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Time Loss Bias and Reducing the Bias by Instruction

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Abstract

People tend to overestimate the time saved by speed increases at high speeds and underestimate the time saved when increasing at lower speeds. This is called the *time saving bias*. This study investigated if this time saving bias has its correspondence also in time loss judgments. Additionally, it is studied whether an instruction about the relationship between time and speed would correct a possible *time loss bias*. Participants (*N* = 126) judged time loss cases and the effectiveness of a debiasing instruction was tested. It was shown that there is a time loss bias similar to the time saving bias, meaning that people underestimate time loss when speed is decreased from a low speed and overestimated time loss when decreased from a high speed. The time loss bias could be decreased by a debiasing instruction, but not eliminated. Further research can improve the efficiency of the instruction since it is important for drivers' speed choice, which is a key factor in traffic safety.

Keywords: time loss bias, time saving bias, debiasing, instruction, reducing bias.

Introduction

In the United States, a total of 32,675 people died due to motor vehicle accidents in 2014. Of these accidents, 28% were speeding-related, meaning that 9,262 people died in crashes where speeding was a factor (National Highway Traffic Safety Administration, 2015). Driver's speed is an important factor for safety in traffic. Increased speed increases the chance of having an accident and also increases the severity when an accident occurs (Aarts & Van Schagen, 2006; Nilsson, 2004; World Health Organization, 2015). A factor playing a role in speeding is that people want to save time during the journey (Fuller et al., 2009). However, people's estimations of time saving are biased (Peer, 2010; Svenson, 1970, 1971, 2008, 2009).

The bias of judgments of time saved is called the *time saving bias* (Svenson, 2009; Eriksson, Patten, Svenson, & Eriksson, 2014). People overestimate the time saved when speed is increased from a high speed and underestimate the time saved when speed is increased from a low speed. Peer (2013) suggested that the bias is a result of people failing to recognize that when the speed increases the time saved for each constant speed increment becomes smaller.

Despite all the research done on the time saving bias, research investigating time loss instead of time saving is lacking. The current study investigates the possible existence of a *time loss bias* similar to the time saving bias. However, besides investigating the existence of a possible time loss bias, it is also important to debias (reduce) the time saving bias and a possible similar time loss bias. This is important because the time saving bias can influence and predict driver's speed choices (Eriksson, Svenson, & Eriksson, 2013; Peer, 2010; Peer 2011) and speed is an important factor in traffic accidents (Aarts & Van Schagen, 2006, Nilsson, 2004, World Health Organization, 2015). Therefore, the current study will also investigate an instruction with the aim of reducing a possible time loss bias. However, before discussing the current study further, a background in heuristics and biases, the time saving bias and debiasing biases is presented.

Heuristics and Biases

Human cognitive information processing abilities have limitations, which could result in biases and heuristics (Simon, 1955). Heuristics are rules of thumbs, rules to simplify the decision making (Gigerenzer, 2001). Normally, this means less effort but also less accuracy, which is called the effort-accuracy tradeoff (Payne, Bettman, & Johnson, 1993). However, in some situations, less effort can lead to more accuracy, called the less-is-more effect, and this is shown with the recognition heuristic (Goldstein, & Gigerenzer, 2002). Some heuristics can give an answer close to the correct answer or best option, like the take-the-best method (Gigerenzer, & Goldstein, 1996), and the recognition heuristics (Goldstein, & Gigerenzer, 2002).

Gigerenzer (2001) introduced the adaptive toolbox for decision making which holds the total of heuristics an individual has. In situations of uncertainty in combination with limited time, computational resources, and information, people choose a heuristic from the adaptive toolbox suiting the situation best (Gigerenzer, 2001). The theory of the adaptive toolbox also applies to problems involving numbers and calculations like the time saving bias.

Dealing with numbers and making calculations play a role in everyday life. Some problems are probabilistic of nature and other problems can involve more complex mathematical functions. These calculations can sometimes be too complex and this shows the limitations of human information processing (Kahneman, Slovic, & Tversky, 1982). Often, a heuristic is used to simplify the calculation.

For example, this is the case with exponential functions. When people make judgments concerning exponential functions a strong bias is shown (Wagenaar & Sagaria, 1975; Stango, & Zinman, 2009) where people systematically underestimate the exponential growth in intuitive extrapolation tasks. This is called the exponential growth bias and is shown in different situations such as in household finance (Stango, & Zinman, 2009). People tend to linearize complex functions to solve problems even if the functions are not linear, like in exponential functions (Stango, & Zinman, 2009).

Time Saving Bias

The relation between speed increase and time saving is also described by a complex mathematical function. The function is curvilinear which makes it hard for people to judge quickly. People fail to see the curvilinear relationship and fail to recognize the importance of the initial speed in time saving (Fuller et al., 2009; Peer, 2013). People therefore tend to not use the correct, more complex, function, but instead use a heuristic when judging quickly (Fuller et al., 2009). In mathematical identical and similar curvilinear problems, like in judgments of resource savings (Svenson, Gonzalez, & Eriksson, 2014) and health care planning (Svenson, 2008), a similar bias occurs.

The time saving bias is also related to the planning fallacy. Like the time saving bias, the planning fallacy is also time related. The planning fallacy shows an optimistic bias in predictions of how much time is needed for a certain task (Kahneman, & Tversky, 1979). People tend to underestimate the time they need to complete a task (Kahneman, & Tversky, 1979). When looking at the time saving bias, people overestimate the time they save when increasing speed from higher speeds. In this way they underestimate the time they need to arrive at a destination. Therefore, the time saving bias can contribute to the planning fallacy (Svenson, 2008).

The first studies investigating the time saving bias were done by Svenson (1970, 1971). They investigated how people judge time saving problems with participants comparing two speeds on the same distance and then judge the time saved. People gave systematically biased judgments. They overestimated the time saved when increasing from higher speeds and underestimated the time saved when increasing from lower speeds. Later, this phenomenon was called the time saving bias (Svenson, 2008). The function that was derived from the participant's judgments of individual speed increases (Svenson, 1970, 1971), is as follows:

$$Time\ Saved = \frac{cD^e\,(V_2 - V_1)}{V_2} \qquad (1)$$

(c = fitted constant, e = fitted constant, D = distance, V_1 = original speed, V_2 = new increased speed). This formula was called the *Proportion heuristic* (Svenson, 1970, 1971). The formula shows that people used a proportion, or in other words a ratio, to make their judgments. A simplified version of the formula of the proportion heuristic, using a constant distance (D) instead of a variable distance, will be called the *ratio rule* in the present study.

As mentioned before, people fail to recognize the curvilinear relationship between time and speed (Fuller et al., 2009) and also do not see the importance of the initial speed (Peer, 2013). The actual relationship between time and speed is visualized in Figure 1. As shown in Figure 1, a speed increase for an already high speed saves less time than the same speed increase from a lower speed. For example, the difference in time to complete a 10 km distance at a speed of 10 km/h compared to 20 km/h is 30 minutes, while the difference in time to complete 10 km between 90 km/h and 100 km/h is almost nothing.

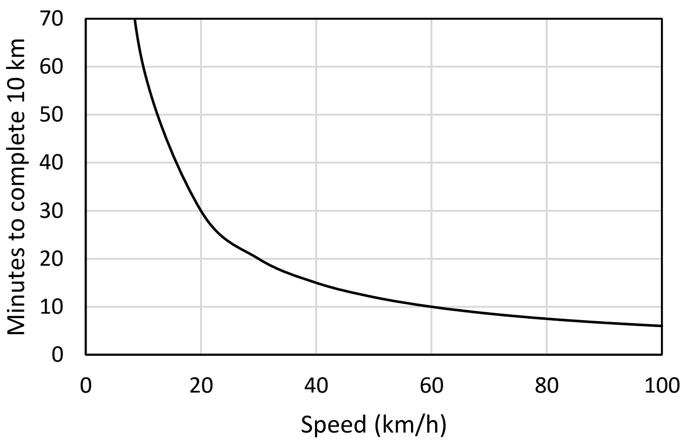

Figure 1. The curvilinear relationship between speed and time. This figure shows the time to complete a distance of 10 km at different speeds.

Studies following the first two studies about the time saving bias (Svenson, 1970, 1971) used other ways of investigating the time saving bias. Participants compared two speed changes in an A and B situation, as shown below, and made the time saving equal (Svenson, 2008, 2009). For example, a speed increased from 35 km/h to 40 km/h with a second case in a pair that had a speed of 80 km/h and participants judged the new higher speed which would give the same time saving for B as for A. The problems were presented like this:

A	B
Old speed: 35 km / h	Old speed: 80 km / h
New speed: 40 km / h	New speed: ____ km / h

The answers of the participants were compared to the ratio rule, a so called *difference rule*, and the correct answers. The ratio rule for this type of problems, without taking into account the distance, gives the equation:

$$\frac{(V_{a2}-V_{a1})}{V_{a2}} = \frac{(V_{b2}-V_{b1})}{V_{b2}} \tag{2}$$

(V_{a1} = the old speed in situation A, V_{a2} = new speed in situation A, V_{b1} = the old speed in situation B, V_{b2} = new speed in situation B).

The difference rule for this type of problems gives the equation:

$$(V_{a2} - V_{a1}) = (V_{b2} - V_{b1}) \tag{3}$$

The equation for computing correct answers is:

$$\frac{(V_{a2}-V_{a1})}{V_{a1}V_{a2}} = \frac{(V_{b2}-V_{b1})}{V_{b1}V_{b2}} \tag{4}$$

The answers of the participants in these studies were described by the ratio rule and not by correct equation or the difference rule (Svenson, 2008, 2009).

