Judgment and Decision Making, Vol. 5, No. 7, December 2010, pp. 477–488

Exploring the time-saving bias: How drivers misestimate time saved when increasing speed

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Abstract

According to the time-saving bias, drivers underestimate the time saved when increasing from a low speed and overestimate the time saved when increasing from a relatively high speed. Previous research used a specific type of task — drivers were asked to estimate time saved when increasing speed and to give a numeric response — to show this. The present research conducted two studies with multiple questions to show that the time-saving bias occurs in other tasks. Study 1 found that drivers committed the time-saving bias when asked to estimate (a) the time saved when increasing speed or (b) the distance that can be completed at a given time when increasing speed or (c) the speed required to complete a given distance in decreasing times. Study 2 showed no major differences in estimations of time saved compared to estimations of the remaining journey time and also between responses given on a numeric scale versus a visual analog scale. Study 3 tested two possible explanations for the time-saving bias: a Proportion heuristic and a Differences heuristic. Some evidence was found for use of the latter.

Keywords: time-saving bias, speed estimation, time estimation, driving behavior.

1 Introduction

If you need to complete a 20 km journey, how much time would it take at a mean speed of 40 kph? Most people would find it easy to answer such a question — 20 km at 40 kph takes half an hour or 30 minutes. But what if you wanted to increase speed in order to reduce journey time? How much time would you save if you increase your speed to 50 kph or to 60 or 70 kph? Many people consistently give the wrong answers to these questions. Several studies have shown that people underestimate the time saved when increasing from a relatively low speed and overestimate the time saved when increasing from a relatively high speed (Fuller et al., 2009; Peer, 2010; Svenson, 2008, 2009). This phenomenon has been termed the time-saving bias (Svenson, 2008).

1.1 The time-saving bias

When drivers choose to increase their travel speed, they do so in many cases because they believe that it will reduce their journey time considerably. Indeed, reducing journey time has been found to be the main reason for drivers increasing speed. Drivers feel frustrated when their speed is too low, and select routes and speeds that will shorten journey time as much as possible (Tarko, 2009). In addition, speeding behavior is often related to time pressure or the desire to save time (Gabany, Plummer, & Grigg, 1997; McKenna, 2005). For example, in one study, 33% of drivers caught speeding indicated that they chose to speed because of time pressure (McKenna, 2005). Being late for a meeting or an appointment is a common reason cited for increasing speed (Campbell & Stradling, 2003).

An increase in speed does indeed result in a decrease of journey time. But the question remains, how much time is gained when speed is increased? and do drivers' lay intuitions correspond to the physical reality? The answer typically found by research is that drivers' estimations of the time gained by increasing speed are biased. As mentioned earlier, people overestimate the time gained by increasing from an already relatively high speed and underestimate the time gained by increasing from a relatively low speed (Fuller et al., 2009; Peer, 2010; Svenson, 1970, 1973, 2008, 2009). For example, when asked to judge which of two road improvement plans would be more efficient in reducing mean journey time, respondents preferred a plan that would increase the mean speed from 70 to 110 kph more than a plan that would increase the mean speed from 30 to 40 kph, although the latter actually saves more time (Svenson, 2008).

*This study was sponsored by a grant from the Israeli National Road Safety Authority. The author wishes to thank Elisha Babad and Eyal Gamliel for their guidance and direction, to Ola Svenson, Jonathan Baron and two anonymous reviewers for their helpful comments and to Lidor Salomon for research assistance. Email: eyal.peer@mail.huji.ac.il.

The correct formula for calculating time gained by increasing speed is

$$t = cD(1/V_1 - 1/V_2) \quad (1)$$

where c is constant, t is the time gained, D is the distance traveled and V_1 and V_2 are the original and increased speeds, respectively (Svenson, 2008, 2009). By using this formula, one can see that, among the options offered to participants in the above research, the second plan (increasing from 30 to 40 kph) saves more time than the first plan (increasing from 70 to 110 kph). For example, when trying to cover a distance of 10 km, the time saved by increasing mean speed from 70 to 110 kph is 3 minutes whereas when increasing from 30 to 40 kph the time saved is about 5 minutes.

A recent study on speeding and the time-saving bias offered another example relevant to real life driving situations (Peer, 2010). In this study, drivers estimated the time a journey of 20 km might take when increasing from a speed of 40 kph to 50, 60 or 70 kph. The study found that drivers systemically underestimated the time that could be saved when increasing from this relatively low speed. Drivers estimated that increasing from 40 kph would save, on average, about 15% less time than in reality. Moreover, their underestimations led drivers to choose unduly high speeds: drivers who showed a high time-saving bias, as opposed to drivers who had a low time-saving bias, indicated a much higher speed as the speed required for arriving on time. This effect was also evident in choices of personal speed and the speed drivers believed other drivers would choose in such situations (Peer, 2010). Another research found that the time-saving bias was associated with drivers' tendency to underestimate how braking distance and the risk of an accident increase when accelerating (Svenson, 2009).

