8	0.0	1.0
Mean age (M/SD)	43.5/13.2	42.7/13.7	42.2/13.1
Non-response (%)	3.8	2.9	2.6
Number of children (M/SD)	0.7/1.0	0.8/1.1	0.8/1.0
Non-response (%)	8.9	6.9	9.4
Household type (%)			
Single household without children	24.5	25.7	20.4
Single household with children	7.1	2.6	7.8
Cohabiting household without children	36.4	33.7	36.4
Cohabiting household with children	29.9	37.7	33.8
Non-response (%)	2.1	0.3	1.6
Monthly household gross income in '000 SEK[a] (%)			
<42	34.3	40.9	39.6
42–64	29.6	32.9	26.9
>64	24.9	14.9	17.5
Non-response (%)	11.2	11.5	15.9
Driver's license (%)	80.9	88.3	83.7
Non-response (%)	6.5	4.9	7.1
Type of owned car (%)			
Small	22.3	26.6	30.8
Medium	39.6	51.2	45.5
Large	21.6	25.4	25.8
SUV or minibus	7.0	4.0	3.7

[a] 1 SEK was approximately equal to USD 0.15 at the time of the survey

contacted. After screening, the sample consisted of 713 work commuters (58.3 % female; age ranging from 20 to 65 with a mean of 41.2 years) living in the three largest urban areas of Sweden (Stockholm, pop. 850,000; Göteborg, pop. 510,000; Malmö, pop. 395,000). See Table 1 for sample characteristics.

Questionnaire

The mail questionnaire had three consecutive modules consisting of questions about the work commute, overall subjective well-being, and socio-demographics. Here we only describe the module with questions about the work commute. See Olsson et al. (2011) for a detailed description of the survey and summary of descriptive statistics.

The most recent normal commute to work and from work was targeted in the questionnaire. Date, departure and arrival times, and whether being alone or accompanied during the whole trip were first reported. The STS was then administered to assess

Table 2 The ratings scales comprising the satisfaction with travel scale (STS)

Cognitive evaluation
Worst imaginable (−3)—best imaginable (3)
Very low standard (−3)—very high standard (3)
Worked very well (−3)—worked very poorly (3)
Positive activation versus negative deactivation
Very tired (−3)—very alert (3)
Very bored (−3)—very enthusiastic (3)
Very fed up (−3)—very engaged (3)
Positive deactivation versus negative activation
Very hurried (−3)—very relaxed (3)
Very worried (−3)—very confident (3)
Very stressed (−3)—very calm (3)

satisfaction with both the commute to work as a whole and the commute from work as a whole (hence referred to as *whole trip STS* to work and from work, respectively). As Table 2 shows, the STS consists of three numerical seven-point adjective scales ranging in equal steps from −3 to 3 measuring quality of travel, another three identical numerical seven-point adjective scales measuring positive activation versus negative deactivation, and three identical numerical seven-point adjective scales measuring positive deactivation versus negative activation. The participants were asked to make a rating corresponding to their experience during the trip. For instance, if they felt very stressed they were asked to choose −3, if they felt very calm 3, or if they felt neither stressed nor calm 0. If they felt only slightly stressed or slightly calm, they were asked to choose an appropriate number in between. The adjective scales were presented in a counter-balanced order.

After having answered the questions about the commute to work as a whole, at most five consecutive intermediate stops of the commute to work were indicated. For each stage defined by the stop, information was obtained about travel mode, duration in minutes, degree of street congestion, degree of in-vehicle crowdedness for public-transit trips, and activities performed during the trip. Thereafter, the STS was obtained for each stage (hence referred to as stage STS). The same questions were then answered about the commute from work as a whole and about each stage of the commute.

Measures

Index measures of the cognitive evaluation, positive activation, and positive deactivation dimensions of STS were constructed by averaging across the scale ratings. Table 3 reports sample sizes, means, and standard deviations. Cronbach's αs reported in the table for each measure suggest a satisfactory reliability (>0.70) (Nunnally and Bernstein 1994; Peterson 1994).

Specification of aggregation rules

The peak-end, summing, equal-weight averaging rule, and duration-weighted averaging rules are specified as follows (where STS_i denotes the STS values for stage i, I the set of all stages ($i \in I$), n the number of stages, and t_i the duration of stage i).