Thus far, a number of studies have investigated the time saving bias and also confirmed the systematic deviation from the correct answers (Peer, 2010; Svenson, 1970, 1971, 1973, 2008, 2009). However, it has not been investigated if the same bias is reflected in time loss judgments. Therefore, the present study investigates if there is a time loss bias. However, first the studies about debiasing the time saving bias will be discussed.

Debiasing the Time Saving Bias

The effect of the time saving bias can be debiased (Svenson et al., 2014). Debiasing the time saving bias was done in different ways in previous studies. Debiasing was investigated in a study by Eriksson et al. (2014). In this study, participants drove the same route two times in a car simulator. The first time they were instructed to drive at a given speed and the second time they were instructed to gain 3 minutes compared to the first time and they could choose their own speed. The control group had a speedometer and the experimental group had an alternative meter which indicated the inverted speed. Participants in the experimental group were closer to the target which indicated that the bias was decreased by using a speedometer with inverted speeds (Eriksson et al., 2014).

A study by Peer (2013), using online surveys, studied if direct pace information, by using an extra speedometer, similar to the inverted speedometer (showing min/km) by Eriksson et al. (2014), could lead to improved estimations of time savings. An extra speedometer was used which showed extra information about the minutes it takes to drive 10 miles (e.g. for 10 miles/h this was 60, for 120 miles/h this was 5). This extra information showed a debiasing effect on the time saving bias.

In a study by Svenson et al. (2014) participants received an instruction with the purpose of debiasing the resource saving bias which is similar to the time saving bias (Svenson et al., 2014). Participants were asked to estimate resource savings in manpower when certain production line speeds were increased. Similar to time saving judgments, participants were asked to make the resource savings equal for production lines A and B. An example of a problem participants answered is:

Line A	Line B
Before improvement:	Before improvement:
40 units/man-month,	80 units/man-month,
After improvement:	After improvement:
50 units/man-month,	_______units/man-month.

Participants filled in the blank space. In this case, when the speed was increased from lower production line speeds, the saved resources were underestimated and with higher production speeds, the saved resources were overestimated. Two different studies were conducted, each with a different instruction to test the effectiveness of an instruction to debias the bias. In both studies the same 10 problems were used. In the first study, before the participants judged the 10 problems they got an instruction on how to approach the problems. The instruction explained participants to first judge the man-months saved for the already implemented improvement of line A and after this estimate how many how many units/man-month was needed in production line B to make both lines equal in resource savings (man-month). This instruction method slightly decreased the bias. In the second study, as a learning instruction, participants received a different set of problems before they judged the same 10 problems as the other study. In the different set of problems, it became clear that the difference rule and ratio rule do not give the correct answer. The problems contained two following production speed improvements. For example, a production line speed was first improved from 30 units/man-month till 40 units/man-month and participants had to judge the saved man-months. Then the speed was raised again till, for example, 60 units/man month. Again, they had to judge the resources (man-month) saved, but now from 40 units/man-month till 60 units/man-month. This method of using the extra set of different problems resulted in a significantly decreased bias, but the bias did not disappear completely.

These results shown thus far show possibilities for debiasing the time saving bias, although in all these cases the bias was not totally eliminated. However, there is evidence that the bias can be debiased entirely. In a study by Svenson (1971), a phase with feedback about correct times saved was used to debias the time-saving bias. In this study the participants in the experimental group received correct answers directly after they gave their answers. Within one week with two and a half hour sessions every day, the participants were able to give correct and unbiased answers to questions about time saving. These results show that the time saving bias can be successfully debiased by using feedback. However, this procedure takes a lot of time to get the desired results and long-term performance is not known.

Other ways, instead of a learning phase of several sessions, might be more efficient in debiasing the time saving bias. Debiasing a certain bias can be done in multiple ways. According to Fischhoff (1982), there are four ways to diminish the effects of a bias, which are: giving warnings about the possibilities of the bias; providing descriptions of the direction of the bias; giving feedback on the person's behavior; providing an elaborate program of feedback training. Using feedback, as done in the study by Svenson (1971), is one of the four possibilities for eliminating biases listed by Fischhoff (1982). The other possibilities, like giving warnings and providing a description of the directions of the bias, have not been investigated so far specifically for the time saving bias. Giving people an instruction about the relation between speed changes and time savings and giving people information about the possibilities of the time saving bias could be an efficient way of eliminating the effects of the time saving bias.

The Present Study

Time loss bias.

A number of studies showed the presence of a time saving bias or similar bias (Peer, 2010; Svenson, 1970, 1971, 2008, 2009). However, it is unknown if a similar bias is present when it is about time loss: when the speed is decreased instead of increased. The present study investigates if there is a time loss bias and whether this works through the same principle (using the ratio rule) as the time saving bias. Similar cases as in previous studies (Svenson, 2008, 2009) will be used for the whole present study. The correct equation that participants should use to get correct answers is the equation 4 given above. It is expected that the same principle as the time saving bias will apply here. Therefore, the hypotheses that will be investigated in this study are:

1. People give answers which differ systematically from the correct time loss answers.
2. People judge in the same way as they judge time savings and show the time saving bias:
   2.1. For higher speed cases, the answers of the participants are higher than the correct answer and for lower speed cases, the answers of the participants are lower than the correct answer.
   2.2. People give answers leaning towards ratio rule predictions.

Debiasing by instruction.

Using a warning instruction as a tool for debiasing has been studied for the framing bias (Cheng, & Wu, 2010). In this study, a provided warning showed a debiasing effect (Cheng, & Wu, 2010). Warnings about the influence of the anchoring and adjustment bias were used in a study by Block and Harper (1991) with the purpose of eliminating the effect of that bias. The results of this study showed a reduced effect of the bias, but the bias did not disappear. For the hindsight bias, a warning can also successfully reduce the effects of the bias (Hasher, Attig, & Alba, 1981). Instructing people about time loss or saving and the curvilinear relationship it contains could have a debiasing effect as well, but research about this is lacking so far. Therefore, the current study also investigates if a possible time loss bias can be debiased by giving participants an instruction about the real time loss. As mentioned above, participants should use equation 4 to achieve correct answers for cases similar to those in previous studies (Svenson, 2008, 2009). The hypothesis that will be tested is:

3. A debiasing instruction improves the answers of the participants, meaning answers closer to the correct answer.

Method

Participants

Participants were recruited by handing out the questionnaires at the Kungliga Tekniska högskolan (KTH) and at the department of Psychology of the Stockholm University (SU). Participants studying Psychology received participation hours and students with another education field received nothing. Questions about the demographics of the participants were included in all three questionnaires.

Based on a several criteria, various participants were excluded from the study. The questionnaires included a question checking whether the participant had read the instructions or not (see Appendix A). Participants who failed this test were excluded (*N* = 15). Participants who did not fill in this reading check question were included in the study. Participants who studied a field not belonging to engineering or social sciences and participants for whom this information was missing were also excluded (*N* = 6).

Finally, a total of 126 participants were included in this study: 63 students with a study field within Engineering and 63 students with a study field within Social Sciences. One participant who studied both fields was included in the Social Sciences category.[1] The participants were randomly assigned to the different research groups: 20 Engineering and 22 Social Sciences students in experimental group 1 (total of 42), 23 Engineering and 20 Social Sciences students in experimental group 2 (total of 43), and 20 Engineering and 21 Social Sciences students in the control group (total of 41).

Participants' age varied between the age of 19 and 47 (*M* = 25.08, *SD* = 5.44). 63 participants were male (14 Engineering students and 44 Social Sciences students), 58 were female (47 Engineering students and 17 Social Sciences students), and for 5 participants this information was missing (3 for the Engineering students and 2 for the Social Sciences students). 95 participants reported having a driving license (51 for Engineering students and 44 for Social Sciences students; 31 participants reported having no driving license) of which 60 obtained their driving license in Sweden (23 for Engineering students and 37 for Social Sciences students; 35 participants did not obtain their driving license in Sweden).

[1] Participants have been in possession of a driving licence between 0 and 29 years (*M* = 6.28, *SD* = 5.66). 1 participant did not want to tell how long he/she had his/her driving licence. Participants were Swedish (*N* = 80), from other European countries (*N* = 23), from Asian countries (*N* = 15), from South American Countries (*N* = 3), from African countries (*N* = 3), and from Oceanian countries (*N* = 1). 1 participant did not want to share his/her country of origin. 57 participants study at KTH, 61 at SU, 6 study at other universities, and 2 participants did not want to share this information. Other universities include Linköping University (*N* = 2), Politecnico di Milano (*N* = 2), EPFL (*N* = 1), and Utrecht University (*N* = 1). 15 participants failed the reading check question and 3 did not fill in that question at all. All others (*N* = 109) filled in the question correctly.

Design and Materials

A three group, pre-test, post-test research design was used as shown in Table 1. Three different questionnaires were used belonging to the three experimental groups (version 1: experimental group 1, version 2: experimental group 2, and version 3: control group). Depending on the type of questionnaire it contained a pre-test (see Appendix B), a teaching instruction about time loss (see Appendix C), the Rasch-based Numeracy Scale (Weller et al., 2013) consisting of 8 items (see Appendix D), and a post-test (see Appendices E and F). The questionnaire for experimental group 1 contained the pre-test, the teaching instruction about time loss, and the post-test. The questionnaire for experimental group 2 contained the teaching instruction about time loss and the post test. The questionnaire of the control group contained the pre-test, the Rasch-based Numeracy Scale (Weller et al., 2013), used as a filler task, and the post-test. The pre-tests for experimental group 1 and the control group were identical. Also the teaching instruction for experimental group 1 and 2 was the same and all the three questionnaires contained identical post-test cases.

Additionally, the questionnaires also contained questions where participants could rate: the confidence on pre-test, the confidence on post-test, the understanding of the teaching instruction, and the applicability of the teaching instruction (see Appendix G). Also, the questionnaires included a question about for how many years they had their driving license and about the knowledge about time savings they had beforehand (see Appendix H). All questionnaires also contained additional questions which are not analyzed in the present study (see Appendices G and H).