1.2 Why people make the time-saving bias?

If, indeed, people's judgments deviate from the normative mathematical calculation, the question becomes what rule or principle do they follow? By presenting participants with the question of "how many minutes would you save if you increase your mean speed from 70 kph to 110 kph on a 100 km trip?" using different combinations of speed and distance, Svenson (1970, 2009) formulated a function describing people's judgments:

$$t = cD\frac{(V_2 - V_1)}{V_2} \quad (2)$$

where c is constant, t is the time gained, D is the distance traveled and V_1 and V_2 are the original and increased speeds, respectively. The difference between Formulas (1) and (2) shows the bias in judgments of time saving in relation to the actual time saved (Svenson, 2009). For example, a driver increasing speed from 40 to 60 kph for a 20 km journey, which results in an actual saving of 10 minutes, is predicted to underestimate the time saved as about 7 minutes.

Formula (2) is not meant to be an explanation of the cognitive process underlying people's judgments of time gained by speed increase but a description of the typical responses given to such questions. It is still unknown why people commit this erroneous calculation and what factors, if any, increase or reduce its magnitude. Although some reasons have been proposed, to date no study has addressed the possible reasons underlying this cognitive bias.

One reason that drivers may have a time-saving bias is that they fail to take into account the impact the initial speed has on the overall time saved when accelerating (Fuller et al., 2009). This neglect of initial speed leads people to judge the time saved mainly on the basis of the higher speed; they falsely believe that the higher the target speed, the greater the time saved. However, the initial speed strongly affects the potential time saving, as was demonstrated in the examples above. Svenson (2008) also implicitly advocated this explanation when he stated that the differences between Formulas (1) and (2) are mainly due to the smaller weight the initial speed is given in biased Formula (2) relative to correct Formula (1).

Another possible explanation can be related to the way time-saving bias problems have been presented to drivers. Some element in presentation of the problem may have influenced respondents and caused the bias. Accordingly, a different presentation manner may potentially diminish or remove the bias. As an analogy to this argument consider, for example, the problem of miles per gallons vs. gallons per mile, also known as the MPG illusion (Larrick & Soll, 2008). In the U.S.A., fuel efficiency is measured by miles per gallon, instead of liters per kilometers used outside the U.S.A. This form of presentation of data has been found to have a biasing effect on people's perceptions of the relation between a car's MPG and the amount of gas it consumes: "People falsely believe that the amount of gas consumed by an automobile decreases as a linear function of a car's MPG. The actual relationship is curvilinear. Consequently, people underestimate the value of removing the most fuel-inefficient vehicles." (Larrick & Soll, 2008, p. 1593). However, when given fuel efficiency as amount of gas consumed per given distance (e.g., gallons per 100 miles — GPM), respondents adequately assessed differences in cars' fuel efficiency (Larrick & Soll, 2008, Study 3).

Alternatively or additionally, a person's ability to estimate time saved due to a speed increase as opposed to estimating the remaining journey time after a speed in-

https://doi.org/10.1017/S1930297500001649 Published online by Cambridge University Press

crease may not be the same. In most studies to date researchers asked drivers to estimate the time saved, and not the remaining journey time (Fuller et al., 2009; Svenson, 2008, 2009). Possibly, estimating the remaining journey time, instead of the time saved, may affect the time-saving bias. These two alternative modes of presentation (time saved vs. remaining journey time) have yet to be empirically compared.

Tasks also differ in the nature of the data the question provides and the data participants are asked to estimate. Questions typically give drivers the distance and initial speed and ask them to estimate the time saved (or journey time) at higher speeds (Fuller et al., 2009; Peer, 2010; Svenson, 1970, 1973, 2008, 2009). However, if we want to know how drivers estimate distance or speed, instead of time saved, we can give the journey time and ask respondents to estimate the other parameters of speed or distance. That is, ask drivers to estimate the distance that can be completed in a given time when increasing speed. For example, a question can present a driver who is increasing from 40 kph for 30 minutes and then ask participants to estimate the distance the driver will cover in these 30 minutes when driving at higher speeds (i.e., 50, 60 or 70 kph). A differently worded question can present a given distance and ask respondents to estimate the required speed for various journey times. The responses to such questions can tell us whether or not drivers also commit the time-saving bias when answering differently phrased questions.

The response scale may also influence the time-saving bias. The opportunity to provide more precise responses might diminish the bias. An analog scale, rather than a numeric scale, may be one solution. Researchers (e.g., Grant et al., 1999) showed that visual analogue scales (VAS) are sometimes more sensitive than other scales such as Likert or Borg scales. If VAS are more sensitive, it is important to check whether the time-saving bias occurs when they are used, as opposed to numeric responses.

To conclude, several task properties may be involved in the time-saving bias. The present research explored these properties in two independent studies: Study 1 used a within-participants paradigm to explore differences in drivers' responses to time-saving bias questions with different parameters to be estimated: Some questions were traditional time-saving bias questions asking drivers to estimate the journey time after a speed increase (with varying distances and initial speeds); some questions asked drivers to estimate the distance that could be completed within a given time when increasing speed; and other questions asked drivers to estimate the required speed to complete a given distance in varying times. Study 2 used a between-participants paradigm to explore whether drivers' estimations of journey time when increasing speed differ when they are asked about time saved vs. remaining journey time. In addition, Study 2 manipulated the response scale given to participants and compared responses made on a numeric scale versus a visual analog scale. Study 3 is an additional analysis of data from the first two studies.

