Perception bias in route choice

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ABSTRACT

Travel time is probably one of the most studied attributes in route choice. Recently, perception of travel time received more attention as several studies have shown its importance in explaining route choice behavior. In particular, travel time estimates by travelers appear to be biased against non-chosen options even if these are faster. In this paper, we study travel time perception and route choice of routes with different degrees of road hierarchy and directness. In the Dutch city of Enschede, respondents were asked to choose a route and provide their estimated travel times for both the preferred and alternative routes. These travel times were then compared with actual travel times. Results from previous studies were confirmed and expanded. The shortest time route was chosen in 41% of the cases while the *perceived* shortest time route was chosen by almost 80% of the respondents. Respondents overestimated travel time in general but overestimated the travel time of non-chosen routes more than the travel time of chosen routes. Perception of travel time depends on road hierarchy and route directness, as more direct routes and routes higher up in the hierarchy were perceived as being relatively fast. In addition, there is evidence that these attributes also influence route choice independently of perceived travel time. Finally, travel time perceptions appear to be most strongly biased against non-chosen options when respondents were familiar with the route or indicated a clear preference for the chosen routes. This result indicates that behavior will be more difficult to change for the regular travelers.

INTRODUCTION

This paper presents the results of a survey that builds upon previous research on drivers' perception of route alternatives [1]. The general research interest is to identify and quantify perception errors associated to route choice as these are presumed to be a good indicator for so-called indifference bands. The latter is related to satisficing behavior which states that drivers consciously make choices that are satisfactory rather than optimal [2, 3]. Moreover, it is assumed that drivers only alter their choice when the utility, e.g. travel time, difference between two alternatives becomes larger than some individual-situation-specific threshold (i.e. the indifference band) [4, 5]. Suboptimal choice behavior also occurs unconsciously due to limited awareness and errors in perception, which is caused by imperfect knowledge and limited cognitive abilities [6, 7]. This behavior is better known as bounded rationality. Finally, there is evidence that drivers do not necessarily choose shortest time routes [8-13], which can be explained by the importance of many other route attributes: directness, road hierarchy, number of intersections and turns [9-11, 14-16], reliability of travel time, distance and maximum speed [9, 15, 17, 18], information and weather [19], and the moment of congestion [20-22]. It is however not clear if these attributes are consciously considered by the decision maker and therefore explicitly contribute to the utility, or if they influence route choice indirectly because they alter the travel time perception of the driver. To connect psychological and behavioral mechanisms with route choice mechanisms, to improve traffic models and/or traffic information systems is not new [e.g. 23, 24-28]. However, there is a strong need for more empirical evidence to better understand these mechanisms and to support the assumptions made.

Although traditionally it is assumed that drivers objectively weight the attributes of the choice options available to them, there may be a strong connection between *perceived* travel times on the one hand and route attributes and route choice on the other hand. Recently the interest to study travel time perception has increased. One study concluded that drivers attach higher value to travel time variability when examining perceived travel time measurements, whereas they attach higher value to expected travel time when only real measurements of travel times are analyzed [29]. Another study highlights that the travel time perception error of travelers has been largely ignored and concludes that drivers use thresholds to determine whether a travel time is within an acceptable margin or not, while simultaneously considering the frequency of travel times (they are able to recall) within these acceptable margins [30]. A third study showed that perceived travel times are highest for shorter distance trips and for networks with many alternatives and/or no clear optimal alternative, whereas perceived travel times are lower when high hierarchy links are present [31]. Lastly, [32] found that perceptions were only 50% accurate and that drivers' perceptions of travel speeds were more accurate than their perceptions of travel time.

In the previous study of the authors [1] we found that compared to actual travel times, the perception of travel time was significantly worse for options that were not chosen. This provides evidence in favor of the choice supportive bias which suggests that people are more likely to attach positive feeling to options they choose and attribute negative emotions to options they reject. Furthermore, perceived travel time appeared to be a more relevant attribute for route choice than actual travel time. At the same time, there was some indication that drivers perceived the preferred 'high speed' orbital routes as being faster than the fewer chosen 'short distance' center routes, even if the average travel time of the former was higher. However, none of these results were found to be statistically significant due to low number statistics.

In anticipation to these aspects, the aim of this study is threefold: (1) reproduce the findings from the previous study; (2) study the influence of road hierarchy and directness on route choice and the perception of travel times, and; (3) study the influence of familiarity and preference on route choice and the perception of travel times. In the next section the approach for data collection is further described. Thereafter the results are presented followed by discussion and conclusions.

APPROACH

To assess perception bias of route choice alternatives we compared perceived travel times with actual travel times. The actual and perceived travel times consist of the following four travel times:

1. ATT+, the actual travel time of the chosen alternative
2. PTT+, the perceived travel time of the chosen alternative
3. ATT-, actual travel time of the non-chosen alternative
4. PTT-, perceived travel time of the non-chosen alternative

Data was collected in the medium-sized city Enschede in the Netherlands, which has about 130.000 inhabitants. Although the city is rather small and compact in an international context, it can be considered a large city (13^{th} in the Netherlands) in the Dutch context.
Perceived travel times were measured by means of an interview survey, while actual travel times were derived from probe vehicles. For decades survey methods and survey design has been an important topic [e.g. 33, 34] that recently revived with the availability of new technologies [e.g. 35, 36]. To overcome some of the deficiencies of stated choice data such as discussed in these studies, realistic choice options based on real-world routes were used in this experiment. These choices represent real choices that are being made by many motorists every day when they traverse the center of Enschede.