Table 1. Research design with three groups, a pre-test, a teaching instruction, and a post-test.

	Pre-test	Teaching instruction	Post-test
Exp. group 1	X	X	X
Exp. group 2	-	X	X
Control group	X	-	X

Pre-test and post-test cases.

The pre-test consisted of 8 cases about time loss (cases 1 to 8, Table 2) and the post-test consisted of 8 new cases about time loss (cases 9 to 16, Table 3). The cases were similar to the cases used in earlier studies about time savings by Svenson (2008, 2009). In both tests the participants got the instruction to compare two speed change situations (situation A and B) and give intuitive answers about the new lower matching speed in situation B. Thus, participants received the instruction to make both situations A and B equal in their time loss on a distance of 25 km and write their answer in the open space in situation B. Below a case example is showed:

A	B
Old speed: 110 km / h	Old speed: 45 km / h
New lower speed: 70 km / h	New lower speed: ____ km / h

For the pre-test, 4 cases had a higher old speed in situation B (*higher speed cases*; cases 2, 4, 6, and 7) and 4 cases had a lower old speed in situation B (*lower speed cases*; cases 1, 3, 5, and 8). The post-test also had 4 lower speed cases (cases 10, 12, 14, and 15) and 4 higher speed cases (cases 9, 11, 13, and 16).

Teaching instruction.

The teaching instruction about time loss, as seen in Appendix C, instructed participants about the relation between speed changes and time loss. A graph which visualized this relation, the same as in Figure 1, was included in this instruction. Also, the common mistakes in time loss judgments were presented.

Procedure

Participants were given one of the three questionnaires belonging to the different experimental groups. The questionnaires were distributed in cycles in the repeated order: experimental group 1, experimental group 2 and control group. A consent form was added to inform about their rights as a participant and was signed by the participant. Participants were not allowed to use calculators or phones as external help or discuss the content of the questionnaire with other participants. Participants completed the questionnaires in different environments within Kungliga Tekniska högskolan and Stockholm University buildings. They did not have a time limit and completed the questionnaire in a time interval ranging from 15 to 45 minutes.

Results

This results section is divided in three parts: a part about time loss bias, debiasing by instruction and interrelations of questionnaire items. First, the initial differences and similarities between the different research groups (control group, experimental group 1 and experimental group 2) and the main groups of participants (Engineering and Social Sciences) were analyzed. After this, the analyses concerning the hypotheses were performed. The first part is about the time loss bias and the analyses of the scores in the pre-test. The second part, about debiasing, discusses the results of the post-test. This is done by comparing the scores on the post-test between the control group and the two experimental groups (see Table 1). Also, the scores on the post-test are compared to the scores on the pre-test in the control group and experimental group 1 (see Table 1). The third part discusses the interrelations of the questionnaire items.

Time Loss Bias

This part discusses the pre-test results and answers the question whether people gave answers which differ from the correct answers of the time loss cases (hypothesis 1) and whether people judged in the same way as with the time saving bias (hypothesis 2). More specifically, this part shows the tests analyzing if for higher speed cases, the answers of the participants were higher than the correct answer and for lower speed cases, the answers of the participants were lower than the correct answer (hypothesis 2.1) and if people give answers towards the ratio rule prediction (hypothesis 2.2). Before testing these hypotheses, the equality of the research groups and educational groups in terms of scores on the pre-test was analyzed.

Comparing groups.

To compare experimental group 1 and the control group on their total scores on the pre-test, an independent samples t-test was used. The score was computed by taking the mean of the absolute deviations from the correct answers for cases 1 to 8 (pre-test) and hereafter this score will be called *pre-test MDCorrect score*. The independent sample t-tests revealed that there was no significant difference between the experimental group 1 (M = 15.72, N = 42, SD = 6.69) and the control group (M = 16.34, N = 41, SD = 6.98) when comparing the pre-test MDCorrect score, $t(81) = -.41$, $p = .681$. Additionally, independent sample t-tests were performed for each case (1 to 8) individually. The tests revealed that experimental group 1 and the control group did not significantly differ in their answers, $p > .05$ for any of the cases.

To compare the answers on the pre-test between Social Sciences students and Engineering students an independent samples t-test was performed. The independent samples t-test revealed that the pre-test MDCorrect scores did not differ between the Social Sciences students ($M = 16.05$, $N = 43$, $SD = 6.64$) and the Engineering students ($M = 16.01$, $N = 40$, $SD = 7.05$), $t(81) = -0.03$, $p = .977$. Therefore, the Social Science students and Engineering students will be combined in the analyses concerning the pre-test. Analyses comparing the educational groups and research groups on the post-test results will be presented later in this results section.

Is there a bias?

One sample t-tests were performed to see if the mean answers per experimental group for cases 1 to 8 differ from (1) the correct answer, described by equation 4, (2) the ratio rule predictions, described by equation 2, and (3) the difference rule predictions, described by equation 3. The results, as shown in Table 2, reveal that all the mean answers per case in the pre-test differed significantly from the correct answers. Additionally, Figure 2 shows, per case on the pre-test, the deviation of the mean answer compared to the difference rule prediction, ratio rule prediction, and correct answer.

Differences between case types.

There are two different type of cases used in the tests: cases that started with higher speeds and a lower speed cases has to be answered (lower speed cases) and vice versa (higher speed cases). The lower speed cases were the cases 1, 3, 5, and 8 and the higher speed cases were cases 2, 4, 6, and 7 (see table 2). A paired sample t-test showed that participants differ significantly in the mean of the deviations from the correct answer between the higher speed cases ($M = 22.29$, $N = 83$, $SD = 10.08$) and lower speed cases ($M = -7.83$, $N = 83$, $SD = 6.85$), $t(82) = -17.98$, $p < .001$. Paired sample t-tests showed that participants in both the experimental group 1 and control group differed significantly in the direction of deviation from the correct answer between the higher and lower speed cases, $p > .001$ for any of the cases. The results indicate that participants answer higher than the correct answer on higher speed cases and lower than the correct answer on lower speed cases.

Ratio rule prediction.

Besides from the pre-test MDCorrect score, scores for the pre-test based on the mean absolute deviation from the ratio rule predictions (*pre-test MDRatio score*) and the difference rule predictions (*pre-test MDDifference score*) were computed. The pre-test MDRatio score is the mean deviation from the ratio rule prediction for cases 1 to 8 (pre-test). For the pre-test MDDifference score, it is the mean deviation from the difference rule prediction for the cases 1 to 8 (pre-test). The mean pre-test MDCorrect score was 16.03 ($SD = 6.80$), for the pre-test MDRatio score it was 8.75 ($SD = 4.67$) and for the pre-test MDDifference score it was 15.19 ($SD = 7.32$). This means participants answered closer to the ratio rule predictions than the correct answers or difference rule predictions. However, the average judgments were in statistical terms not sufficiently well approximated by any of the proposed rules.

To look more closely at each individual case, one sample t-tests were performed for each of the 8 cases in the pre-test. The results are shown in Table 2. Except for the mean answers for case 1 and 3, all cases significantly differed from the ratio answer. Furthermore, there were t-tests performed to compare the mean answers to the difference rule prediction as shown in Table 2 and Figure 2. The mean answers for all cases significantly differed from the difference prediction answer. It can be concluded that there is a time loss bias, but it is not described by the ratio rule as in for judgments of time savings.

When comparing the answers on higher speed cases (cases with a higher old speed in situation B; cases 2, 4, 6, and 7) and on lower speed cases (cases with a lower old speed in situation B; cases 1, 3, 5, and 8) in the pre-test to the ratio prediction, participants answered slightly higher than the ratio prediction on lower speed cases. In the higher speed cases, except from case 2, the participants answered lower than the ratio rule (as seen in Table 2 and Figure 2).

Table 2. Average judgments per experimental group and in total, difference rule predictions, ratio rule predictions, correct answers, and proportional deviations from the correct answers.

Cases		Averages			Predictions			Average proportion (J – c)/ c		
		EXP 1 (*N* = 42) (*SD*)	Control (*N* = 41) (*SD*)	Total (*N* = 83) (*SD*)	Difference	Ratio	Correct	EXP 1 N=42 (*SD*)	Control N=41 (*SD*)	Total N=83 (*SD*)
1	A: 110/70, B: 45/x	27.86*** (9.33)	26.90*** (11.07)	27.39 (10.18)	5.00***	28.64	36.47***	-0.24 (0.26)	-0.26 (0.30)	-0.25 (0.28)
2	A: 40/30, B: 130/x	91.18*** (18.59)	94.84*** (19.03)	92.99 (18.79)	120.00***	97.50*	62.40***	0.46 (0.30)	0.52 (0.30)	0.49 (0.30)
3	A: 130/110, B: 110/x	92.24** (7.30)	91.90* (9.83)	92.07 (8.59)	90.00*	93.08	95.33***	-0,03 (0.08)	-0.04 (0.10)	-0.03 (0.09)
4	A: 55/35, B: 90/x	62.57*** (10.56)	61.71*** (10.86)	62.14 (10.66)	70.00***	57.27***	46.51***	0.35 (0.23)	0.33 (0.23)	0.34 (0.23)
5	A: 130/100, B: 50/x	34.36*** (7.42)	35.56*** (8.76)	34.95 (8.08)	20.00***	38.46***	44.83***	-0.23 (0.17)	-0.21 (0.20)	-0.22 (0.18)
6	A: 65/50, B: 115/x	91.02*** (8.48)	92.85*** (10.46)	91.93 (9.49)	100.00***	88.46***	75.13***	0.25 (0.12)	0.27 (0.14)	0.26 (0.13)
7	A: 25/10, B: 70/x	38.45*** (13.93)	36.34*** (14.52)	37.41 (14.17)	55.00***	28.00***	13.46***	1.86 (1.03)	1.70 (1.08)	1.78 (1.05)
8	A: 90/55, B: 50/x	28.17*** (7.57)	27.51*** (8.60)	27.84 (8.05)	15.00***	30.56**	36.94***	-0.24 (0.20)	-0.26 (0.23)	-0.25 (0.22)

Note: *= p ≤ .05, **= p ≤ .01, ***= p ≤ .001. For research group 1 and the control group separate: one sample t-test are performed to compare the average answers compared to the correct answer. For the total group: one sample t-tests are performed to compare the average answers to the difference rule prediction, the ratio rule prediction, and the correct answer.