2 Study 1

2.1 Method

Participants. Seventy-nine participants (32 males and 47 females) who held a valid driving license and reported being active drivers were included in this study. Drivers' ages ranged between 21 and 53 with a mean of 24.9 and standard deviation of 3.8. Drivers had had their driving license between 1 to 34 years with a mean of 7.0 years (SD = 3.8). Participants reported driving an average of 618.6 km a month (SD = 480.6).

Design and procedure. Participants filled out a questionnaire described as part of a driving behavior research program and received 20 NIS (˜6 USD) for their participation. First, participants answered eight different questions measuring the time-saving bias. In each question, a driving situation was presented in which a driver accelerates speed in order to save time and participants were asked to estimate the journey times at higher speeds. For example, question #1 stated: *"A truck driver is travelling at a mean speed of 40 kph for a journey of 40 km. At this speed, it will take him 60 minutes to complete his journey. Your task is to estimate, without any formal calculation, how much time it will take to complete this 40 km journey if the driver speeds up."* Participants were asked to estimate how much time (in minutes) the journey will take at speeds of 50, 60, 70 or 80 kph. The hypothesis for these type of questions was that drivers would underestimate the time saved when increasing from a relatively low speed.

Additional three questions followed the same format with differences in initial speed and distance: Question # 2 was about a train increasing from a lower speed (20 kph) and covering a longer distance (60 km); Question # 3 concerned a tractor increasing from a low speed (10 kph) for a shorter distance (10 km) and question #4 was about a cheetah increasing from a higher speed (50 kph) for a very short distance (100 meters). In each question, participants were asked to estimate the journey time at higher speeds: In questions #1 and #2 at 10, 20, 30 or 40 kph higher than the initial speed and in questions #3 and #4 at 5, 10, 15 or 20 kph higher than the initial speed. The full wording of the questions and items can be found in the Appendix.

Four more questions asked participants to estimate either distances in a given speed and journey time or the re-

https://doi.org/10.1017/S1930297500001649 Published online by Cambridge University Press

quired speed at a given distance and journey time. Question #5 was modeled after the question in Peer's (2010) study except that here a driver was increasing from 40 kph for 30 minutes and participants were asked to estimate the distance he will cover in these 30 minutes at speeds of 50, 60 or 70 kph. Question #6 was similar to question #5 except that the initial speed was 50 kph. The hypothesis for these type of questions was that drivers would underestimate the distance that can be completed when increasing from a relatively low speed.

Question #7 involved driving at a speed of 50 kph for 50 km (which results in a journey time of 60 minutes) and participants were asked to estimate the speed required for arriving in 50, 40, 30 or 20 minutes. Question #8 was the same as question #7 but the initial speed was 40 kph, the distance was 20 km (resulting in a journey time of 30 minutes), and participants were asked to estimate the speed required for arriving in 25, 20, 15 or 10 minutes. Since speed is inversely related to time, the hypothesis for these questions was that drivers would overestimate the speed required to arrive at a destination at a given time when the initial speed is relatively low.

The order of all questions was counter-balanced across questionnaires. Participants then provided demographic details including gender, age, type of driving license, years of having a license and the amount of kilometers they drive per month. Participants also reported speeding violations they had had in the last five years.

2.2 Results and discussion

To prepare the data for analysis, first, the validity of responses was checked and responses that deviated from the possible range of answers were omitted. For example, if a participant indicated that journey time was longer for a speed of 50 kph than for a speed of 40 kph, that answer was omitted. These omitted items, with the addition of unmarked items, summed up to 8.1% (77/948) missing values.

In order to compare results across questions and items, the following transformations were made to the raw scores. (The raw scores' means and difference from the correct response for each item are given in the Appendix.) For the first four questions, drivers' estimated journey time was converted to estimations of time saved by reducing journey time estimates from the original journey time at the initial speed. These time saving estimates were compared to the real time saved calculated mathematically using Formula (1) above. For example, if in question #1, the respondent said that if the truck driver increased his speed from 40 to 60 kph, it would take him 50 minutes to complete the journey, whereas Formula 1 shows that the correct response is actually 40 minutes, the answer was coded as -10. The respondent underestimated the time saved by 10 minutes (in reality journey time decreased from 60 to 40 min so that 20 min could have been saved). This score was then converted into the proportion of overestimation. For example, the above difference of 10 minutes between estimated and actual time saved represents an underestimation of 50%, or an overestimation of -50%, and was coded as $-.5$. Thus, positive values represented overestimations whereas negative values represented underestimations.

High reliability coefficients were found for the items within each question, for all the questions. Cronbach's alpha measures ranged from .83 to .98 with a median of .94; moreover, the vast majority of items (87%) within questions showed high correlations ($r > .8$) with the question's corrected-total score. Thus, responses to different items within a question were averaged to produce a score that showed the average proportion of overestimation (positive values) or underestimation (negative values). For the additional questions in which the responses concerned distances or speeds, participants' responses were compared to the correct answer computed in terms of distances or speeds. The percentage of over- or underestimation was computed in a similar manner to that employed for the first questions.