We also distinguish between familiar and non-familiar respondents. For respondents that are familiar with the situation, we can assume that they have actually made these route choices before. For these respondents, the data may therefore be viewed as revealed choice data in which reported travel times are based on the respondents' actual experiences. The choice data of non-familiar respondents offers an interesting opportunity to evaluate this assumption and to determine the effect of familiarity on route choice and perception.

Ideally, perceived and actual travel times should be collected for individual trips, which unfortunately was not possible in this case. Inevitably, this means that we used averages when comparing perceived and actual travel times. However, we will also compare mutual perceived travel times, i.e. those between chosen and non-chosen alternatives. In this case, individual perceived travel times of different alternatives can be compared in a relative way, meaning that possible biases in perception caused by the experimental setup will cancel each other out.

Interview survey

The survey was based on a real-world scenario and included 4 choice situations for 1 OD-pair based on 4 route alternatives. Respondents were recruited at parking areas on the university campus on two different days with 6 weeks in between. The respondents represent a random sample of university employees, students and visitors. To study the effect of road hierarchy (i.e. orbital or urban route) and directness (i.e. north or south route) on perceived travel times, a pairwise survey design was chosen. The choice situations for the two treatments were as follows:

- Treatment 1 on day 1 (north vs. south):
  - Choice situation 1: orbital-*north* vs. orbital-*south*
  - Choice situation 2: center-*north* vs. center-*south*
- Treatment 2 on day 2 (orbital vs. center):
  - Choice situation 1: *orbital*-north vs. *center*-north
  - Choice situation 2: *center*-south vs. *orbital*-south

At the start of the interview a map was shown on which the choice situations were indicated (see **Figure 1**). The respondents were asked to imagine they had to make a business trip from the university to a business park in the morning peak period. Four questions had to be answered for each of the choice situations. First the respondents had to indicate their level of familiarity with each of the routes on a 4-point scale (very familiar, moderate familiar, used 1-2 time, never used). Next the respondents had to indicate which route they would choose before they had to give an estimate of the travel time of both routes. Finally it was asked to indicate the preference strength on a 4-point scale (high, medium, low, none).

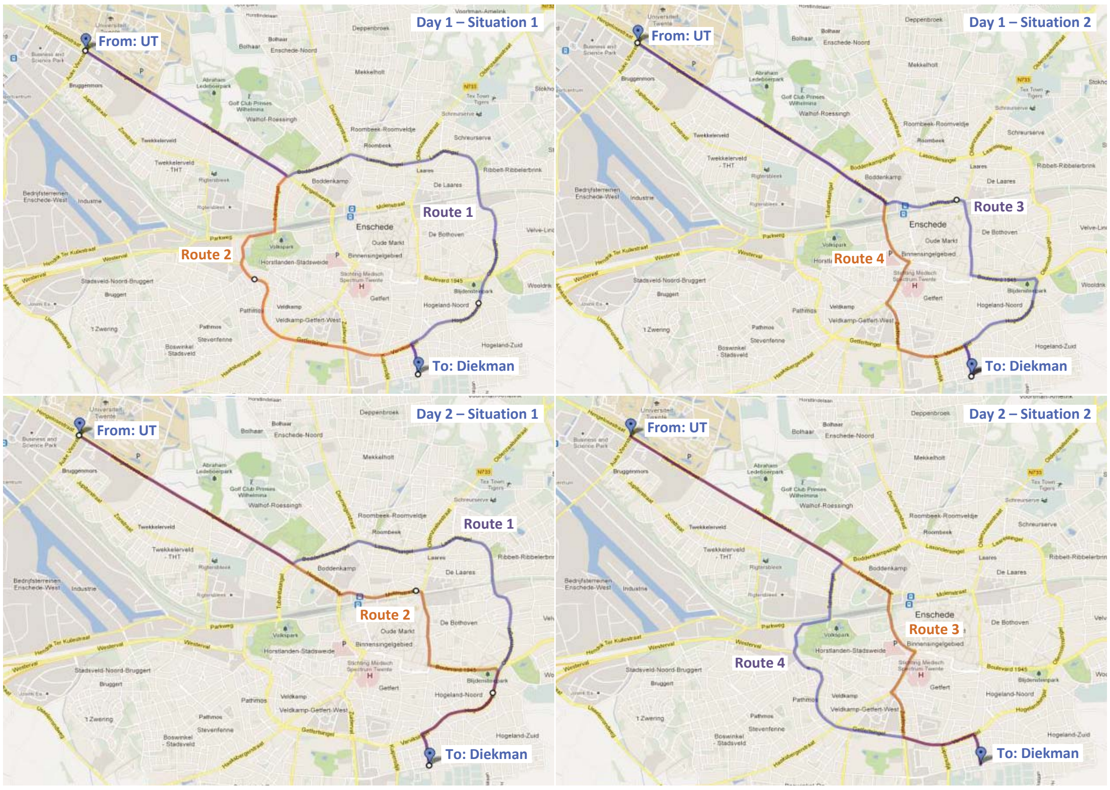

Figure 1 – Route choice situations treatment 1 (top) and treatment 2 (bottom)

Travel time measurement

Actual travel times were derived from vehicle inductive profiles that were sampled by traffic light inductive loop detectors. The system algorithm matches vehicle inductive profiles from loop detectors located at neighboring intersections to derive the actual travel time accordingly [37]. Hence, travel time sections run from signalized intersection to signalized intersection. In the city of Enschede all signalized intersections are covered by the system. For 5-minute intervals the system outputs the average, minimum and maximum travel time. Route travel times are based on the cumulative travel time of subsequent sections. AM-peak measurements (7:30 – 9:30) were used for this analysis. For each 5-minute interval an average was calculated based on data of 15 working days.