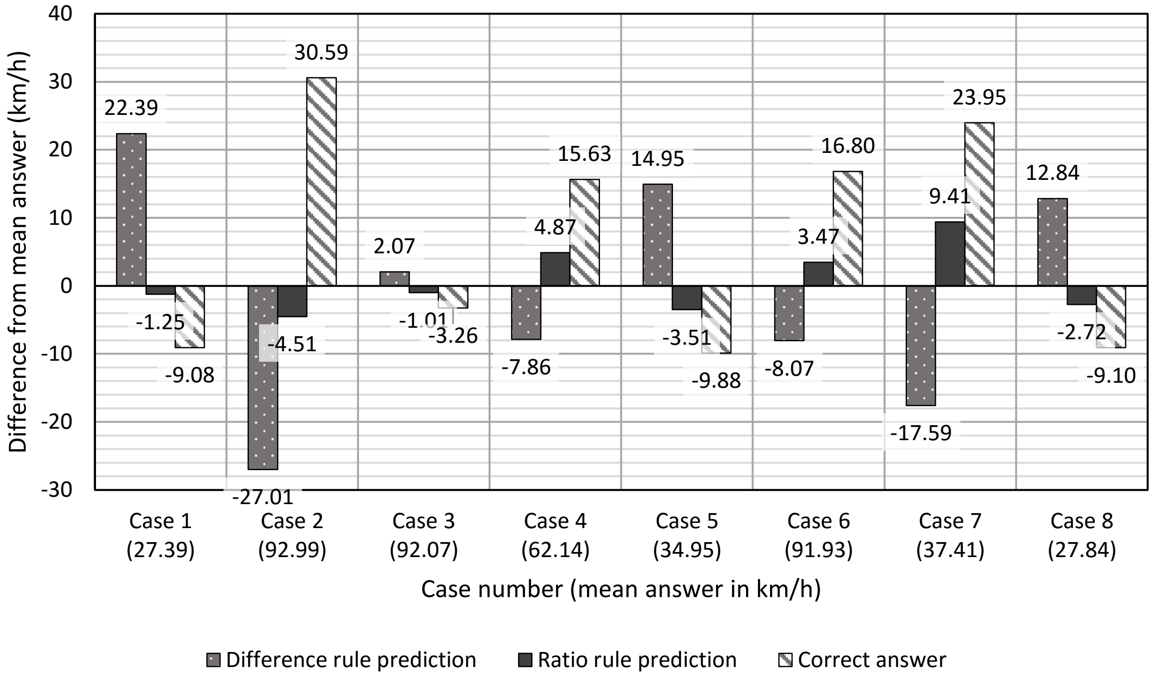

Figure 2. Mean answer of experimental group 1 and the control group per case of the pre-test compared to the difference rule prediction, ratio rule prediction, and correct answer.

Debiasing by Instruction

This part is about whether the answers of the participants after a debiasing instruction became significantly closer to the correct answers compared to the participants who did not get a debiasing instruction and compared to the answers before the debiasing instruction (hypothesis 3). First, this part will discuss the equalities and differences between the different research and educational groups in the scores on the post-test (see Table 1). After this, the results of the analyses comparing the answers on the post-test will be shown. A comparison was done between experimental group 1 and 2 combined and the control group and the pre-test scores were compared with the post-test scores for experimental group 1 and the control group (see Table 1). Answers were compared with the correct answers and the ratio rule predictions.

Combining groups.

To compare the scores on the post-test for experimental group 1 and 2, an independent sample t-test was performed. The score on the post-test was computed by taking the mean absolute deviation from the correct answer for cases 9 to 16, which will be called *post-test MDCorrect score* from now on. The t-test revealed no significant difference on the post-test MDCorrect scores between experimental group 1 ($M = 14.10$, $N = 42$, $SD = 7.30$) and experimental group 2 ($M = 14.82$, $N = 43$, $SD = 7.00$), $t(83) = -.465$, $p = .643$. Experimental group 1 and 2 were also compared in their scores for each of the cases 9 to 16 separately by performing independent samples t-tests. The tests revealed no significant differences between experimental group 1 and experimental group 2, $p > 0.05$ for any of the cases. These results mean that there was no difference between experimental group 1 and experimental group 2 in their answers in the post-test. Therefore, experimental group 1 and experimental group 2 were combined in some analyses. The combined data for experimental group 1 and 2 will be called *EXP 1&2*.

Additionally, the differences between the educational groups, Social Sciences and Engineering, were checked. For both EXP 1&2 and the control group an independent samples t-test was performed for the post-test MDCorrect scores comparing Engineering students and Social Sciences students. No significant difference in the post-test MDCorrect scores was found within EXP 1&2 between Engineering students (*M* = 13.41, *N* = 43, *SD* = 7.37) and Social Sciences students (*M* = 15.54, *N* = 42, *SD* = 6.76), $t(83) = -1.39$, $p = .169$ (for the control group the Levene's Homogeneity of Variance test was not completely satisfied, $F(39) = 4.18$, $p = 0.048$). Also for the control group there were no significant differences in post-test MDCorrect scores between Engineering students (*M* = 17.12, *N* = 20, *SD* = 9.19) and Social Sciences students (*M* = 17.45, *N* = 21, *SD* = 6.17), $t(33.05) = -.14$, $p = .894$.

Despite the lack of significant difference between the Social Sciences students and the Engineering students, there was a possibility that the post-test MDCorrect scores were different for different educational fields and experimental group or that there was an interaction. A 2 x 2 two-way ANOVA was conducted to see if there were different effects between the different experimental groups (experimental group 1 and 2) and the different education fields (Social Sciences and Engineering).[2] No significant differences or interactions were found. This means that it can be assumed that Engineering students and Social Sciences students did not differ significantly in their answers on the post-test. Therefore, these categories of participants were combined in further analyses.

Comparisons between research groups.

To look for differences in post-test MDCorrect scores between experimental group 1 (*M* = 14.10, *N* = 42, *SD* = 7.30) paired with experimental group 2 (*M* = 14.82, *N* = 43, *SD* = 7.00) and the control group (*M* = 17.29, *N* = 41, *SD* = 7.69), a One-way ANOVA with planned comparisons was run. No significant overall difference between the groups was found in the ANOVA test, $F\ (2,23) = 2.16$, $p = .120$. The contrast test revealed a significant difference between the paired experimental groups 1 and 2 and the control group, $t(123) = 2.03$, $p = .045$. This means that the answers of the experimental group were significantly closer to the correct answers than the answers of the control group. The effect size appeared to be small to moderate, Cohen's d = .39.

To look if differences existed between experimental group 1 and 2 paired and the control group when looking at the different cases, another 8 paired samples t-tests were executed. The results of the tests are shown in Table 3. A significant difference was found in the mean answers between the paired experimental groups 1 and 2 and the control group for cases 12, 14, and 16. For those three cases, the answers of the experimental groups were significantly closer to the correct answer. Figure 3 shows the mean answers on the questions of the post-test for EXP1&2 compared to the correct answer, ratio rule prediction, and the difference rule.

[2] No significant difference was found between experimental group 1 (*N* = 42, *M* = 14.10, *SD* = 7.30) and experimental group 2 (*N* = 43, *M* = 14.82, *SD* = 7.00), $F\ (3,81) = .33$, $p = .570$, partial $\eta^2 = .004$, as well as for Engineering students (*N* = 43, *M* = 13.41, *SD* = 7.37) and Social Sciences students (*N* = 42, *M* = 15.54, *SD* = 6.76), $F(1,81) = 1.98$, $p = .163$, partial $\eta^2 = .024$. The interaction between education field and experimental group (experimental group 1: Engineering: *N* = 20, *M* = 14.20, *SD* = 8.75; Social Sciences : *N* = 22, *M* = 14.00, *SD* = 5.90; experimental group 2: Engineering : *N* = 23, *M* = 12.72, *SD* = 6.05; Social Sciences *N* = 20, *M* = 17.23, *SD* = 7.38) on the score on the post-test also was also not significant, $F(1,81) = 2.38$, $p = .127$, partial $\eta^2 = .029$.

Table 3. One-way ANOVA with planned comparisons combining experimental group 1 and 2 compared to the control group on the scores on the cases on the post-test.