Table 1 shows the mean proportions of overestimations or underestimations of time saved when increasing speed (questions #1 to #4), overestimations or underestimation of distance that could be completed when increasing speed (questions #5 and #6), and overestimations or underestimation of speed required to complete a given distance in less time (questions #7 and #8). As can be seen, in three of the four first questions the expected misestimations are evident: participants underestimated the time saved when increasing speed by 8%, 15% and 24%, respectively, on average. However, in the cheetah question (#4) participants overestimated the time saved when increasing speed by 16% on average. This finding contradicts the prediction of the time-saving bias and will be discussed later on. One-sample t-tests were conducted for each question separately, comparing each to the zero value, which represents no deviation from the correct estimation and the result in all cases was the rejection of the null hypothesis. More importantly, 90% confidence intervals were computed for each question and are shown in Table 1.

To examine estimation of distance instead of time, question #5 asked participants to estimate the distance that can be covered when increasing from 40 kph to 50, 60 or 70 kph for a 30-minute journey. As shown in Table 1, drivers consistently underestimated this distance by an average of 17%. This means that drivers believed that they would cover a shorter distance in 30 minutes when increasing speed than in reality. For example, drivers estimated on average that when increasing from 40 to 60

Table 1: Mean proportion of overestimation, standard deviations, t-test and confidence interval values for the responses to 8 time-saving bias questions in Study 1.

(#) Question	Mean (SD) proportion of overestimation[a]	t	90%Confidence Interval
(1) **Time** when (truck) accelerating from 40 kph	−.08 (.1)	−5.10*	[−.11, −.05]
(2) **Time** when (tractor) accelerating from 10 kph	−.24 (.3)	−6.89*	[−.30, −.18]
(3) **Time** when (train) accelerating from 20 kph	−.15 (.2)	−8.02*	[−.19, −.12]
(4) **Time** when (cheetah) accelerating from 50kph	.16 (.1)	11.30*	[.14, 19]
(5) **Distance** completed accelerating from 40 kph	−.17 (.3)	−4.30*	[-.23, -.10]
(6) **Distance** completed accelerating from 50 kph	−.17 (.4)	−3.85*	[-.24, -.09]
(7) **Speed** required to complete 50 km	.12 (.1)	8.66*	[.10, .14]
(8) **Speed** required to complete 20 km	.09 (.2)	4.23*	[.05, .12]

[a] The figures here represent the proportion of overestimation of time saved compared to the actual time that can be saved according to Formula (1), averaged across each question's options. Positive values represent overestimations while negative values represent underestimations.
* $p < .01$

kph, they would drive approximately 25 km in 30 minutes when, in reality they would have driven 30 km. The same degree of bias was also found for question #6. These findings show that drivers demonstrated a time-saving bias in the same direction both when asked to estimate the distance that can be covered at higher speeds and when asked to estimate the time saved when increasing speed.

Questions #7 and #8 examined estimations of required speed instead of time or distance. Here, the distance was fixed (50 or 20 km, respectively) and drivers had to estimate the speed required to arrive in less than an hour (question #7) or less than half an hour (question #8). In this case, the time-saving bias predicts that drivers would overestimate the speed required to arrive on time and indicate higher speeds than actually required. As predicted, drivers overestimated the speed required to arrive in less time by 9% to 12%. Again, this shows that the time-saving bias was found in the predicted direction whether the question required drivers to estimate time, distance or speed.

To test for any differences within-participants in their responses to the three types of questions (estimating time, distance or speed), repeated measures analyses were performed with the question type as a within-participants factor. In order to conduct this analysis, responses to questions of the same type were averaged to produce a single mean score for each question type: the mean of questions #1 to #4 were labeled "time" type questions; questions #5 and #6 were "distance" type and questions #7 and #8 were "speed" type questions. All scores were computed with absolute values so that underestimations of time could be compared to the underestimations of distance and to overestimations of speed. These three scores showed similar means: 16.3%, 18.6% and 13% for time, distance and speed, respectively (SD = .15, .32 and .1, respectively). Repeated measures analysis with the question type as a within-participants factor showed no statistically significant differences within participants among the three types of questions; Wilk's Lambda = .93, F (2, 148) = 2.64, p = .08, eta squared = .07. The correlations between these three composites were inconsistent: While "time" questions correlated negatively with "speed" questions (r =.21, p = 0.07) and with "distance" questions (r = .37, p < .01), "distance" questions did not correlate with "speed" questions (r = .08, p = .52).

These three composite scores were also used to examine individual differences in the time-saving bias regarding gender, age, years of having a license and number of speeding violations. Multiple regression analyses predicting the scores in the time, distance or speed questions showed that none of these independent variables was a significant predictor. This lack of individual differences in the time-saving bias corresponds to the findings of previous studies (Peer, 2010).