As a result, **Figure 2** shows the historic average travel time of the four routes. What stands out is that the AM-peak period is relatively short while the PM-peak period lasts relatively long. Usually, the orbital north route is the shortest time route while the orbital south route has the highest average travel time. Except for the PM-peak period, the average travel time of the center south route is higher than the travel time of the center north route.

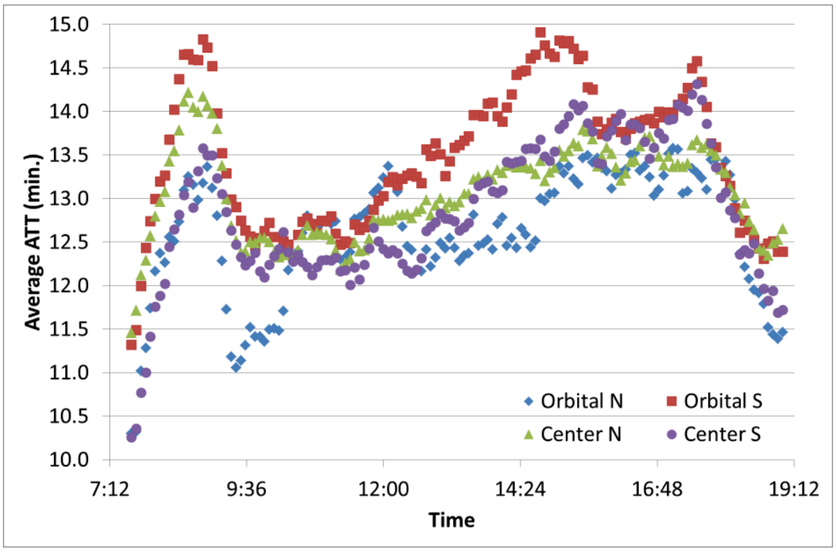

Figure 2 – Actual Travel Time of the four routes

RESULTS

Results Perceived Travel Times

A total of 214 respondents completed the survey on day 1 and 103 respondents completed the survey on day 2. This response provided 624 valid choice situations as not all respondents completed both choice situations. The results are summarized in **Table 1** and **Figure 3**. To derive the p-values for rows 12, 14, 16, 17 and 18 t-tests were used. Differences are significant with $p \leq 0.05$ and highlighted in bold.

The first row indicates the choice situation as shown in **Figure 1**, while the rows 6 to 10 indicate the route characteristics in terms of route type, route distance, average travel speed and actual travel time (ATT). The rows 2 to 5 summarize the choices made by the respondents. Columns (a) to (i) show results for individual choice situations while the other columns show aggregated results per route, by road hierarchy (orbital vs. center) and by route directness (north vs. south). Based on the choices and the route characteristics it can be seen that 41% of the respondents chose the shortest time route. In comparison, 46% of the respondents chose the route with the highest average speed and 54% chose the shortest distance route. The rows 11 and 12 deal with perceived travel times of all respondents together (PTT+/-) and show that travel times are generally overestimated while **Figure 3** shows that travel time estimates are largely variable. On average, travel times were overestimated by 5.5 minutes which equals about 40% of the average ATT.

Dependent on whether a route is often chosen or not, perceived travel times be different. We therefore also considered estimates of respondents who selected a route (i.e. users) and those who did not (i.e. non-users) separately. Rows 13 and 14 summarize results of perceived travel times of users (PTT+), while rows 15 and 16 deal with travel time perceptions of non-users (PTT-). Note that the sample size of users equals the number of choices in row 2, whereas the sample size of non-users equals the number of non-choices in row 3. The rows 17 and 18 compare the perceptions of users and non-users, per route (e.g. cell 13a vs. cell 15a) and per choice situation respectively (e.g. cell 13a vs. cell 15b).

For both users and non-users the perceived travel times are larger than the actual travel times, with statistical significance. Besides, the difference between PPT+ and PTT- shows that the respondents on average overestimated travel times of non-chosen routes by 1.3 minutes *more* than the travel times of chosen routes. This equals about 9% of the actual travel time. Due to the large variation in the perceived travel time and the relatively small samples for choice situation 3 and 4, this finding is only statistically significant on a limited number of routes. Interestingly, row 17 shows that on a route level it concerns the orbital south and center south routes.