	Averages			Predictions			Average proportion (J – c)/ c			ANOVA planned comparisons		
Cases	EXP 1 (*N* = 42)	EXP 2 (*N* = 43)	Control group (*N* = 41)	Difference	Ratio	Correct	EXP 1	EXP 2	Contr. group (*N* = 41)	ANOVA Sig. *p* =	Contrast (2-tailed) *p* =	Cohen's d, conf. int. 0.95
9 A: 30/15, B: 80/x	39.83 (16.21)	37.95 (13.88)	42.12 (12.91)	65.00	40.00	21.82	0.83 (0.74)	0.74 (0.64)	0.93 (0.59)	.417	.241	-.23
10 A: 115/70, B: 60/x	39.31 (13.94)	41.19 (14.88)	34.80 (11.90)	15.00	36.52	44.93	-0.13 (0.31)	-0.08 (0.33)	-0.23 (0.26)	.094	.038	.40
11 A: 60/45, B: 110/x	73.10 (16.27)	71.51 (17.78)	79.40 (16.46)	95.00	82.50	68.28	0.07 (0.24)	0.05 (0.26)	0.16 (0.24)	.082	.029	-.43
12 A: 135/90, B: 50/x	32.63 (10.95)	37.98 (24.35)	28.15 (12.62)	5.00	33.33	42.19	-0.23 (0.26)	-0.10 (0.58)	-0.33 (0.30)	.035	.030	.42
13 A: 50/30, B: 105/x	66.62 (16.26)	66.51 (16.60)	69.27 (15.78)	85.00	63.00	43.75	0.52 (0.37)	0.52 (0.38)	0.58 (0.36)	.682	.383	-.17
14 A: 80/45, B: 40/x	26.85 (12.62)	26.97 (10.25)	21.40 (8.80)	5.00	22.50	28.80	-0.07 (0.44)	-0.06 (0.36)	-0.26 (0.31)	.028	.008	.52
15 A: 120/100, B: 100/x	82.67 (9.55)	84.05 (12.59)	81.32 (12.03)	80.00	83.33	85.71	-0.04 (0.11)	-0.02 (0.15)	-0.05 (0.14)	.554	.351	.18
16 A: 45/35, B: 125/x	87.21 (17.82)	91.79 (18.99)	99.02 (14.93)	115.00	97.22	69.69	0.25 (0.26)	0.32 (0.27)	0.42 (0.21)	.009	.005	-.55

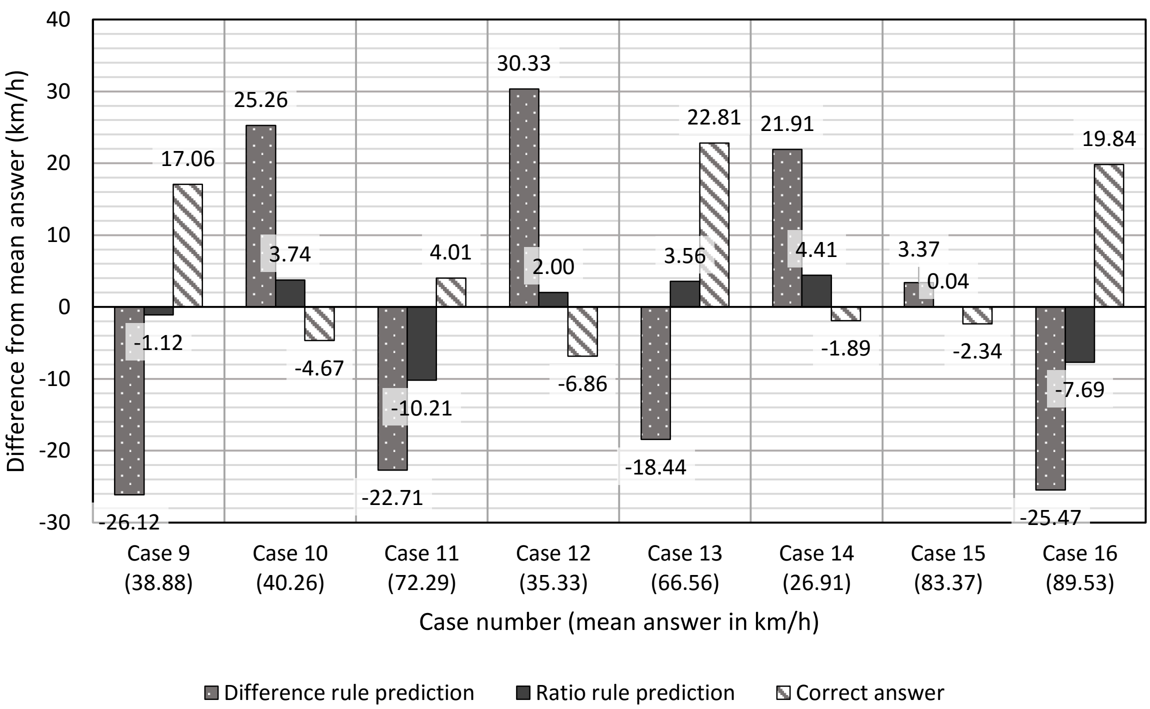

Figure 3. The mean answer of EXP1&2 per post-test case compared to the difference rule prediction, ratio rule prediction, and correct answer.

Comparisons within research groups.

To see if participants within the experimental group 1 and the control group improved their scores on the post-test compared to the pre-test, paired samples t-tests were performed for both groups. The pre-test MDCorrect scores and the post-test MDCorrect scores were compared to each other and the means are shown in Figure 4.[3] It should be noted that the cases in the pre-test (cases 1 to 8) and the cases in the post-test (cases 9 to 16) were different and that this comparison was only approximate. No significant difference was found for experimental group 1 (N = 42) between the pre-test MDCorrect scores (M = 15.72, SD = 6.69) and the post-test MDCorrect scores (M = 14.10, SD = 7.30), $t(41) = 1.83$, $p = .075$. Neither a significant difference was found for the control group (N = 40) between the pre-test (M = 16.34, SD = 6.98) and the post-test (M = 17.29, SD = 7.69), $t(40) = -1.60$, $p = .117$. This means that experimental group 1 moved closer to the correct answers on the post-test compared to the pre-test, but not significantly. The control group moved farther away from the correct answers in the post-test compared to the pre-test but neither significantly. Although the cases in the pre-test and post-test were different, the pattern in Figure 4 appeared independently of this difference.

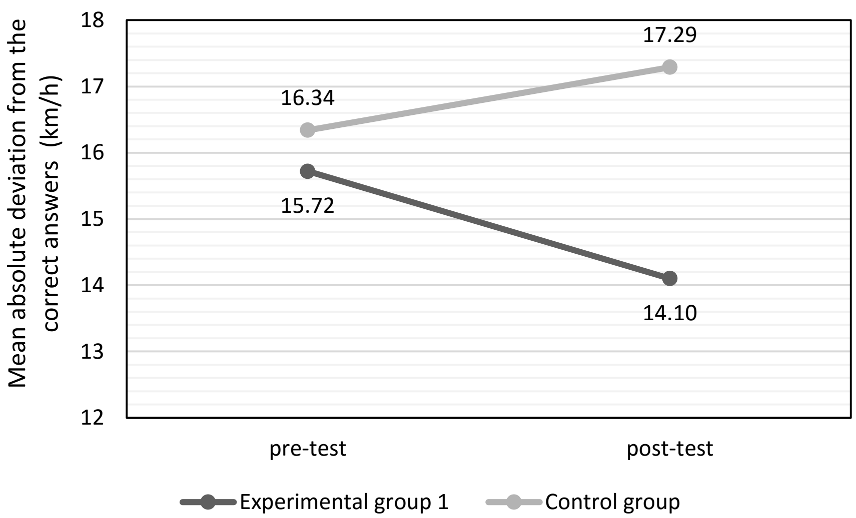

Figure 4. Pre-test and post-test comparisons for experimental group 1 and the control group.

To see if participants were answering more towards the ratio answer instead of the correct answer, paired samples t-test were performed for experimental group 1 and the control group, comparing the scores on the pre-test and the post-test. The scores were computed based on the mean absolute deviation from the ratio answer for cases 1 to 8 for the pre-test (pre-test MDRatio scores) and cases 9 to 16 for the post-test (*post-test MDRatio scores*). Experimental group 1 (N = 42) had a significantly higher post-test MDRatio score (M = 11.48, SD = 5.05) compared to the pre-test MDRatio score (M = 8.77, SD = 4.13), $t(41) = -3.69$, $p = .001$. The scores in the control group (N = 41) did not significantly differ between the pre-test MDRatio scores (M = 8.73, SD = 5.21) and the post-test MDRatio scores (M = 9.54, SD = 5.62), $t(40) = -1.47$, $p = .150$. This means that participants in the experimental group in the post-test deviated more from the ratio predictions compared to the pre-test. To be more specific, the participants in the experimental group moved farther from the ratio prediction and moved closer to the correct answers.

[3] As mentioned before, experimental group 1 did not differ significantly from the control group on the pre-test MDCorrect scores. For the post-test MDCorrect scores, an independent samples t-test revealed a marginal significant difference between experimental group 1 and the control group, $p = .056$.

Although the answers of the participants moved closer to the correct answer, the answers were still closer to the ratio prediction compared to the correct answer.

Interrelations of Questionnaire Items

This part will present two Principal Component Analyses (PCA) which were performed for exploratory purposes and in order to identify patterns between the questionnaire items shown in Table 4. One PCA was performed for EXP 1&2 and one for the control group.

Table 4. Items used for the PCA's

Item	Description
Pre-test MDCorrect score	Mean of the absolute deviations from the correct answers for cases 1 to 8 (pre-test).
Post-test MDCorrect score	Mean of the absolute deviations from the correct answers for cases 9 to 16 (post-test).
Confidence on pre-test	"On a scale from 0 to 10, how confident were you that your answers at Instruction (x) were correct?"
Confidence on post-test	"On a scale from 0 to 10, how confident were you that your answers at Instruction (x) were correct?"
Understanding Teaching Instruction	"On a scale from 0 to 10, how easy was it to understand the instruction at Instruction 2?"
Applicability Teaching Instruction	"On a scale from 0 to 10, after you learned more about time loss at Instruction (x) how easy was it to apply the instruction to the following questions?"
Driving License (years)	The number of years people are in possession of a driving license.
Pre-knowledge	"In my driving lessons I was taught about the relation between speed and time: yes / no"
Score Numeracy test	The number of correct answers on the numeracy test.