Study 1 showed that certain forms of the task — asking people to estimate the distance or speed instead of estimating the remaining journey time — did not affect the time-saving bias. This affirms that the time-saving bias may indeed be a genuine cognitive bias, rather than an artifact of mode of presentation. However, one question (question #4, the cheetah accelerating from 50 kph for 100 meters) showed an overestimation of time saved, contrary to the prediction of the time-saving bias: that people underestimate the time saved when increasing from a low speed and overestimate the time saved when increasing from a high speed (Svenson, 2008). A speed of 50 kph is considered relatively low in most time-saving bias studies and should have produced an underestimation of time saved instead of an overestimation. One possible explanation for this anomaly may be the factor of distance. Distance is related to the degree of the time-saving bias such that in higher distances, the bias is predicted to be larger (Svenson, 2008). In question #4 the distance used was extremely short — only 100 meters — compared to typical distances found in other time-saving bias studies. It is possible that the short distance made people evaluate the speed as relatively high and reversed the direction of the bias. Moreover, the general public may consider a cheetah to be a very fast animal, so that when presented with both 50 kph and a very fast animal, moving at 50 kph sounded fast. Another possibility is that the overestimations are due to the fact that in question #4 the distance was given in meters instead of kilometers. This may have made participants judge the question differently than the other questions that used kilometers.

3 Study 2

Study 1 compared three alternative task formats (time, distance or speed questions) and showed that participants did not display any differences in these three modes of presentation. However, Study 1 did not examine two other task variations: estimations of journey time vs. time saved, and estimations based on numeric responses vs. a more precise analog visual scale. These factors could not have been examined in Study 1, which used a within-participants design, so another study was conducted in order to manipulate these factors between participants.

3.1 Method

Participants. One hundred and thirty-nine students (49 males and 90 females) who held a valid driving license and reported to be active drivers were included in the sample. Participants' age ranged from 21 to 30 with a mean of 25.6 (SD = 2.5). All held a valid car driving license from between 1 to 13 years with a mean of 6.8 years (SD = 3.5). Participants reported driving an average of 481.2 km a month (SD = 470.4).

Design and Procedure. Participants filled out a questionnaire that was described as part of a driving behavior research program and received 10 NIS (about $3, U.S.) for their participation. Participants first answered three time-saving bias questions similar to the questions used in Study 1: The truck increasing from 40 kph for 40 km; the tractor increasing from 10 kph for 10 km; and the train increasing from 20 kph for 60 km. Half of the participants were asked to estimate the new journey time following the speed increase (as in Study 1) while the others were asked to estimate the time saved due to the speed increase. Half of each group was asked to provide numerical responses (as in Study 1) while the other half gave their estimation on an analogue scale. The analogue scale was a straight line that ranged from minimal to maximal values: for the "time saved" condition the range was from zero time saved to the original full time of the journey; for the "journey time" condition, the range was from the original full time of the journey to zero journey time. The scale also had a mark exactly in the middle showing the middle range value of the scale. Participants were asked to mark their estimations of time saved or remaining journey time, according to the condition to which they were assigned, on the line. Participants also filled out demographic details as described in Study 1.

3.2 Results and discussion

The validity of the responses to all questions was checked as described in Study 1, resulting in 4.6% (77/1591) missing values, including unmarked items, which were omitted from the analyses. For the analogue scale group, responses were coded using a centimeter ruler and the marks were converted into minutes of time saved. For the group estimating the remaining journey time, responses were converted to time saved by subtracting the response from the original journey time. Finally, responses were converted to proportions of overestimation, averaged across question items and converted into mean proportions in the same manner as detailed in Study 1.

Table 2 compares the mean proportions of underestimations of time saved when increasing speed for the four conditions, across the three questions. As can be seen, the time saved when increasing speed was significantly underestimated in all cases, ranging from −6% to −38% with a median of −15%. However, the differences between the four conditions were not consistent in the different questions. In the truck question a larger bias (higher underestimation) was found when participants were asked about time saved and gave numeric responses. In the other two questions participants who estimated remaining journey time on an analog scale showed the highest bias.

A multivariate analysis of variance (MANOVA) on all questions, with type of question (remaining time vs. time saved) and type of scale (numeric vs. analog response) as between-participants factors, showed a significant effect for type of scale and type of question (Wilk's Lambda = .9, .82, F (3, 85) = 3.0, 6.1, respectively, p <.05) but

https://doi.org/10.1017/S1930297500001649 Published online by Cambridge University Press

Table 2: Mean proportion of overestimation of time saved by type of response scale (numeric vs. analog) and question type (remaining time vs. saved time) (SDs are in parentheses)

			Question			
Scale	Question type	N	Truck	Tractor	Train	Overall
Numeric	Remaining time	30	−.10 (.02)	−.28 (.04)	−.16 (.02)	−.15 (.03)
	Saved time	37	−.14 (.01)	−.13 (.04)	−.06 (.02)	−.10 (.03)
Analog	Remaining time	31	−.10 (.01)	−.38 (.04)	−.22 (.02)	−.20 (.03)
	Saved time	29	−.07 (.02)	−.33 (.04)	−.21 (.02)	−.18 (.03)

