

## **Impact of speed change on estimated journey time: Failure of drivers to appreciate relevance of initial speed**

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### **Abstract**

Higher speeds are associated with increases in the probability of crashing and the severity of the outcome. Logically drivers speed to save time, and research evidence supports this assertion. It is therefore important to investigate drivers' understanding of how speed change impacts on journey time. Since it is likely that drivers do not appreciate the reciprocal nature of the function which links these two variables, and its implications, two predictions can be made: the impact of a speed change will be underestimated at low speeds and overestimated at high speeds. This issue was addressed through four questions generated by manipulating Speed Change (increase vs. decrease) and Starting Speed (30

mph vs. 60 mph) with the participants being asked how they *felt* these variables would impact on journey time. These were included in a large survey addressing speed related issues. Participants were a representative quota sample of 1,005 UK drivers, interviewed by questionnaire. The findings indicated that three of the four questions produced results consistent with the predictions made. Furthermore a repeated measures factorial ANOVA indicated that there was no real appreciation of how starting speed impacted on journey time. A disordinal interaction provided evidence that drivers wrongly believed that as starting speed increased the impact of a speed rise also increased; the opposite is true. For speed decreases, drivers appeared to think that starting speed had little impact on the amount of time saved. It is recommended that these findings be integrated into driver training and speed awareness courses.

### **Keywords**

Driving speed, journey time, time estimation, reasons for speeding

### **Introduction**

Speeding is a major problem. The National Highway Traffic Safety Administration (2005) estimates that speed was a contributing factor in 31% of all road fatalities in the USA between 1996 and 2003. Mosedale and Purdy (2004) produced a similar figure of between 28 and 30% for the UK. The relationship between speed and collision outcome has been well established. As a general rule of thumb, a 1% increase in speed is approximately associated with a 2% increase in the injury crash rate, a 3% increase in the severe crash rate and a 4% increase in the fatal crash rate (Aarts and van Schagen, 2006). It follows therefore that that higher speeds are not just associated with an increase in crash probability but also

an increase in crash severity. Four groups of states in the US which adopted higher interstate speed limits during 1995-96 (ranging from 5 to 15 mph) found the expected increase in average speeds but also an increase of about 17% in crashes which were fatal (Farmer et al., 1999).

When a crash occurs, its severity depends on the change in speed of the vehicle at impact. Outcome is directly related to the kinetic energy released, where kinetic energy is a function of vehicle mass and velocity squared ( $E_k = \frac{1}{2} mv^2$ ). Because kinetic energy is determined in part by the square of a vehicle's speed, rather than by speed alone, the probability of injury and the severity of injury increase exponentially with vehicle speed (Federal Highway Administration, 1998). For car occupants in crashes with an impact speed of 50 mph (80 km/h), the likelihood of death is about 20 times that for an impact speed of 20 mph (32 km/h), given the increases in kinetic energy and the contribution of other factors. For pedestrian victims, although there are differences of opinion in different jurisdictions (Thomas et al., 2005), it is estimated that 5% of those struck by a vehicle travelling at 20 mph (32 km/h) die, at 30 mph (48 km/h) 45% die and at 40 mph (64 km/h) 85% die (ETSC, 1995). Thus, since the consequences of high speed are so severe, understanding the conditions for inappropriate high speed is a particularly compelling issue.

Before any attempt is made to alter speeding behaviour it is important to appreciate its antecedents. A popular research approach adopted to address this issue is the identification of epidemiological and psychological factors that predict speeding behaviour. For example it would appear logical that one of the motivations for speeding would be to effect a

reduction in journey time. If this is found to be the case then it is important to investigate drivers' appreciation of how a *change* in speed influences journey time. If drivers feel more time is saved by speeding it is logical to conclude that such an error could be directly contributing to road fatalities.