First, a Principal Component Analysis, PCA, with a Varimax (orthogonal) rotation for 8 questions of the questionnaire was conducted for EXP 1&2. The result of an orthogonal rotation (Varimax) of the solution is shown in Table 5. The analysis resulted in a three-factor solution using the components with eigenvalues above 1.

Table 5. Rotated component loadings for EXP1&2 (8 items).

	Component		
	1	2	3
Understanding Teaching Instruction	**.848**	.098	.050
Applicability Teaching Instruction	**.837**	.274	-.232
Confidence on post-test	**.815**	.124	-.289
Driving License (years)	**-.571**	.294	-.179
Pre-knowledge	.034	**.885**	.151
Confidence on pre-test	.118	**.818**	.009
post-test MDCorrect score	-.267	-.066	**.872**
Pre-test MDCorrect score	.099	.232	**.854**
Percentage of total variance	31.309	21.217	21.043

Note: the bold values indicate the corresponding component.

The same was done for the control group with a few differences in the set of questions. A Principal Component Analysis with a Varimax (orthogonal) rotation was performed for 7 questions of the questionnaire. The result of an orthogonal rotation (Varimax) of the solution is shown in Table 6. For the total control group, the result of the analysis held a 2 component solution using the components with an eigenvalue above 1.

Table 6. Rotated component loadings for the control group (7 items).

	Component	
	1	2
Confidence on pre-test	**.943**	.061
Confidence on post-test	**.947**	-.009
Driving License (years)	**.590**	-.227
Pre-knowledge	.313	**.684**
Pre-test MDCorrect score	-.577	**.662**
post-test MDCorrect score	-.580	**.660**
Score Numeracy test	.118	**-.606**
Percentage of total variance	41.654	25.201

Note: the bold values indicate the corresponding component.

A clear pattern was shown when looking at the factor analysis for EXP1&2. The items which form the first factor were understanding teaching instruction, applicability teaching instruction, confidence on post-test, and driving license. It shows that the longer the possession of a driving license the less confident on the post-test and the lower the participants rated the applicability and understanding of the teaching instruction. The second component was formed by pre-knowledge and confidence on pre-test. This shows that when people reported not to have learned about the relation between time and speed during their driving lessons, they seem to be more confident in the pre-test. The third component was formed by the post-test MDCorrect score and the pre-test MDCorrect score meaning that higher scores on the pre-test goes along with higher scores on the post-test.

A different result was shown for the control group. The first factor contained the items confidence on pre-test, confidence on post-test, and driving license. The results showed that the longer participants were in possession of a driving license the more confident they are on both tests. The second component was formed by pre-knowledge, pre-test MDCorrect score, post-test MDCorrect score, and the score on the numeracy test. The items in this component showed that if people reported to not have been taught about the relation between time and speed during their driving lessons, they scored farther away from the correct answer on the pre-test and post-test and they also scored lower on the numeracy test.

Discussion

This study investigated whether people give biased answers on time loss cases and if so, whether they do it in the same way as the time saving bias by using the ratio rule and answering higher on higher speed cases and lower on lower speed cases. Additionally, it was studied whether a possible time loss bias can be ameliorated or eliminated by giving an instruction about the relationship between time and speed. Amelioration means that participants give answers closer to the correct answers and more deviant from the ratio prediction answers.

As expected, people answered the time loss cases in a biased way. The answers cannot be explained by the correct formula, the ratio rule or the difference rule. The answers came closest to the ratio rule, although not significantly in most cases (only the mean answers for cases 1 and 3 of the 8 cases in the pre-test were in accordance with the ratio rule). People answered higher than the correct answer on higher speed cases (cases with a higher speeds in situation B) and lower than the correct answer on lower speed cases (cases with lower speeds in situation B), which is also in line with the expectations.

Additionally, participants who received a teaching instruction made judgments significantly closer to the correct answer than the control group who did not receive an instruction. Participants in the experimental condition decreased the bias, but it was not fully eliminated. Participants who received instruction deviated significantly more from the ratio answer compared to the control group. This suggests that the instruction helped participants to release the ratio rule and helped them answer more towards the correct answers, although not sufficiently to reach the correct answer exactly.

The results concerning the time loss bias from this study are similar to results from the time saving studies (Svenson, 2008, 2009; Svenson et al., 2014). Without instruction, people tend overestimate the time loss from decreases of speed from higher speeds and underestimate the time loss from decreases of speed from lower speeds. Participants in the present study gave answers according to the ratio rule with an aberration from the correct answer towards the difference rule prediction. This result for time loss judgments appears to be the same for time saving judgement when comparing the results from this study with studies about time saving (Svenson, 2009). However, when comparing the results with another study about time saving (Svenson, 2008) the trend is a little different. In this study, the answers were near the ratio rule prediction. Only in five of the six cases the answers were slightly more towards the correct answer instead of farther away from it. Overall, it seems that the time loss bias behaves globally in the same way as the time saving bias. Although to confirm this, a study comparing both time saving and time loss in the same experiment should be conducted.

When looking closer to the results, participants answered differently on higher speed cases compared to lower speed cases. The participants answered higher than the ratio prediction on lower speed cases and for the higher speed cases in three of the four cases, the participants answered lower than the ratio rule prediction. Participants could have used the ratio rule as a starting point and then adjusted it towards the difference rule answer, which is farther away from the correct answer.[4]

The results concerning the improvement by the instruction are also comparable to other studies. In the present study, the participants who received the teaching instruction improved their answers but not significantly and not sufficiently, which is similar to the results from a study by Svenson et al. (2014) about resource judgments. In this study they used two different ways of instructing participants as a tool to improve judgments on similar cases as the current study. In the study by Svenson et al. (2014) the answers improved significantly but neither sufficiently to fit the correct answer. This result is similar to the current study.

The planned comparison test revealed that there was a significant difference in overall score on the post-test between the experimental groups and the control group. The participants who received the instruction answered significantly closer to the correct answer. However, comparing the scores on each case revealed only a significant difference for cases 12, 14, and 16. An explanation for the significance of these specific cases is hard to find when looking at case characteristics [5].

When looking at the different questionnaire items it is remarkable that for EXP1&2 there was a trend that the longer participants had a driving license the less confident they were on the post-test and the lower they rated understanding the teaching instruction and the applicability of the teaching instruction. In contrast, for the control group the longer the people had a driving license the more confident they were on both the pre-test and post-test. The longer people had a driving license could make them more confident about this type of questions. Only as a speculation, the fact that EXP1&2 showed less confidence on the post-test could be interpreted as a lack of confidence in basic mathematics.

A more intuitive result was the relation between pre-test and post-test. The pre-test and post-test scores were highly correlated for both the control group and EXP1&2. This means that when people already scored high on the pre-test they were also likely to score high on the post-test.

Additionally, within the control group, pre-test scores and post-test scores were also positively correlated to the pre-knowledge obtained in driving lessons about the relationship between time and speed. This means that pre-knowledge correlated with scores closer to the correct answers in the tests. However, at the same time better scores on the pre-test and the post-test also correlated positively with better scores on the numeracy test. Therefore, it is hard to see if the pre-knowledge or the numeracy skills influence the answers on the pre-test and post-test more.

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[4] As a minor observation, only case 2 (A 40/30, B 130/x) did not follow this conclusion: participants moved closer towards the correct answer instead of towards the difference rule prediction. This might be because case 2 has the largest difference in the difference rule prediction, ratio rule prediction and correct answer. The global trend of answers is similar to the results of the study by Svenson (2009) in which people answered more closely to the ratio answer with a deviation towards the difference rule and farther away from the correct answer.

[5] These three cases differ from each other in several ways (Case 12: A 135/90, B 50/x; case 14: A 80/45, B 40/x; case 16: A 45/35, B 125/x) like speed change, higher or lower speed case, and position in questionnaire. This makes an explanation hard to find in case characteristics. Cases 9, 13, and 15 were far from significantly different when comparing the mean answers of EXP1&2 and the control group. Also for these cases it is hard to find an explanation in the design of the case (A 30/15, B 80/x; Case 13: A 50/30, B 105/x; case 15: A 120/100, B 100/x).

Implications

The results show the time loss bias and this could have an effect in traffic. In many situations speed limits make people drive slower than they might want to. People lose time and the time loss bias makes that they have a wrong conception of time lost in their mind. For example, for higher speeds the decrease in speed does not have that much effect on the time lost as people think, compared to the time lost for decreases from lower speeds. The results suggest that people think they lose more time than they actually do. This could make them feel more hurried or stressed which could result in more unsafe behavior. This could be different if they know the correct time loss which is less than the time loss they think. This should be taken into account when, for example, road constructions make people drive slower on certain parts of the roads and many more traffic situations. For example, making people more aware on the road construction site itself that the time loss is not as big as they expect could be one way to deal with these kind of situations.

The presence of the time loss bias and the possible consequences makes a debiasing solution for both time saving and losing more desired. It is of importance to teach driving pupils about the time saving and time loss bias and instruct them about the time and speed relation. Although a better way of instruction is desired, even just instructing people about time saving and time loss already improves their judgments. When people know more about time saving and losing they could be less worried about differences in speed and act in a safer way instead of driving too fast and more dangerously (Peer, 2010; Nilsson, 2004).

Limitations

Some limitations of this study need to be taken in consideration. The groups of participants in this study were rather homogenous, which should be taken into account when considering generalizability. There was an equal amount of Social Sciences students and Engineering students but within those groups there was a large variety of age, gender, background, and the ownership of a driving license. For example, the Social Sciences group was largely composed of Swedish female participants and the Engineering students were often from different backgrounds. Additionally, only university students took part in this study which makes the results less ecologically valid for the whole population and perhaps closer to the correct values, because of a higher educational background.