Note: Figures represent the proportion of overestimation of time saved compared to the actual time that can be saved according to Formula (1), averaged across each question's options. Positive values represent overestimations while negative values represent underestimations.

not for the interaction (Wilks's Lambda = .95; F (3, 85) = 1.41, p = .25). Analysis of between-participant effects showed that the effect found for type of scale was evident only in the tractor question, F (1, 87) = 7.48, $p <$ .01. This effect showed that in the tractor question participants who gave a numeric response underestimated the time saved more than participants in the analog scale condition (average of 33% compared to 22%, respectively). Pair-wise comparisons showed that this was a statistically significant difference ($p < .05$) whose 95% confidence interval ranged from .05 to .32. No significant differences were found for the truck or train question. Regarding type of question, effects were found in both the tractor and train questions, F (1, 87) = 6.38, 5.42, respectively, $p < .05$. This effect showed that for the tractor and train questions participants in the remaining time condition underestimated the time saved less than participants in the time saved condition (averages of 19% and 11% compared to 35% and 22%, respectively). Pair-wise comparisons showed that both were significant differences ($p < .05$). The 95% confidence intervals of the differences were .04 to .31 for the tractor question and .02 to .19 for the train question.

Although some differences were found between the different modes of presentation, the time-saving bias was demonstrated in the predicted direction in all conditions in Study 2. The fact that the time-saving bias was larger or smaller in different conditions (i.e., larger for time saved than for remaining journey time) does not imply that the existence of the bias is dependent on the mode of presentation. Moreover, because each question could be considered a different measure of the time-saving bias for the particular situation, it is important to examine the differences between modes of presentation across all questions combined. Consequently, an additional analysis was computed for an overall score that was the average of the three questions combined. The means of this overall score are shown on Table 2. Analysis of variance showed no statistically significant differences in the overall score among the types of scales or questions, F (1, 123) = .5, 1.45, p = .48, .23, eta squared = .004, .01, respectively. The conclusion here is that the time-saving bias occurred similarly in all conditions in Study 2, regardless of the type of question (time saved or remaining journey time) or the scale used for the response (numeric or visual analog scale).

The three questions showed low to medium correlations (r = .29 between the truck and tractor questions, r = .39 between the truck and train questions; and r = .45 between the tractor and train questions, all $p < 0.01$). As in Study 1, regression analyses showed no individual differences in the time-saving bias for each of the questions or for the overall score regarding gender, age, years of having a license or number of speeding violations.

4 Study 3

The results of Study 1 and Study 2 showed that the majority of participants gave responses that deviated from the normative response. An important remaining question concerns what, if any, strategies people employ that lead them to these non-normative responses. The aim of Study 3 was to re-analyze the responses for questions in Study 1 and Study 2 in order to explore possible models that can describe non-normative responses.

One such model already described here is the Proportion heuristic (Svenson, 2008). According to the Proportion heuristic, people use the speed increase as a proportion of the higher speed when estimating the time saved. Formula (2) above can be used to predict responses that follow the Proportion heuristic. Another model that can be tested may be called the Differences heuristic. Ac-

Table 3: Number and percentage of responses classified to each of the three models in the three questions used in Study 1 and Study 2 (N=159).

	Truck		Tractor		Train	
Model	N	Percent	N	Percent	N	Percent
Normative	50	31.45	44	27.67	42	26.42
Proportion	58	36.48	19	11.95	42	26.42
Differences	98	61.64	90	56.60	82	51.57
Differences and Normative overlap	39	24.53	39	24.53	39	24.53
Differences and Proportion overlap	36	22.64	10	6.29	26	16.35
Unclassified	28	17.61	47	29.56	43	27.04

cording to this heuristic, people may judge the time that can be saved based solely on the difference between the higher and lower speed, assigning no weight at all to the initial speed. This model predicts that people's estimations for increasing from 30 to 40 kph, for example, would be the same for increasing from 40 to 50 kph, etc.

5 Method

One hundred and fifty-nine drivers (65 males and 94 females) who participated in Study 1 or Study 2 and responded to the three questions used both in Study 1 and Study 2 (the "Truck", "Train" and "Tractor" questions) were selected for the analysis. Participants' responses to the three questions were analyzed and classified to one of the following models: a) Normative — responses that were up to 5 percent higher or lower than the correct response as calculated by Formula (1); b) Proportion heuristic — responses that were up to 5 percent higher or lower than responses calculated by Formula (2) and c) Differences heuristic — responses in which the differences between at least three out of the four items in a question were similar (up to 5 percent higher or lower). Due the margins used for the classification of the models, some overlap between the Differences model to the Normative and Proportion models was possible. Thus, two more categories were constructed containing responses that fitted either the Normative and the Differences models or the Proportion and Differences models. There was no overlap between the Normative and Proportion models. Responses that did not fit to any of the models were denoted as "Unclassified".

6 Results and discussion

Table 3 shows the number and percentage of responses for each question that were classified to either the Normative model, Proportion heuristic or Differences heuristic. These categories include the responses which were also classified to another model. The next two categories show the percentage of overlap between the Differences heuristic to the Normative or Proportion models. For example, in the Truck question, the 61.64% of responses classified to the Differences model include 24.53% which were also classified to the Normative model and 22.64% which were also classified to the Proportion model.