Table 1 – Summary of survey results – route level (p < 0.05 in bold)

* 'Hierarchy is the sum of choice situations 3 and 4 (i.e. treatment 2), while 'directness' is the sum of choice situations 1 and 2 (i.e. treatment 1)

	Rows / Columns	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**	**(k)**	**(l)**	**(m)**	**(n)**	**(o)**	**(p)**	**(q)**
(1)	Choice situation	1		2		3		4		Cum.	Agg. Route				Agg. Hierarchy		Agg. Directness	
(2)	Number of choices	81	133	87	118	52	50	66	37	624	133	199	137	155	118	87	168	251
(3)	Number of non-choices	133	81	118	87	50	52	37	66	624	183	118	170	153	87	118	251	168
(4)	Choices in situation (%)	38%	62%	42%	58%	51%	49%	64%	36%		42%	63%	45%	50%				
(5)	Choices overall (%)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		21%	31%	22%	25%	58%	42%	40%	60%
(6)	Road hierarchy	Orbital	Orbital	Centre	Centre	Orbital	Centre	Orbital	Centre		Orbital	Orbital	Centre	Centre	Orbital	Centre		
(7)	Route direction	North	South	North	South	North	North	South	South		North	South	North	South			North	South
(8)	Route distance (km)	7.3	6.4	6.8	5.8	7.3	6.8	6.4	5.8		7.3	6.4	6.8	5.8	6.9	6.3	7.1	6.1
(9)	Average speed (km/h)	33.09	26.12	29.31	24.95	33.09	29.31	26.12	24.95		33.09	26.12	29.57	24.95	29.6	27.3	31.3	25.5
(10)	Actual travel time (ATT)	13.2	14.7	13.8	13.9	13.2	13.8	14.7	13.9	14.0	13.2	14.7	13.8	13.9	14.0	13.9	13.5	14.3
(11)	Perceived travel time (PTT+/-)	19.5	19.01	19.56	19.77	19.98	19.86	18.88	20.59	19.5	19.7	19.0	19.7	20.0	19.4	20.2	19.5	19.4
(12)	Difference (9)-(9)	**6.3**	**4.3**	**5.6**	**5.8**	**6.7**	**5.9**	**4.2**	**6.6**	**5.5**	**6.5**	**4.3**	**5.9**	**6.1**	**5.5**	**6.4**	**6.0**	**5.1**
(13)	Perceived travel time (chosen) - (PTT+)	20.04	17.75	19.52	18.81	19.44	19.24	18.41	19.68	18.9	19.8	18.0	19.4	19.0	18.9	19.5	19.8	18.3
(14)	Difference (15)-(9)	**6.8**	**3.0**	**5.6**	**4.9**	**6.2**	**5.3**	**3.7**	**5.7**	**4.9**	**6.6**	**3.3**	**5.6**	**5.1**	**5.0**	**5.6**	**6.3**	**4.0**
(15)	Perceived travel time (non-chosen) - (PTT-)	19.17	21.07	19.59	21.06	20.54	20.46	19.73	21.11	20.2	19.5	20.7	19.9	21.1	20.1	20.8	19.4	21.1
(16)	Difference (19)-(9)	**5.9**	**6.4**	**5.7**	**7.1**	**7.3**	**6.5**	**5.0**	**7.2**	**6.2**	**6.3**	**6.0**	**6.1**	**7.1**	**6.2**	**6.9**	**5.9**	**6.7**
(17)	Difference PTT+ - PTT- (route)	0.9	**-3.3**	-0.1	**-2.3**	-1.1	-1.2	-1.3	-1.4	**-1.3**	0.3	**-2.7**	-0.4	**-2.1**	-1.2	-1.3	0.4	**-2.8**
(18)	Difference PTT+ - PTT- (choice situation)	**-1.0**	**-1.4**	**-1.5**	**-0.8**	**-1.0**	-1.3	**-2.7**	-0.1	**-1.3**	**-1.0**	**-2.1**	**-1.4**	**-0.4**	**-1.9**	-0.6	**-1.3**	**-1.1**

This can be explained by the values in the rows 13 and 15 which suggest that the respondents were far more optimistic about the southern alternatives compared to the northern alternatives. As a result, when these routes are chosen, estimates are considerably lower in general therefore also for the corresponding non-chosen route alternative. In turn this influences the comparison of PTT+ and PTT- on a route level. See for example 13b versus 15a, and 13a versus 15a.

Aggregation on a route level supports the previous finding. Columns (j) to (m) shows that the orbital south route was chosen most often (31% of the respondents) followed by the center south route (25%). Also PTT+ of these routes is on average smaller than that of the other routes, and also smaller than the actual travel times. A closer look based on columns (n) to (q) teaches that 58% of the respondents chose orbital routes and 60% of the respondents chose a southern route. Same as earlier, the PTT+ of orbital and south routes are on average considerably lower than the PTT+ of center and north routes. Besides, the difference between 'difference PTT+ and PTT-' of orbital routes (cell n18) and center routes (cell o18) versus orbital routes (cell p18) and center routes (cell q18) shows that road hierarchy affects perceptions more than route direction does.