The evidence for a link between speed choice and the desire to save time comes largely from questionnaire-based research. Gabany et al. (1997) developed a speed perception inventory and found through factor analysis that time pressure was one of five constructs identified as contributing to speed behaviour, the other four being Ego-gratification, Risk-taking, Disdain of driving, and Inattention. The validity of this finding is supported by McKenna (2004) who found that a considerable proportion of a sample of 440 drivers caught speeding indicated through questionnaire items that time pressure had played some role in their speed choice. In a subsequent study of 9,470 speeders (McKenna, 2005), 33% indicated that time pressure at the time of their speeding offence was 'quite' to 'very' important and those who had broken the limit by a large margin reported more time pressure.

Again using questionnaires, Adams-Guppy and Guppy (1995) sampled 572 British company car drivers and found that around 20% agreed with the statement that it was important to be punctual for appointments, even if it meant breaking the speed limit. This variable accounted for 13% of the variance in reported speeding behaviour. Stradling et al. (2003), Campbell and Stradling (2003), and Stradling et al. (2004) found, on the basis of in-home interviews of quota samples of drivers in Scotland, that the most prevalent reason

given for driving faster than usual was ‘when late for a meeting or appointment’ (52-58%).

Additional support also comes from simulator studies and the invoking of scenarios.

Oliveras et al. (2002) instructed participants in a simulator to either drive as they normally would or under time pressure. They found that those instructed to drive under time pressure felt more activation, more aroused and more stress – and drove faster.

The function which describes how speed change impacts on journey time has various forms (e.g. Svenson, 1970) and can be represented by Equation 1:

$$|T| = D (1/V_l - 1/V_h) \text{ [Equation 1]}$$

where  $T$  is the magnitude of the time difference produced,  $D$  is the distance travelled,  $V_l$  is the lower of the two speeds and  $V_h$  the higher. Two important implications follow from this relationship. Firstly, when changing between two specific speeds, speeding up produces the same magnitude of time change as slowing down. Secondly, and most importantly, since velocity impacts on time difference through its reciprocal, the greater the speeds involved the less an impact there will be on time gained or lost. Since it is possible that drivers do not appreciate the reciprocal nature of this relationship two predictions can be made.

Firstly, at low speeds drivers will underestimate the impact of a speed change leading them to conclude that time gained or lost will be less than it actually is. Secondly, at high speeds drivers will overestimate the impact of a speed change leading them to conclude that time gained or lost will be greater than it actually is. These questions have been indirectly addressed by Svenson (1970, 1973).

In his first study participants were asked a series of questions about how much time they would save by increasing their speed while travelling a fixed distance. Three independent variables were manipulated: starting speed, the magnitude of the speed increase and the fixed distance travelled. Across 2 experiments there were respectively 54 and 60 different experimental trials (produced by different combinations of the IVs). Each trial was presented on a projected slide that automatically changed every 10s. This short time period prevented participants from trying to calculate the true mathematical answer. Results showed that for the short distance (13km) there was an underestimate of the time saved when the initial speed was low (33.6 cm/s) while there was an overestimate of time saved when the initial speed was high (47.1 cm/s), thus supporting the two predictions made above. For the other distances studied (53, 84 and 210 km) there was a consistent underestimation of the time saved which increased with initial speed.

In his second study (1973), Svenson opined that more accurate journey time judgments might be made if a physical object was manipulated, since this would produce physical cues for velocity and distance thus generating a scenario that bore greater similarity to actual driving. In this study participants were instructed to alter the speed of a model train across a fixed distance, to either increase or decrease the journey time by 10 seconds. A second variable of starting speed (slow vs. high) was also manipulated producing a repeated measures factorial design. The results are summarised in Figure 1<sup>1</sup> which depicts the mean result for each manipulation.

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<sup>1</sup> These data were originally presented in tabular format in Svenson (1973) but they have been graphically reproduced here for ease of interpretation.

Insert Figure 1 about here

Consistent with prediction one above, when travelling at an initial slow speed the impact of a speed change was underestimated. For the high initial speed, only one of the results was consistent with prediction two above. When attempting to decrease journey time there was the expected overestimate of the impact of a speed change such that the journey time was reduced by an amount smaller than the instruction of 10s. However when the participants were instructed to increase journey time the expected overestimate of the impact of speed change did not occur with the estimate being just slightly above 10s (instead of below 10s).