As can be seen, the three models were able to classify the majority of responses in all three questions leaving less than 30% of the responses unclassified. Among the three models, more responses fitted the Differences heuristic than the Proportion heuristic or the Normative model, in all three questions. However, there was a high degree of overlap among the models as approximately 40% of the responses fitted more than one model: Almost 25% of the responses in all the three questions fitted both the Differences and the Normative models; also, an average of 15% of responses fitted both the Differences and the Proportion heuristics across the three questions. There were differences between the frequency of the models across the three questions (χ^2 (25) > 62.7, $p <$ .01).

The high degree of overlap, as well as the differences between the frequencies of models in the different questions, hampered the attempt to arrive at a conclusive conclusion regarding a model that describes participants' non-normative responses. These limitations are mainly due to the values used as distances, times and initial and higher speeds in the three questions. Future research should encompass a wider array of questions and problems and choose the values used as distance, time and speed in a way that will enable a discriminating analysis among the models.

7 General discussion

Drivers' estimations of time saved when increasing speed were found to be systematically biased: drivers generally perceived the time saved when increasing from a relatively low speed to be lower than in reality. This finding is consistent with previous studies that explored the time-saving bias (Fuller et al., 2009; Peer, 2010; Svenson, 1970, 1973, 2008, 2009). The results of both Study 1 and 2 confirmed that the time-saving bias may be considered a genuine, systemic and robust cognitive bias that occurs in the predicted direction when different tasks are employed. Specifically, the bias occurs whenever drivers are asked to estimate journey time following a speed increase as well as when asked to estimate the distance that can be covered in a given time following a speed increase. Similar bias was also found when drivers had to estimate the minimal speed required to cover a given distance in less time. Study 2 compared estimations of time saved to estimations of remaining journey time and also compared responses given on a numeric scale versus a visual analog scale. The bias occurred in all situations to a similar degree, without any major differences between the four conditions.

The lack of within-participants differences in Study 1 is an especially interesting finding. The absence of such differences across eight different questions is strong evidence that the bias occurs on the individual level. People have biases whether they are estimating time saved, distance to be completed or speed required for arriving on time. In addition, the bias appeared in questions concerning different levels of speed, journey distances or periods of time. Moreover, in both Study 1 and 2 there were no effects of gender, age or years of having a license or number of speeding violations on the time-saving bias.

Although, overall, the magnitude of the time-saving bias in the differently phrased questions did not vary much, some differences are still worth mentioning as directions for future research. First, answers to question #4 in Study 1 (the cheetah accelerating from 50 kph for 100 meters) showed an overestimation of time saved opposed to underestimations found in responses to other questions involving estimations of time saved (questions #1 to# 3) and in contradiction to the time-saving bias' prediction. As proposed earlier in the discussion of Study 1, the short distance (100 meters) may have been the cause for the reversed bias. The interesting point here — and a possible further research direction — is that drivers may be considering speed in these cases in relation to some other factor, which in turn determines the direction of the time-saving bias. Thus, a speed considered low in one situation and leading to an underestimation of time-saved, if "framed" as a relatively high speed may induce the opposite bias of overestimation. Additional research can pursue this line of investigation.

Another difference worth mentioning was the one found in Study 2 that suggests that some elements of the task may affect the magnitude of the bias. Specifically, in two of the three questions in Study 2 it was found that participants who estimated the time saved showed a greater bias than participants who estimated remaining journey time. Since many studies have used the "time saved" type of question (Fuller et al., 2009; Svenson, 2008, 2009), this finding may point to the possibility that some estimations of the time-saving bias magnitude have been inflated. The form used by Peer (2010), for instance, for asking about remaining journey time produces a smaller bias in most cases and can thus be considered a more conservative measurement of the bias. The problem remains, however, as to how to ascertain which type of question leads to the more correct bias measurement.

Peoples' estimations of time saved when increasing speed are generally biased in a systemic and predictable manner. The current study added to the existing studies in the area that demonstrated the time-saving bias and linked it to speed choices (Peer, 2010) and to faulty estimations of braking distance and accident risk (Svenson, 2009). However, this study did not include questions of increasing from a relatively high speed, which is predicted to result in overestimations of the time that can be saved. Future studies may explore increases from high speed as well.

Faulty estimations of time saved when increasing from a low or a high speed can have either positive or negative consequences. On the one hand, if people realize that increasing from a low speed saves them more time than they need, they may choose a lower speed. On the other hand, if people know they can save more time by increasing speed, they may do so more often. The same holds true when increasing from a high speed: If drivers know that a speed increase will save them less time than they estimate, they may be inclined to drive even faster; on the other hand, they may choose to avoid the higher risk of an accident and not speed at all.