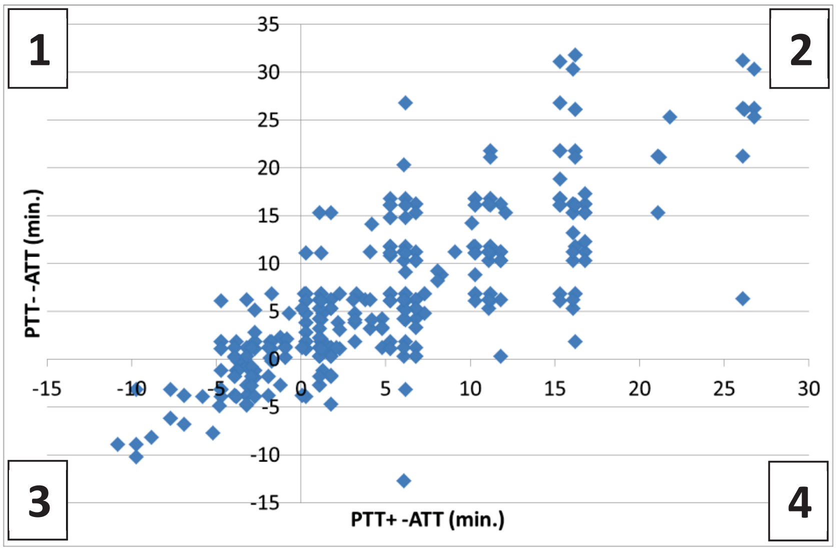

Figure 3 – Difference between PTT and ATT for the chosen and non-chosen route.

In **Figure 3**, we take a slightly different perspective. For each OD pair and each respondent, the difference between perceived and actual travel time is compared for the chosen and non-chosen routes. Each symbol in **Figure 3** thus represents one respondent and one OD pair. From **Figure 3**, we draw the following conclusions. The perceived travel time estimates vary widely with respect to the actual travel time and users both overestimate and underestimate travel times. Not surprisingly, there is a clear correlation between the rate of overestimation of travel time of chosen and non-chosen routes. Most respondents overestimated the travel times of both routes (82% in quadrant 2). Quadrant 1 contains 6% of the samples, quadrant 3 contains 10% and quadrant 4 contains 2%. The median of the x-values is 5.1 minutes and the median of the y-values is 6.1. This confirms the earlier finding that respondents that overestimate the travel time of the chosen route tend to overestimate the travel time of the non-chosen route even more. In fact, the relation between PTT- - ATT- and PTT+ - ATT+ can be well described as: *PTT- - ATT- = PTT+ - ATT+ + x minutes*. In other words, when correcting for differences in actual travel time (or when assuming the same actual travel time), the perceived travel time of the non-chosen route is on average x minutes higher than that of the chosen route. In this case and based on **Figure 3** and **Table 1**, x equals 2.05 minutes.

Table 2 – Analysis hierarchy and directness based on treatments

		Treatment 1	Treatment 2	p
(1)	Perceived travel time (PTT +/-) ALL	19.41	19.75	0.391
(2)	Difference PTT – ATT; ALL	5.19	6.01	0.039
(3)	Difference PTT+ - PTT-; ALL	-1.19	-1.45	0.428
(4)	Difference PTT – ATT; Orbital	5.12	5.47	0.546
(5)	Difference PTT – ATT; Center	5.81	6.27	0.448
(6)	Difference PTT+ - PTT-; Orbital (vs. Center)	-1.27	-1.95	0.097
(7)	Difference PTT+ - PTT-; Center (vs. Orbital)	-1.10	-0.77	0.541
(8)	Difference PTT – ATT; North	5.53	6.43	0.127
(9)	Difference PTT – ATT; South	5.38	5.33	0.927
(10)	Difference PTT+ - PTT-; North (vs. South)	-1.30	-1.17	0.779
(11)	Difference PTT+ - PTT-; South (vs. North)	-1.12	-1.75	0.165
(12)	Difference PTT – ATT; Orbital North	5.36	6.49	0.176
(13)	Difference PTT – ATT; Orbital South	4.88	4.47	0.622
(14)	Difference PTT – ATT; Center North	5.70	6.37	0.428
(15)	Difference PTT – ATT; Center South	5.91	6.18	0.764
(16)	Difference PTT+ - PTT-; Orbital North	-1.04	-1.02	0.978
(17)	Difference PTT+ - PTT-; Orbital South	-1.41	-2.70	0.019
(18)	Difference PTT+ - PTT-; Center North	-1.54	-1.30	0.758
(19)	Difference PTT+ - PTT-; Center South	-0.78	-0.05	0.349

Comparison of treatments

Next we compared data of the two treatments (see approach section) to further explore hierarchy and directness effects. The hypothesis is that the characteristics of a contrasting route alternative in a choice situation as is the case of treatment 2, will show a higher preference (revealed by more choices and decrease in perceived travel time) for orbital and south routes.
Most notable results are shown in **Table 2**. The rows 1 to 3 show that on average the perceived travel times hardly changed but that travel times were overestimated more in treatment 2 than in treatment 1. This can be explained by an increase in the difference between PTT+ and PTT-. Interestingly, rows 6 and 7 show that the difference between PTT+ and PTT- increased for orbital routes and decreased for center routes. This confirms that the preference of orbital routes increased in treatment 2 which is a sign of hierarchy. Similarly, the same pattern can be observed for south routes versus north routes in rows 8 to 11. Another observation is that for the north route the perceived travel times increased while those of the south route remained more or less the same. In contrast, the perceived travel times of orbital and center routes both increased from treatment 1 to treatment 2.

On a route level (rows 12-19), the figures again suggest that especially the attractiveness of the orbital north routes decreased (e.g. row 12) and the attractiveness of the orbital south routes increased (e.g. row 17). Although most figures on a route level are not statistically significant, their signs and size are in line with the rest of the table. It holds that choices cannot be explained by travel time alone. Unmistakably, the choice set provided to the respondents affects the choice outcomes and perceptions. Orbital and south routes are preferred.