Table 3 Subsample size (n), means (M) of ratings on the different scales (see Table 2), standard deviations (SD), and Cronbach's αs for each STS dimension per stage and overall for commutes to and from work

	Cognitive evaluation				Positive activation				Positive deactivation			
	n	M	SD	α	N	M	SD	α	N	M	SD	A
Commute to work												
Stage (1)	730	1.24	1.10	0.83	733	0.59	1.11	0.81	747	0.91	1.28	0.86
Stage (2)	366	0.99	1.12	0.86	365	0.36	1.10	0.82	372	0.77	1.23	0.85
Stage (3)	202	0.97	1.16	0.87	201	0.46	1.21	0.87	207	0.71	1.29	0.86
Stage (4)	76	0.94	1.25	0.91	76	0.55	1.19	0.82	78	0.71	1.39	0.89
Stage (5)	27	0.87	1.23	0.86	27	0.38	0.95	0.59	27	0.71	1.23	0.81
Whole trip	792	1.08	1.13	0.83	791	0.32	1.09	0.74	797	0.96	1.29	0.86
Commute from work												
Stage (1)	673	1.07	1.13	0.87	673	0.43	1.13	0.82	673	0.98	1.23	0.89
Stage (2)	363	0.96	1.16	0.88	363	0.36	1.20	0.84	363	0.89	1.26	0.90
Stage (3)	185	1.11	1.21	0.91	185	0.46	1.21	0.85	185	0.91	1.32	0.92
Stage (4)	79	0.96	1.07	0.84	79	0.27	1.17	0.82	79	0.76	1.19	0.85
Stage (5)	30	0.68	1.14	0.88	30	0.20	1.02	0.73	30	0.53	0.91	0.82
Whole trip	794	1.07	1.13	0.83	794	0.32	1.09	0.73	801	0.97	1.28	0.86

Peak-end rule

The peak rule posits that the average of peak stage STS (i.e. *PeakSTS*) and last stage STS (i.e. *EndSTS*) determines whole trip STS. *PeakSTS* is given as

$$PeakSTS = STS_{i(max)} \tag{1}$$

where $i(max)$ denotes the sequential number of the stage excluding the last one whose STS gives the largest deviation from the average STS. Note that this implies that the peak is either the highest or lowest stage STS whichever is the largest. *EndSTS* is the STS of the last stage given as

$$EndSTS = STS_n \tag{2}$$

Thus the peak-end rule is given as

$$Peak - end\,rule = Sum(PeakSTS + EndSTS)/2$$

Summing rule

The summing rule posits that summing of all stage STS (i.e. *SumSTS*) determines whole trip STS. *SumSTS* is given as

$$SumSTS = \sum_{i=1}^{n} STS_i \tag{3}$$

Equal-weight averaging rule

The equal-weight averaging rule posits that the average of all stage STS (i.e. *AverageSTS*) determines whole trip STS. *AverageSTS* is given as

$$AverageSTS = \frac{\sum_{i=1}^{n} STS_i}{n} \tag{4}$$

Duration-weighted averaging rule

The duration-weighted averaging rule posits that the sum of all stage STSs weighted by the duration of the stage relative to the total duration (i.e. *Duration-WeightedSTS*) determines whole trip STS. *Duration-weightedSTS* is given as

$$Duration\text{-}weightedSTS = \frac{\sum_{i=1}^{n} (STS_i \times t_i)}{\sum_{i=1}^{n} t_i} \tag{5}$$

Estimation results

In tests of which aggregation rule gives the best fit to the data, only STS for trips with 3 and 4 stages are used ($n = 180$ for STS to work, $n = 166$ for STS from work). Table 4 shows means and standard deviations of the rule-aggregated values defined as in Eqs. (1)–(5), product-moment correlations between these variables and *whole trip STS*, and the average error (root mean square error or RMSE) between observed and rule-aggregated values. As may be seen, the highest correlations and lowest RMSE are observed for the duration-weighted averaging rule.