This study has shown that the time-saving bias should be considered a genuine cognitive bias that probably stems from some flaw in our human reasoning regarding this issue. As mentioned earlier, the common reason for committing the time-saving bias is considered to be people's tendency to neglect the effect of the initial speed on the time that can be saved and focus primarily on the higher speed: when increasing to a high speed people expect to save more time than in actuality and when decreasing to a relatively low speed people expect to save less time than in actuality. This over-emphasis on increasing speed results in neglect of the initial speed, which is much more important in determining the time that can be saved: if the initial speed is low, much time can be saved; if the initial speed is relatively high, little time can be saved. The results of this study, which ruled out irrelevant factors as being responsible for the bias, paves the way for more research that may further test the explanation that people commit the time-saving bias because of a neglect of the effect of initial speed on the time that can be saved when increasing speed.

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Appendix: Questions' wording, correct responses and descriptive and inferential statistics for Study 1.

Question wording	Item	Correct response	N	Mean	SD	Mean Diff.	t	p
1. A truck is travelling at a mean speed of 40 kph for a journey of 40 km. At this speed, it will take the truck 60 minutes to complete the journey. Estimate, without any formal calculation, how many minutes it will take the truck to complete this 40 km journey if the driver speeds up. **What will be the journey time if the truck will increase to**:	60 kph	40	75	44.44	7.3	4.44	5.25	<.01
	70 kph	34	75	38.92	10.1	4.92	4.21	<.01
	80 kph	30	75	32.28	12.6	2.28	1.57	.12
2. A tractor is travelling at a mean speed of 10 kph for a journey of 10 km. At this speed, it will take the tractor 60 minutes to complete the journey. Estimate, without any formal calculation, how many minutes it will take the tractor to complete this 10 km journey if it speeds up. **What will be the journey time if the tractor will increase to**:	15 kph	40	72	47.71	6.7	7.71	9.77	<.01
	20 kph	30	72	38.40	10.0	8.40	7.15	<.01
	25 kph	24	72	32.58	12.0	8.58	6.09	<.01
	30 kph	20	72	25.65	14.9	5.65	3.23	<.01
3. A train is travelling at a mean speed of 20 kph for a journey of 60 km. At this speed, it will take the train 180 minutes to complete the journey. Estimate, without any formal calculation, how many minutes it will take the train to complete this 180 km journey if it speeds up. **What will be the journey time if the train will increase to**:	25 kph	144	75	156.77	17.5	12.77	6.33	<.01
	30 kph	120	75	140.52	21.8	20.52	8.16	<.01
	35 kph	103	75	126.87	28.7	23.87	7.20	<.01
	40 kph	90	75	109.95	34.3	19.95	5.03	<.01
4. A cheetah is running after its prey, which is standing 100 meters away, at a mean speed of 50 kph. At this speed, it will take the cheetah 12 minutes to complete the journey. Estimate, without any formal calculation, how many minutes it will take the cheetah to complete these 100 meters if it speeds up. **What will be the journey time if the cheetah will increase to**:	60 kph	10.8	74	10.62	1.7	−0.18	−0.91	.36
	70 kph	9.94	75	9.17	2.8	−0.77	−2.40	.02
	80 kph	9.3	75	7.80	3.7	−1.50	−3.57	<.01
	90 kph	8.8	74	6.63	4.7	−2.17	−3.99	<.01

Question wording	Item	Correct response	N	Mean	SD	Mean Diff.	t	p
5. A driver travelling at a mean speed of 40 kph for 30 minutes can complete 20 km. Estimate, without any formal calculation, **what is the distance that can be completed if the driver will increase to**:	50 kph	25	78	28.74	8.8	3.74	3.75	<.01
	60 kph	30	78	34.83	10.5	4.83	4.06	<.01
	70 kph	35	78	41.47	12.3	6.47	4.66	<.01
6. A driver travelling at a mean speed of 50 kph for 30 minutes can complete 25 km. Estimate, without any formal calculation, **what is the distance that can be completed if the driver increases to**:	60 kph	30	77	34.23	12.1	4.23	3.08	<.01
	70 kph	35	77	40.82	13.3	5.82	3.84	<.01
	80 kph	40	77	47.40	15.0	7.40	4.34	<.01
7. You need to get to a destination 50 km away. If you drive at a mean speed of 50 kph, it will take you 60 minutes to arrive at your destination. Estimate, without any formal calculation, **what is the speed required to complete this 50 km journey at**:	50 min.	60	76	61.26	6.6	1.26	1.66	.10
	40 min.	75	76	72.87	12.0	−2.13	−1.54	.13
	30 min.	100	76	89.14	18.6	−10.86	−5.10	<.01
	20 min.	150	76	106.51	29.2	−43.49	−12.97	<.01
8. You need to get to a destination 20 km away. If you drive at a mean speed of 20 kph, it will take you 60 minutes to arrive at your destination. Estimate, without any formal calculation, **what is the speed required to complete this 20 km journey at**:	25 min.	48	75	49.33	11.3	1.33	1.02	.31
	20 min.	60	75	59.88	13.5	−0.12	−0.08	.94
	15 min.	80	75	72.36	17.7	−7.64	−3.73	<.01
	10 min.	120	75	88.37	27.0	−31.63	−10.16	<.01

https://doi.org/10.1017/S1930297500001649 Published online by Cambridge University Press