Choice strategies

In **Table 2**, we compared two treatments in which travel time averages and differences therein were considered, as well as fractions along the non-shortest travel time route. However, these results don't tell the whole story. First, although treatment 1 mainly considers directness and treatment 2 mainly distinguishes hierarchy, directness and hierarchy are not completely disentangled by the two treatments. For example, the center north route is clearly more direct than the orbital north route. Here, directness may thus play a role in addition to hierarchy. Secondly, the resolution of the perceived travel times is about 5 minutes, i.e. respondents typically round off to multiples of 5 minutes, which is quite large compared to the travel times themselves. As a result, in slightly more than 50% of the cases, respondents perceive both routes as equally long.

Table 3 – Perceptions versus choice strategies

Chosen route	**PTT_a < PTT_b**	**PTT_a = PTT_b**	**PTT_a > PTT_b**	**PTT+ < PTT-**	**PTT+ > PTT-**
Orbital North [a]	24	46	11	76.4%	26.6%
Orbital South [b]	14	62	57		
Total	***38***	***108***	***68***	***STDEV 4.1%***	
Center North [a]	26	58	3	80.5%	19.5%
Center South [b]	14	60	44		
Total	***40***	***118***	***47***	***STDEV 4.3%***	
Orbital North [a]	13	30	9	66%	34%
Center North [b]	9	19	22		
Total	***22***	***49***	***31***	***STDEV 6.5%***	
Orbital South [a]	31	29	6	71.9%	28.1%
Center South [b]	10	17	10		
Total	***41***	***46***	***16***	***STDEV 6.0%***	

In **Table 3**, we therefore show the choice frequencies for each individual choice situation, and separately for cases in which the first route [a] was perceived shorter (column 2), equally long (column 3), or longer (column 4) than the second route [b]. In doing so, we reveal three choice strategies: (1) respondents perceived one route as being shorter in time and choose that route; (2) respondents perceived no difference in travel time and choose one of the routes, and; (3) respondents perceived one route as being shorter in time yet choose the non-shortest time route.

As mentioned, most respondents (51%) perceived no difference in travel time. Given small differences in actual average travel time (in the range of two minutes), this result may be intuitively expected. However, as differences in actual travel time are still considerable (about 10%) this result does not well correspond with traditional utility models. The fact that the majority apparently does not (want to) observe these small travel time differences is more in line with theories about perception error and indifference band. Travel time estimates are also complicated by the fact that there is no clear correlation between actual travel time and distance. On the contrary, the northern orbital route, for example, is the longest distance route, but has the shortest average travel time. However, this situation is not considered as exceptional, and probably is quite common in route choice situations of this kind.

That it is not straightforward to estimate travel time follows from the 49% of answers in which respondents indicated one route to be faster than the other. When we only consider these cases, 60% of the respondents (115 vs. 78) perceived the southern route (orbital south vs. orbital north and center south vs. center north) as being faster, while in reality (i.e. based on actual travel times) southern routes were slower on average. This result is statistically significant (95% confidence level), and the difference is especially clear for the orbital. As southern routes are more direct, this result suggests that other attributes can influence the perception of travel time. At the same time, route choice strongly depends on perceived travel time. This is shown in column 5, which shows that in the first treatment (i.e. north versus south) almost 80% of the respondents chose the route they perceived as having the shortest travel time (not considering the respondents who perceived both routes as being equally long).

From this, one might conclude that other attributes only influence route choice indirectly by altering travel time perception. However, a detailed look reveals that southern routes are more favorable than might be expected from perceived travel times alone. When perceived travel times were equal a majority (122 vs. 104) chose the southern route, although this result is not statistically significant. More significantly, however, compared to northern routes, southern routes are relatively more chosen when the perceived travel time is longer (38 out of 78, i.e. 36% for southern routes vs. only 14 out of 115, i.e. 12% for northern routes). The latter is statistically significant and suggests other attributes (in this case directness) are also consciously considered when choosing routes.

For the second treatment regarding hierarchy, the results are more mixed. For the southern routes, the orbital is perceived as being shorter by a clear and statistically significant majority (72%, i.e. 41 out of 57). This points to the effect of hierarchy, as the orbital is in reality not more direct or faster than the center route. For the northern route, the center route is mostly perceived as being shorter. However, this result is not statistically significant. In this case, the effect of hierarchy might be offset by the center route appearing to be more direct, both in distance as in direction.

For the southern routes, the choice frequencies follow a similar pattern compared to the first treatment. More than 70% of the respondents chose the route they perceived as fastest and the preferred orbital route was more popular as might be expected from perceived travel time alone. When perceived travel times were equal a majority (29 vs. 17) chose the orbital route. Also, compared to the center route, the orbital was chosen more often when the perceived travel time was longer (6 out of 16, i.e. 38% for the orbital route vs. 10 out of 41, i.e. 24% for the center route). All these results are comparable with those from the first treatment, although less strong and not statistically significant.

For the northern routes, the results are more ambiguous, probably because hierarchy and directness are competing effects in this case. Among the respondents who perceived one route as being shorter in travel time than the other, 'only' 66% of the respondents chose the route with the perceived shortest travel time. In most of the cases, this was the center route (as mentioned before), and in addition the center route was also chosen relatively more often when the perceived travel time was longer (9 out of 22 for the center route vs. 9 out of 31 for the orbital). Although not statistically significant, these results are in line with the other choice situations. However, in total the northern orbital was still chosen more often, because most respondents for whom perceived travel times were equal preferred the orbital (29 for the orbital vs. 17 for the center route). As these results are all not statistically significant, we just consider this ambiguity as being coincidental and conclude that for the northern routes opposite factors (i.e. hierarchy and directness) competed with each other.