Hierarchical OLS multiple linear regression analyses were then conducted to investigate how much the model fit would be improved by adding the more complex aggregation rules to the peak-end rule. In the first step the peak-end rule was entered as an explanatory variable. As can be seen in Table 5, all increments in variance (ΔR^2) from zero are significant at $p < 0.05$ or less. In the next step, the summing rule is entered resulting in significant increments in explained variance. This indicates that the summation model outperform the peak-end rule. In the third step, the equal-weight averaging rule is entered. Significant or marginally significant increases in variance are observed except for positive activation for the from-work trip. In the final step the duration-weighted averaging rule is entered. The results again show that significant increases in variance are observed except for positive activation for from-work trips. The regression analyses thus suggest that the duration-weighted averaging rule gives a better fit to the data than the other aggregation rules. A possible exception is positive activation for from-work trips where the variance increments failed to reach significance.

Discussion

In this paper we compared several rules by which people may aggregate satisfaction with the stages of a work commute to satisfaction with the work commute as a whole. The STS (see Ettema et al. 2011, 2012; Friman et al. 2012) was used to measure three dimensions of satisfaction with travel, a cognitive evaluation dimension and two affective dimensions. The data analyzed were obtained from a survey of work commuters in the three largest urban areas in Sweden (Olsson et al. 2011).

Table 4 Means (M) and standard deviations (SD) of model-aggregated STS, product moment correlations with *overall STS* (r), and route mean squared error (RMSE)

	Cognitive evaluation					Positive activation					Positive deactivation				
	n	M	SD	R	RMSE	n	M	SD	R	RMSE	n	M	SD	R	RMSE
Commute to work															
PeakSTS	175	1.45	1.19	0.57	1.88	174	0.62	1.44	0.63	1.57	177	1.07	1.39	.69	1.75
EndSTS	172	1.11	1.17	0.56	1.65	172	0.62	1.24	0.61	1.29	174	0.80	1.26	0.62	1.60
SumSTS	175	3.38	3.15	0.65	3.19	174	1.51	3.41	0.70	2.46	177	2.45	3.59	0.72	3.05
AverageSTS	175	1.06	0.98	0.68	1.60	174	0.48	1.06	0.71	1.22	177	0.76	1.08	0.75	1.54
Duration-WeightedSTS	175	0.95	0.98	0.68	1.57	174	0.37	1.07	0.73	1.20	177	0.74	1.08	0.74	1.52
Commute from work															
PeakSTS	157	1.43	1.28	.57	1.92	157	0.47	1.50	0.63	1.56	161	1.29	1.40	0.53	1.90
EndSTS	156	1.30	1.20	0.45	1.68	156	0.53	1.26	0.46	1.32	160	1.13	1.23	0.49	1.65
SumSTS	157	3.36	3.21	0.72	3.24	157	1.04	3.38	0.64	2.53	161	2.96	3.58	0.72	3.19
AverageSTS	157	1.00	1.00	0.73	1.54	157	0.32	1.02	0.65	1.22	161	0.90	1.08	0.74	1.57
Duration-WeightedSTS	157	0.89	0.97	0.77	1.53	157	0.22	1.05	0.65	1.22	161	0.83	1.08	0.76	1.56

Ms and SDs are the rule-aggregated values, *r*s the correlations based on *n* observations between the rule-aggregated values and the *overall STS*. Root mean square error (RMSE) is calculated as Sqrt(Sum(Sqrt(observed value—rule-aggregated value)))/n

Table 5 Increments in explained variance (ΔR^2) in hierarchical multiple linear regression analyses

	Cognitive evaluation		Positive activation		Positive deactivation	
	ΔR^2	*p*	ΔR^2	*p*	ΔR^2	*p*
STS to work						
Step 1						
Peak-end rule	0.345	<0.001	0.414	<0.001	0.486	<0.001
Step 2						
Summing rule	0.087	<0.001	0.079	<0.001	0.081	<0.001
Step 3						
Equal-weight averaging rule	0.019	0.019	0.011	0.056	0.008	0.083
Step 4						
Duration-weighted averaging rule	0.035	0.001	0.035	0.001	0.029	0.021
STS from work						
Step 1						
Peak-end rule	0.323	<0.001	0.413	<0.001	0.287	<0.001
Step 2						
Summing rule	0.230	<0.001	0.042	0.002	0.231	<0.001
Step 3						
Equal-weight averaging rule	0.054	<0.001	0.007	0.157	0.033	0.001
Step 4						
Duration-weighted averaging rule	0.014	0.022	0.001	0.573	0.024	0.004