Although both of these studies provide some support for the predictions one and two they are not without their difficulties. In the 1970 study both predictions were not realised across the distances 53, 84 and 210 Km. It is possible that these judgements bear no resemblance to decisions that drivers usually make. It is unlikely that drivers complete journeys of such distances while being able to maintain a constant speed. Therefore the additional aspect of distance that came into these estimates possibly undermined the theoretical process that might lead to the fulfilment of predictions one and two. In the 1973 study there was an attempt to increase ecological validity and this may have helped in producing results that lent greater support to predictions one and two. However the instruction to increase or decrease a journey by a set amount may not reflect the experience of drivers who may just be trying to get somewhere more quickly. In addition it may be difficult to extrapolate from the small distances involved, approximately 36.7m, to the various journeys that drivers engage in, as well as from the unusual nature of the model train control task. Finally, the

sheer number of trial repeats (50 and 64 in Study 1 and 16 in Study 2) would have produced a level of practice that drivers would never experience in their vehicles.

The aim of the current research was to establish whether drivers appreciate the impact of initial speed and speed change (increase or decrease) on the amount of time gained or lost by either speeding up or slowing down. It should be emphasised that this research was not interested in having the participants engage in mental arithmetic but rather they were asked to indicate how they *felt* the different scenarios might impact on journey time. Consistent with the argument presented above it was predicted that at low speeds the impact of speed change will be underestimated while at higher speeds the impact of a speed change will be underestimated. If it were demonstrated that the impact of initial speed is not properly understood then drivers may be speeding for fallacious reasons. Counteracting such false reasoning could lead to a reduction in speeding behaviour with an obvious knock-on effect on collision frequency and severity. To address the issues relating to the ecological validity raised above the current research used simple road based scenarios that involved initial speeds, speed changes and a journey distance that drivers are likely to experience on a regular basis.

## **METHOD**

### **Participants**

A representative quota sample of 1,005 drivers from across the United Kingdom who were eligible to participate because they drove more than once a year were interviewed by Ipsos MORI. All interviewing was conducted face-to-face in respondents' homes and took place between the 17th June 2006 and the 14th August 2006. To increase the validity of the data



that were subsequently analysed, a subset of participants were selected on the basis that they exceeded minimum requirements in terms of self-reported driving experience: held a current driving license, had driven 500 miles or more in the previous 12 months, drove more often than ‘a few times a year’, and had driven more often than ‘rarely’ within the previous 3 months. Eight hundred and eighty three participants made it in to the final subset. Fifty four percent of them were male and they had an average age of 50 (SD = 16.0). About half (51%) were from socio-economic groups C1 (Lower Middle Class) and C2 (Skilled Working Class). Fifty percent were in full-time work and of these, 19% drove for a living (i.e. almost 10% of the subset).

### **Materials**

The questionnaire administered dealt with issues broadly concerned with driver behaviour, attitudes, values and experiences with regard to general speed choice and speed violation . In addition to these items there were 4 specific questions relating to estimates of time changes produced through speed changes. It is worth stressing that the interviewers were instructed that it was “important to get people’s initial impression” and to ask for a “quick answer, not a calculation” (see Appendix 1 for full text of instructions and questions used). These instructions were an attempt to encourage participants not to try to calculate the correct answer but rather to engage in a process that potentially mirrors the non-effortful process that is likely to be used in everyday driving when trying to determine the impact of a speed change.”

## Results

Participants were given two sets of questions relating to the impact a speed change would have on time saved or lost when travelling a fixed distance. The first set of questions involved an increase in speed of 10 mph and participants were asked about how much time they *felt* they would gain as a result of this speed increase when travelling a distance of 10 miles. Starting speeds were 60 mph and 30 mph. Figure 2a shows that the scenario with the higher starting speed of 60 mph produced an estimate of time saved that was 346s more than the actual time gain of 86s, an overestimate of almost 6 minutes. In contrast the lower starting speed of 30 mph produced an estimate that was only 58s above the actual time gain of 300s.