Familiarity effects

For each of the routes, respondents were asked to indicate their level of familiarity on a 4-point scale (very familiar, moderate familiar, used 1-2 time, never used). Results showed that the vast majority of respondents (i.e. 78%) were equally familiar with both route alternatives. Most respondents were very familiar or moderately familiar with the route alternatives. As shown in **Figure 4** the perceived travel times of the least familiar respondents were lower than those of the most familiar respondents. This finding is statistically significant (95% confidence interval) for orbital north, orbital south and the average. Differences between the other familiarity levels are not systematic. In addition, differences between the PTT+ and PPT- of different familiarity levels were not statistically significant either, which shows that the results presented earlier are independent of the level of familiarity.

As a reference four actual travel times are indicated in **Figure 4**: Minimum TT = lowest travel time recorded in AM peak, Average TT = average travel time in AM peak, Peak ATT = travel time at the busiest moment of the AM peak, and Maximum ATT = highest travel time recorded in AM peak. Considering that travel times were generally overestimated the estimates of the least familiar respondents were among the most accurate. Similarly, the estimates of the most familiar respondents approximate the Peak ATT and Maximum ATT. These findings suggest that respondents initially are fairly positive about new routes, but that actual usage of these routes makes them increasingly pessimistic over time, or perhaps realistic. This might be explained by bad experiences that inevitably occur and make drivers cautious not to rely on average travel times alone but also on the travel time reliability. Along that same line of thought, the minimum ATT and maximum ATT show that the travel time range of the orbital south route is larger than the range of other routes. Hence, relatively low travel times were measured too. This can be explained by the fact that the south route contains the most signalized intersection. Perhaps respondents anticipate to this gamble.

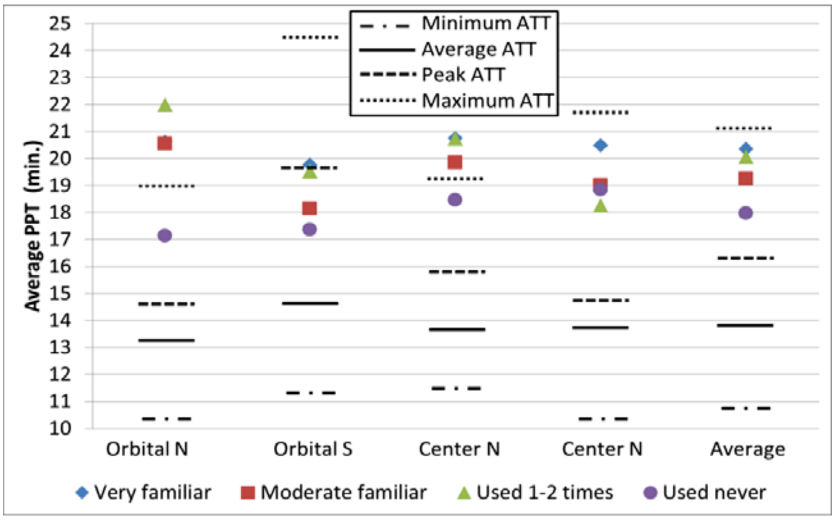

Figure 4 – Perceived travel time versus familiarity

To better understand the findings from **Figure 4**, choice and perceptions figures of the four familiarity levels are shown in **Table 4** (only the cases with equal familiarity of both routes, i.e. 78%). As only the difference between 'very familiar' and 'used never' are statistically significant it is most interesting to examine just these two outer cases. Row 1 shows that most respondents were very familiar or moderately familiar. There are no major differences between the choices of perceived non-shortest time routes (row 2) and the choices of actual non-shortest time routes (row 3). This implies that familiarity does not affect the (dis)ability to select the optimal time route. The rows 4 to 9 suggest that the least familiar respondents chose orbital and south routes more frequently than very familiar respondents did. This suggests that an a priori preference for based on hierarchical and directness principles exists.

Table 4 – Number of choices (%) per choice situation versus level of familiarity

		Very familiar	Moderate familiar	Used 1-2 times	Used never
(1)	Percentage (N = 624)	43%	27%	13%	17%
(2)	Choices perceived non-shortest time route	12%	14%	10%	12%
(3)	Choices of non-shortest time route	59%	47%	63%	65%
(4)	Choices Orbital North (vs. Orbital South)	43%	41%	35%	29%
(5)	Choices Center North (vs. Center South)	51%	40%	56%	31%
(6)	Choices Orbital North (vs. Center North)	49%	77%	33%	50%
(7)	Choices Orbital South (vs. Center South)	68%	60%	57%	75%
(8)	Choices South route (vs. North route)	53%	59%	55%	70%
(9)	Choices Orbital route (vs. Center route)	58%	68%	45%	63%

** Percentages of rows 2 to 9 are out of 100% for each cell*

As mentioned earlier, only 22% of the respondents indicated different levels of familiarity for both route alternatives. In 5% of the cases they were very familiar with one alternative and moderately familiar with the other. The remaining 17% of the cases are randomly spread resulting in too low samples for analysis and therefore excluded. Based on the results shown in **Table 5** it appears that the respondents chose routes which they were most familiar with. While in case of equal familiarity, orbital routes and south routes were chosen more often. It seems that, apart from travel time, familiarity is the primary route choice determinant, followed by road hierarchy (i.e. orbital or center), while directness (i.e. north or south) comes third. This is in line with earlier findings.