Another limitation is that participants showed a big range in the times they took to finish their questionnaires. Some participants might have thought more about it than other participants. In this way it could not be guaranteed that participants had the same time for each question or answered intuitively. It is not unlikely that this influenced the results. Most likely this has increased the variability between judgments and could have made the results less likely to be significant. This should be taken into account when interpreting the results.

Moreover, participants filled out the questionnaires in different environments. Some participants filled out the questionnaire in the lunchroom of the university while others filled it out in a classroom. It could influence how seriously participants were filling out the questionnaires which makes the method less controlled for such variance. This also could have led to greater variance than if the same environment had been used.

As a last limitation, the numeracy test for the control group might have influenced the participants in the control group. It could be that the numeracy test made them aware of their numeracy skills which could influence the results on the post-test. Since the answers on the post-test were worse than the pre-test it could be that this is caused by the use of the numeracy test in between. However, about this subject can only be speculated, because the pre-test and post-test were different from each other. This might have caused part of the decreased score of the control group on the post-test.

Directions for future research

Further research on this topic should focus on different methods in debiasing the time saving and time loss bias. Different teaching instructions can be used. Instructions seem to help although there is still need for a more effective and efficient method of instruction. Both time saving and time loss should be studied in the same study to further inform us about the relationship between the two biases.

Also it is desired to test the current effectiveness of the driving lessons about the relation between time and speed in a controlled way. This study shows indications for a positive result on education in driving lessons about this relation and better answers on the time loss judgments but controlled experimental data is lacking. A study to see whether instructions in driving lessons could improve time saving and time loss judgments could affect the speed choice in a way that is in favor of traffic safety.

Additionally, it is recommended, in favor of the ecological validity, to use experiments in a driving simulator. The effect of different instructions with the purpose of reducing bias can in this way also see if this decrease is translated to drivers' behavior.

Conclusion

There is a time loss bias similar to the time saving bias. Decreasing the bias is possible by applying a teaching instruction although did not totally eliminate the bias. Further research should focus also on other teaching instructions.

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Appendix A

Reading check question

Included in all three questionnaires.

INSTRUCTION

Individual preferences can greatly impact the decision process. In order to facilitate our research on decision making we are interested some more information about you, the decision maker. Specifically, we are interested in whether you actually took the time to read the instructions; if not, then some of our manipulations that rely the instructions will not be effective. So, in order to demonstrate that you have read the instructions simply fill in "I read the instructions" in the space after "Other". Thank you.

□ Watching tv /movies	□ Cultural events	□ Travelling
□ Sport	□ Clubbing	□ Internet
□ Reading	□ Religious activities	□ Outdoor activities
□ Gaming	□ Cooking	□ Other; ____________________

Appendix B

Pre-test

Included in the questionnaire for experimental group 1 and the control group.

INSTRUCTION

When driving, you must not drive faster than the speed limit. Sometimes, because of road works or other circumstances the speed limit has to be decreased on shorter or longer distances. A lower speed limit means that drivers drive more slowly and loose time compared with the normal driving speed.

Below, you find examples of speed decreases from different original speeds and we will ask you to consider the times lost on two different road sections, both 25 km long. Specifically, you will find mean speed reductions on road ***A*** and road ***B*** situations. For ***A*** the new lower speed is given and for ***B*** it is not.

We want you to fill in the missing speed in B to make alternative A and B equal in the time they lose after the new speeds are implemented.

Note, we do *not want you to calculate the answers* (it would take too much time anyways). We do not want you to use phones, calculators or other equipment when you make your judgments.

We want you to give intuitive answers but we still want you to consider each case carefully before you give your judgment.

Here is an illustrative example:

- On road ***A*** a driver has a normal average speed 85 km/h. The new lower average is 45 km/h on 25 km.
- On road ***B***, also 25 km long, the average speed of another driver is 60 km/h before the new lower speed.

Your task is to judge the lower speed on ***B*** that would give ***the same travel time loss on B as the loss of time on road A.***

Obviously, the speed should be lower than 60 km/h, but what lower speed would give exactly the same time loss as on road ***A*** (from 85 to 45 km/h)?

On the next page, you will find some other cases and we ask you to fill in the empty spaces with the speed you think would give **the same time loss** for ***B*** as for ***A***. The distance traveled is 25 km for both road ***A*** and ***B***.

Case 1

A	B
Old speed: 110 km / h	Old speed: 45 km / h
New lower speed: 70 km / h	New lower speed: ____ km / h

Case 2

A	B
Old speed: 40 km / h	Old speed: 130 km / h
New lower speed: 30 km / h	New lower speed: ____ km / h

Case 3

A	B
Old speed: 130 km / h	Old speed: 110 km / h
New lower speed: 110 km / h	New lower speed: ____ km / h

Case 4

A	B
Old speed: 55 km / h	Old speed: 90 km / h
New lower speed: 35 km / h	New lower speed: ____ km / h

Case 5

A	B
Old speed: 130 km / h	Old speed: 50 km / h
New lower speed: 100 km / h	New lower speed: ____ km / h

Case 6

A	B
Old speed: 65 km / h	Old speed: 115 km / h
New lower speed: 50 km / h	New lower speed: ____ km / h

Case 7

A	B
Old speed: 25 km / h	Old speed: 70 km / h
New lower speed: 10 km / h	New lower speed: ____ km / h

Case 8

A	B
Old speed: 90 km / h	Old speed: 50 km / h
New lower speed: 55 km / h	New lower speed: ____ km / h

Appendix C

Teaching instruction

Included in the questionnaire for experimental group 1 and experimental group 2.

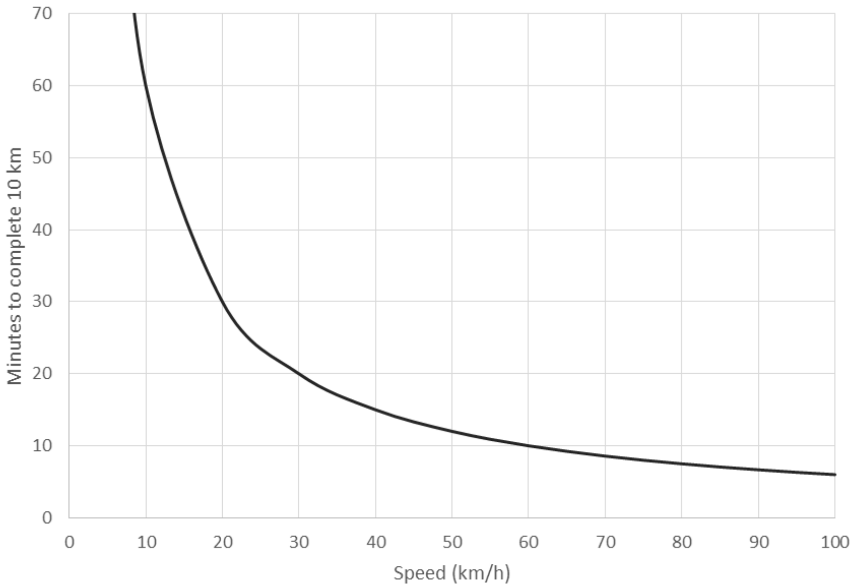
INSTRUCTION

In this part we are going to explain more about losing time when decreasing different speeds and what mistakes people usually make.

Time losing

The time you lose depends on the distance, the change in speed, and also the initial speed. *The higher the initial speed the less time is lost* compared with the same decrease in speed at a lower speed. Below you can see an illustration of the relation between speed and how many minutes it takes to complete a 10 km distance.

Minutes to complete 10 km with different speeds



You can see that the relationship between speed and minutes to complete 10 km is not linear. For example, when you compare a speed decrease from 100 km/h to 80 km/h you lose less time compared to when you decrease speed from 40 km/h to 20 km/h.

Common mistakes in time losing situations

Many people tend to think that the relationship between speed and time to complete a certain distance is linear (so a given speed decrease of for example 15 km/h in speed gives the same time loss independent of the original speed) but this is not the case as you can see in the graph above.

Alternatively, people may think that the relationship is proportional, but also that is not the case. For example, from 60 km/h to 30 km/h means that the speed is decreased by half and you lose 10 minutes on a distance of 10 km. But, if you compare 20 km/h to 10 km/h the speed is also decreased by half but in this case 30 minutes are lost.

Appendix D

Rasch-based numeracy test

Included in the questionnaire for the control group.

INSTRUCTION

Please fill in the following questions:

(1) Imagine that we roll a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up as an even number?
Answer: ____

(2) In the BIG BUCKS LOTTERY, the chances of winning a $10.00 prize are 1%. What is your best guess about how many people would win a $10.00 prize if 1,000 people each buy a single ticket from BIG BUCKS?
Answer: ____people

(3) In the ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets of ACME PUBLISHING SWEEPSTAKES win a car?
Answer: _____

(4) If the chance of getting a disease is 10%, how many people would be expected to get the disease:
Out of 1000
Answer: _____people

(5) If the chance of getting a disease is 20 out of 100, this would be the same as having a ____% chance of getting the disease.

(6) Suppose your friend just had a mammogram. The doctor knows from previous studies that, of 100 women like her, 10 have tumors and 90 do not. Of the 10 who do have tumors, the mammogram correctly finds 9 with tumors and incorrectly says that 1 does not have a tumor. Of the 90 women without tumors, the mammogram correctly finds 80 without tumors and incorrectly says that 10 have tumors. The table below summarizes this information. Imagine that your friend tests positive (as if she had a tumor), what is the likelihood that she actually has a tumor?

	Tested positive	Tested negative	Totals
Actually has a tumor	9	1	10
Does not have a tumor	10	80	90
Totals	19	81	100

Answer: _____ out of _____

(7) A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?
Answer: ____cents

(8) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?
Answer: _____days

Appendix E

Post-test experimental group 1 and control group

Included in the questionnaire for experimental group 1 and the control group.