Insert Figure 2 about here

### Estimate

The second set of questions involved a decrease in speed of 10 mph and participants were asked about how much time they *felt* they would lose as a result of this speed decrease when travelling a distance of 10 miles. Again, starting speeds were 60 mph and 30 mph. Figure 2b shows that the scenario with the higher starting speed of 60 mph produced an estimate of time lost which was 295s (an overestimate of almost 5 minutes) above the actual time lost of 120s. In contrast the lower starting speed of 30 mph produced an estimate that was 167s below the actual time lost of 600s.

These data were analysed using a 2 x 2 repeated measures Factorial ANOVA. The first variable was Speed Change (increase vs. decrease) while the second was Starting Speed (30

mph vs. 60 mph). There was a main effect of Speed Change in that the mean estimated time change for a speed increase (397s,  $SD=344$ ) was lower than that for a speed decrease (419s,  $SD=322$ );  $F(1,698) = 6.05, p < .05, \eta_p^2 = .009$ . This effect was in the correct direction in that in the examples given to participants actual time saved for the stated speed increase is 193s compared to 360s lost with the speed decrease<sup>2</sup>. There was also a main effect of Starting Speed in that the estimated time change for the higher starting speed of 60 mph (424s,  $SD=349$ ) was higher than that for the lower starting speed of 30 mph (394s,  $SD=317$ );  $F(1,698) = 21.08, p < .001, \eta_p^2 = .029$ . This is in direct contrast to the real time change, which would have occurred in the examples, which was on average 103s for the higher starting speed of 60 mph and 450s for the lower starting speed of 30 mph. But perhaps the most important effect was a disordinal interaction between the two variables,  $F(1,698) = 75.22, p < .001, \eta_p^2 = .097$ . As can be seen from Figure 2 this is produced by the fact that for the speed increase questions (Figure 2a) the higher initial speed produces a greater estimate of time saved,  $t(698)=8.79, p < .001, \eta_p^2 = .095$ . This is in direct contrast to the actual time saved which is larger for the speed change with the lower starting speed. On the other hand, for the speed decrease questions (Figure 2b), the higher starting speed produces a lower estimate of time lost,  $t(698)=2.16, p < .05, \eta_p^2 = .008$ . Although the difference is small relative to the actual difference, it is nevertheless in the correct direction.

Although not relevant to the aims of this research the above analysis could be repeated to include the variables Age and Gender producing a 3 x 2 x 2 x 2 Mixed Factorial model.

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<sup>2</sup> In this instance a speed decrease produces a greater time change because of the lower speeds involved. If the two speeds involved in both the increase and decrease were the same, then there would be no difference in the magnitude of time lost or gained.

Age could have say three levels (16-34 vs 35-55 vs 55+) and obviously Gender would have two. When such an analysis is conducted the variable Age was involved in no significant interactions while Gender produced a significant two way interaction with Speed Change and Starting Speed;  $F(1,697)=5.05$ ,  $p<.05$ ,  $\eta_p^2= .007$ . However since the effect size is so small this result is practically meaningless.

## **Discussion**

These data provide support for the two predictions made in the introduction. Figure 2b shows that for the questions relating to a speed decrease, there was an overestimation of the impact of speed change for the higher speed (estimated time lost was much greater than the actual time lost) and an underestimation of the impact of speed change for the lower speed (estimated time lost was lower than the actual time lost). For the questions relating to a speed increase there was only partial support. Figure 2a shows that there was an overestimation of the impact of a speed change at the higher speed but that the predicted underestimation of the impact of the speed change at the lower speed did not materialise. This may be explained if a further corollary of the first two predictions is accepted. If there is an overestimation of the impact of a speed change at higher speeds and an underestimation at lower speeds, there must be a speed where the estimations are close to being accurate. Given that the time estimate for the 30 – 40 mph question was only out by 58s (6% of the total journey time of 15 minutes) then it is quite possible that the 30 – 40 mph range is close to such a speed. Add to this the fact that 30 mph is the speed limit for in-town driving in the UK (where the data were collected) it becomes quite conceivable that the 30 – 40 band could be seen as a range of speeds which is neither relatively low or high and therefore the initial predictions would not apply.