The results clearly refuted the peak-end aggregation rule which has been observed in several previous studies of how remembered utility is aggregated from instant utilities (Fredricksen 2000; Kahneman 2000). An exception is the study by Miron-Shatz (2009) showing that a normatively correct duration-weighted aggregation rule outperformed the peak-end rule. Thus, our results are consistent with Miron-Shatz' results, which were obtained for positive and negative affect associated with everyday activities performed during a day. An important difference between our research as well as that of Miron-Shatz (2009), compared to the research demonstrating the peak-end rule (e.g. Kahneman 2000), is the smaller number of instant utilities over which aggregation was made. One likely reason for using the peak-end rule is to overcome cognitive limitations such as difficulty to remember all the experienced events. In a similar vein Robinson and Clore (2002) argue that affects induced by events in a sequence is only possible to later remember by retrieving information about the experienced events. If time of occurrence or number of events increases such that remembering the events become more difficult, different selection biases would be expected due to simplification of memory retrieval. The peak-end rule is one selection bias but there may be others depending on contextual factors. Such selection biases may not always result in duration neglect (Ariely and Loewenstein 2000).

The issue raised in this paper seems to have been largely neglected in research on travel behavior. It is important then to ask whether our finding that the normatively correct (duration-weighted averaging) aggregation rule best fitted the data generalizes to other types of trips. As already implied, only if the stages ("instant utilities") are few, this is likely to be the case. Therefore, one should always consider the possibility, both in research and applications, that the peak-end rule is a viable alternative. Another factor to note is that in the survey we asked participants to evaluate normal commutes. Such trips are likely to be more stable and would include few salient events. Therefore, "peaks" may have a smaller impact for normal commutes than other trips. This may account for the fact that rules that incorporate all the stage STSs, such as the summing and equal-weight averaging rules, explained the aggregation better than the peak-end rule. Furthermore, the durations of each stage would be rather familiar. Therefore, duration-weights should be available to apply. Thus, we cannot claim that our results rule out that the peak-end rule would explain the aggregation of STS of stages for trips that are not as repetitive as work commutes. This is a question that future research should address.

Another short-coming of the present survey is that we measured both stage STS and whole-trip STS by asking participants to recall the most recent (normal) work commute. In future research it would be desirable to attempt to measure instant utilities for stages during travel. Several methods for doing this have been developed (Stone et al. 1999). It should however be noted that comparable results have been obtained with the Daily Reconstruction Method (Kahneman et al. 2004) requiring participants to judge affect associated with reconstructed episodes that occurred the previous day. Also the Event Reconstruction Method (Schwartz et al. 2009) requiring participants to judge affect associated with specified episodes may lead to comparable results for less recent episodes if these are infrequent such that they stand out.

A remaining issue relevant for transport planning is what determines satisfaction with stages, in the present case stages of normal work commutes. Travel mode is likely to be the most important factor (Olsson et al. 2012). Walking and biking are popular because they provide desirable physical exercise (Lawrence et al. 2006). Driving is preferred because in general it is faster and flexible (Jakobsson Bergstad et al. 2011b). Speaking in favour of public transit is that it allows for engagement in activities such as talking to others, resulting in positive affects, and work or entertainment activities that reduce stress and boredom (Ettema et al. 2012). The emphasis of the present study is however on investigating how stage satisfactions are integrated, rather than on the factors that determine the satisfaction with the stage. We finish by noting some implications for transport planning.

If a stage of a trip is experienced to enhance satisfaction, our results suggest that satisfaction with the whole trip would still suffer if this enhancement fails to apply to other stages. An important practical message is then that no parts of a work commute should be neglected in transport planning. Conversely, our results suggest that in order to increase overall trips satisfaction, improvements in each stage will add to the overall trip satisfaction. Thus, not only increasing the peaks or avoiding the lows are important, but also increasing the satisfaction of an average stage adds to a higher trip satisfaction. At the same time, the duration-weighted aggregation rule suggests that improving the longest stage is the most efficient way to increase trip satisfaction. For more complex trips, such as public transport trips, this would require an analysis of the duration distribution of stage by specific modes (e.g. walking/cycling to/from the public transport station, being in a bus or train) to determine on which modes policy should focus.

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