INSTRUCTION

Now we want you to answer another set of questions about losing time. We do not want you to go to any earlier instructions or your own answers.

Below you find 6 cases each with 2 speed change situations, an **A** and a **B** situation. For situation A the new lower speed is given and for situation B this is not. **We want you to fill in the missing speed in situation B to make alternative A and B equal in the time they lose after the new speeds are implemented.** In every case the travel distance is 25 km.

Note that we do not want you to calculate the answers but we want you to give intuitive answers.

Again, you will find a number of cases and we ask you to fill in the empty spaces with the speed you think would give **the same time loss** for ***B*** as for ***A***.

Case 1

A	**B**
Old speed: 30 km / h	Old speed: 80 km / h
New lower speed: 15 km / h	New lower speed: ____ km / h

Case 2

A	**B**
Old speed: 115 km / h	Old speed: 60 km / h
New lower speed: 70 km / h	New lower speed: ____ km / h

Case 3

A	**B**
Old speed: 60 km / h	Old speed: 110 km / h
New lower speed: 45 km / h	New lower speed: ____ km / h

Case 4

A	B
Old speed: 135 km / h	Old speed: 50 km / h
New lower speed: 90 km / h	New lower speed: ____ km / h

Case 5

A	B
Old speed: 50 km / h	Old speed: 105 km / h
New lower speed: 30 km / h	New lower speed: ____ km / h

Case 6

A	B
Old speed: 80 km / h	Old speed: 40 km / h
New lower speed: 45 km / h	New lower speed: ____ km / h

Case 7

A	B
Old speed: 120 km / h	Old speed: 100 km / h
New lower speed: 100 km / h	New lower speed: ____ km / h

Case 8

A	B
Old speed: 45 km / h	Old speed: 125 km / h
New lower speed: 35 km / h	New lower speed: ____ km / h

Appendix F

Post-test experimental group 2

Included in the questionnaire for experimental group 2 (cases are the same as in the post-test for experimental group 1 and the control group).

INSTRUCTION

When driving, you must not drive faster than the speed limit. Sometimes, because of road works or other circumstances the speed limit has to be decreased on shorter or longer distances. A lower speed limit means that drivers drive more slowly and loose time compared with the normal driving speed.

Now we want you to answer a set of questions about losing time. We do not want you to go to the earlier instructions. Below, you find examples of speed decreases from different original speeds and we will ask you to consider the times lost on two different road sections, both 25 km long. Specifically, you will find mean speed reductions on road ***A*** and road ***B*** situations. For ***A*** the new lower speed is given and for ***B*** it is not.

We want you to fill in the missing speed in B to make alternative A and B equal in the time they lose after the new speeds are implemented.

Note, we do *not want you to calculate the answers* (it would take too much time anyways). We do not want you to use phones, calculators or other equipment when you make your judgments.

We want you to give intuitive answers but we still want you to consider each case carefully before you give your judgment.

Here is an illustrative example:

- On road ***A*** a driver has a normal average speed 85 km/h. The new lower average is 45 km/h on 25 km.
- On road ***B***, also 25 km long, the average speed of another driver is 60 km/h before the new lower speed.

Your task is to judge the lower speed on ***B*** that would give ***the same travel time loss on B as the loss of time on road A.***

Obviously, the speed should be lower than 60 km/h, but what lower speed would give exactly the same time loss as on road ***A*** (from 85 to 45 km/h)?

On the next page, you will find some other cases and we ask you to fill in the empty spaces with the speed you think would give **the same time loss** for ***B*** as for ***A***. The distance traveled is 25 km for both road ***A*** and ***B***.

Case 1

A	B
Old speed: 30 km / h	Old speed: 80 km / h
New lower speed: 15 km / h	New lower speed: ____ km / h

Case 2

A	B
Old speed: 115 km / h	Old speed: 60 km / h
New lower speed: 70 km / h	New lower speed: ____ km / h

Case 3

A	B
Old speed: 60 km / h	Old speed: 110 km / h
New lower speed: 45 km / h	New lower speed: ____ km / h

Case 4

A	B
Old speed: 135 km / h	Old speed: 50 km / h
New lower speed: 90 km / h	New lower speed: ____ km / h

Case 5

A	B
Old speed: 50 km / h	Old speed: 105 km / h
New lower speed: 30 km / h	New lower speed: ____ km / h

Case 6

A	B
Old speed: 80 km / h	Old speed: 40 km / h
New lower speed: 45 km / h	New lower speed: ____ km / h

Case 7

A	B
Old speed: 120 km / h	Old speed: 100 km / h
New lower speed: 100 km / h	New lower speed: ____ km / h

Case 8

A	B
Old speed: 45 km / h	Old speed: 125 km / h
New lower speed: 35 km / h	New lower speed: ____ km / h

Appendix G

Evaluation questions

Specific evaluation questions belonging to the different parts of the questionnaires: pre-test, teaching instruction, and post-test.

Introductory instruction:

What were your thoughts? You can describe how you felt and thought when you judged **the first round of problems.** You may **answer in English or Swedish**. Use the language you are most familiar with. For ease, we give the numbers of the problems in alphabetical form (a, b, c and x).

Hur tänkte du? Du kan använda **svenska eller engelska** när du beskriver hur du tänkte när du bedömde **den första omgången problem.** För att underlätta ger vi siffrorna i bokstavsform (a, b, c and x).

A	B
Present speed: **(a)** km / h	Present speed: **(c)** km / h
New speed: **(b)** km / h	New speed: **_(x)_** km / h

Questions belonging to the pre-test:

(1) How did you reach an answer for the problems in the first test? Please, use the letters above if this explains how you reached a judgment.
Hur gjorde du när du löste problemen i första omgången? Beskriv med bokstäverna hur du tänkte under första omgången.

(2) Did you develop any "thumb rules" to simplify the problems in the first test? If so, please, describe them below.
Tycker du att du använde du några "tumregler" för att förenkla problemen? Var snäll och beskriv dom i så fall.

(3) Did you have the same strategy for all cases or did you have different judgment strategies for different cases within the problems in instruction 1? If you had different strategies, for what kind of cases did you use which strategy?
Under instruktion 1, hade du samma strategi för samtliga problem eller använde du olika bedömningsstrategier för olika problem? Om du använde olika strategier för olika problem, vilka strategier använde du till vilka typ av problem?

(4) On a scale from 0 to 10, how confident were you that your answers at Instruction 1 were correct? (Circle answer)
På en skala mellan 0 och 10, hur säker är du att dina svar vid instruktion 1 var korrekta? (Ringa in ditt svar)

Not confident at all	0	1	2	3	4	5	6	7	8	9	10	extremely confident

Questions belonging to the teaching instruction:

(1) On a scale from 0 to 10, how easy was it to understand the instruction at Instruction 2? (Circle answer)
På en skala mellan 0 och 10, hur lätt var det att förstå instruktionen vid instruktion 2? (Ringa in ditt svar)

Could not understand at all	0	1	2	3	4	5	6	7	8	9	10	extremely easy to understand

(2) On a scale from 0 to 10, after you learned more about time loss at Instruction 2 how easy was it to apply the instruction to the following questions? (circle answer)
På en skala mellan 0 och 10, efter att du fick mer information om förlust av tid vid instruktion 2, hur lätt var de att applicera informationen på frågorna efter instruktionen? (Ringa in ditt svar)

Could not apply at all	0	1	2	3	4	5	6	7	8	9	10	extremely easy to apply

Questions belonging to the post-test:

(1) How did you reach an answer in this set of problems? Please, use the letters (a, b, c and x) to explain how reached a judgment for the <u>second set of problems (instruction 3).</u>
Beskriv med bokstäverna (a, b, c and x) hur du löste problemen och hur du tänkte under <u>andra omgången (instruction 3).</u>

(2) Did you develop any "thumb rules" to simplify the problems in <u>the second set (instruction 3)</u>? If so, please, describe them below.
Tycker du att du använde du några "tumregler" för att förenkla problemen i <u>andra omgången (instruction 3)</u>? Var snäll och beskriv dem i så fall.

(3) Did you have the same strategy for all cases or did you have different judgment strategies for different cases within <u>the second set of problems (instruction 3)</u>? If you had different strategies, for what kind of cases did you use which strategy?
Under <u>instruktion 3</u>, hade du samma strategi för samtliga problem eller använde du olika bedömningsstrategier för olika problem? Om du använde olika strategier för olika problem, vilka strategier använde du till vilka typ av problem?

(4) On a scale from 0 to 10, how confident were you that your answers at Instruction 3 were correct? (Circle answer)
På en skala mellan 0 och 10, hur säker är du att dina svar vid instruktion 3 var korrekta? (Ringa in ditt svar)

Not confident at all	0	1	2	3	4	5	6	7	8	9	10	extremely confident

Appendix H

Additional questions

Included in all three questionnaires.

INSTRUCTION

Now we have some few last questions for you.

Age: ____

Gender: male / female

Nationality: ___________________________

Field of study: _____________________________

Name of your university or school: _____________________________

Driving license: yes / no

If you have a driving license, continue the following questions:

I have my driving license for _____ years

I have obtained my driving license in Sweden: yes / no

In my driving lessons I was taught about the relation between speed and time: yes / no

If yes: what did you learn? ____

____

I drive approximately _______ km per week

I drive approximately _______ km per year

Number of speeding tickets received: _____ (if none answer 0)

Number of accidents (small and big) you were involved in: _____ (if none answer 0)

Compared to the average driver, my driving is*:
Much slower – slower – slightly slower – average – slightly faster – faster – much faster

Compared to the average driver, my driving is*:
Much riskier – riskier – slightly riskier – average – slightly safer – safer – much safer
*circle answer