Table 5 – Number of choice (%) per route by level of familiarity

		Very familiar		Moderate familiar	
		[a]	[b]	[a]	[b]
[1]	Very familiar [a] Orbital North vs. [b] Orbital South	43%	57%	67%	33%
[2]	Moderate familiar [a] Orbital North vs. [b] Orbital South	0%	100%	41%	59%
[3]	Very familiar [a] Orbital North vs. [b] Center South	49%	51%	43%	57%
[4]	Moderate familiar – [a] Orbital North vs. [b] Center South	14%	86%	77%	23%
[5]	Very familiar [a] Center South vs. [b] Orbital South	32%	68%	83%	17%

** Row: familiarity of route [a]; Column: familiarity of route [b]*

Route preference

Finally respondents were asked to indicate the preference strength on a 4-point scale (high, medium, low, none). On an aggregated level, results are contrasted with the level of familiarity and presented in **Table 6**. Again, for reasons of statistical significance it is most interesting to examine the outer cases: very familiar versus used never and high preference versus no preference. It can be seen that the most familiar respondents have the highest preference for a particular route (column 2) while the least familiar respondents have the lowest preference (column 8). Besides, respondents with a high preference appear to overestimate the travel time of the non-chosen route relative to the chosen route more than respondents with no preference do (2.32 minutes vs. 0.12 minutes). Similarly, the least familiar respondents seem to discriminate less between chosen and non-chosen routes than very familiar respondents do (1.74 minutes vs. 1.01 minutes). Not surprisingly, very familiar respondents and/or those who show a strong preference show a relatively high negative bias towards non-chosen options.

Table 6 – Preference versus familiarity and perception (aggregated)

Preference	Very Familiar		Moderate familiar		Used 1-2 times		Used never		Total	
	Freq.	dPTT	Freq.	dPTT	Freq.	dPTT	Freq.	dPTT	Freq.	dPTT
High	19.0%	-2.92	6.8%	-0.86	3.1%	-2.95	2.1%	-0.77	31%	-2.32
Medium	10.5%	-0.78	8.1%	-0.80	3.4%	-0.10	3.6%	-2.27	25%	-0.91
Low	9.6%	-1.17	6.3%	-1.49	4.1%	-1.36	4.7%	-1.03	25%	-1.26
None	4.1%	0.00	5.7%	-0.11	2.6%	0.31	6.5%	-0.38	19%	-0.12
Total	43%	-1.74	27%	-0.84	13%	-1.11	16.8%	-1.01	100%	-1.29

* dPTT denotes the difference between PTT+ and PTT-

CONCLUSIONS

The aim of this study was threefold: (1) reproduce the findings from the previous study; (2) study the influence of road hierarchy and directness on route choice and the perception of travel times, and; (3) study the influence of familiarity and preference on route choice and the perception of travel times. The overall findings confirm results from the previous study and expand them. The following conclusions can be made: (1) the shortest time route was chosen in 41% of the cases while the highest average speed route was chosen in 54% of the cases; (2) respondents overestimated travel time in general by 5.5 minutes on average. However, they overestimated the travel time of non-chosen routes more (6.2 minutes on average) than the travel time of chosen routes (4.9 minutes on average). On a respondent-level the difference between PTT+ and PTT- was 2.05 minutes on average which equals about 14% of the average actual travel time; (3) 58% of the respondents chose orbital routes and 60% of the respondents chose south routes. Consequently, the orbital south route was chosen most often even though this route had the highest average travel time among the route alternatives; (4) differences in road hierarchy and route direction between routes in a choice set affect the perceived travel times and choice strategies. The results showed that in a specific order of importance: familiar routes were preferred over route that were never used before, orbital routes were preferred over center routes, and south routes were preferred over north routes; (5) perceived travel times of the least familiar respondents were lower than those of the most familiar respondents, which suggests that with more experiences of a particular route drivers become increasingly pessimistic or perhaps cautious.

Findings on travel time perception and perception error have important implications for operational traffic management and traffic models. Consider for example the case of route choice and traffic information. When drivers have a negative perception of a particular route, it may require considerable effort to persuade such drivers to use that (shortest travel time) route. Presumably, the incentive (e.g. monetary or travel time reduction) to switch to a non-chosen route must at the least compensate for the perception error. Similarly, a travel time effect of a traffic management measure may be negligible when considering errors in perception, which gives road operators certain freedom for their operational management [38]. These mechanisms are related to the indifference band mentioned earlier for which the perception error is assumed to be a good indicator [1]. Such principles may also contribute to the improvement of for example random utility models and the definition of the random component in particular.

Future research will attempt to further detail insights in perception error with emphasis on situational and individual differences, and to derive probabilistic findings in addition to deterministic ones. Moreover, experienced based sampling will be adopted as a new data collection method. This method uses a smartphone application to collect objective trip data, and is able to gather subjective data by questioning the user timely and precisely about issues relevant to the researcher.

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