The repeated measures factorial ANOVA also provided important insights. The disordinal interaction would suggest that the participants responded as if the function linking starting speed to a speed increase was different to the one linking starting speed to a speed decrease. However given the very low effect sizes one should be cautious about such an interpretation. In the case of speed decreases the effect size was .008, and given that Cohen (1988) suggests that .1 constitutes a small effect size the effect here is practically meaningless. The implication is that when it comes to speed decreases the participants had little or no appreciation of how starting speed affected the amount of time lost. When it comes to speed increases the effect size is larger, approaching .1, but still small according to Cohen's convention. Here the implication is that drivers think that as initial speed increases so the impact of a speed increase also increases. Given that this effect is in the wrong direction this is an important finding and may have implications for driver training. Drivers need to be clearly informed that as starting speed increases there is a decrease in the time saved by any speed increase.

There are a few limitations to the current work. Firstly, It could be argued that individuals with a greater mathematical sophistication e.g. engineers, would not commit the errors highlighted by this research since they would appreciate the ramifications of the reciprocal function in question. In the current research no account was taken of underlying mathematical ability and it remains a possibility that such ability is a confounding factor. However since the participants were asked about how they *felt* the different scenarios would impact on time gained or lost it is unlikely that any form of calculation was entered

into and therefore mathematical sophistication is unlikely to impact on the responses made. Nevertheless this remains an interesting empirical issue to be addressed by future research. Secondly, it is not clear whether the type of 'estimation' entered into by the participants in this research matches the processes that drivers typically engage in when they decide to speed. However it is unlikely that drivers engage actively in a calculation to try and estimate how much time they might save by speeding and therefore the processes engaged in by the participants here are likely to be similar to those used by drivers in everyday driving. Thirdly, the attempt here to elucidate the Participants understanding of how starting speed impacts on the amount of time saved (for speed increases) or lost (for speed decreases) was based on only four scenarios. A fuller understanding of how drivers think about the impact of changes in their speed on journey time will arise from future research using a greater range of starting speeds, speed changes and distances travelled.

There are at least a few instances where there have been attempts to point out the limited benefits of speeding. The NHTSA produced a brochure (*Speeding : Minimal Gains and Big Potential Losses*, 1996) in which there was a table quoting the small amount of time saved while travelling at different speeds. In addition (Fylan et al., 2006, p.72) indicate that some United Kingdom speed awareness courses try to challenge the belief that speeding saves a significant amount of time. However this message needs to be made clearer and the different impact depending on starting speed needs to be emphasized, particularly the low impact of a speed increase when starting speed is already high. The way in which this information should be communicated is however not clear. Svenson (1970) found no significant difference between the time gain estimates of participants who were given a full

mathematical explanation of the effects of speed change on time saved or lost versus participants who were given no instruction. Thus, to have the desired impact, this important information needs to be communicated in as simple a fashion as possible. It would be important to replicate these findings using more scenarios and different research methodologies such as driving simulators and real journeys. However to retain ecological validity the high number of trials used by Svenson (1970, 1973) should be avoided. If speeding is indeed motivated at least in some instances by the desire to save time it is imperative that faulty overestimates of the impact of increased speed is addressed in drivers' minds. If this motivation to speed were removed it could have a significant knock-on effect on the number and severity of collisions.

**Acknowledgement**

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## Appendix 1

### Instructions for interviewers reproduced on each questionnaire

“The following are questions asking people how much time they think journeys Would take. It is important to get people’s initial impressions of time so ask them for a quick answer, not a calculation”

### Text read to each participants before the series of questions

“We are interested in how much time drivers feel they gain if they go faster or feel they lose if they have to go more slowly. In the next four questions, we don’t want you to calculate an answer – just say how much time you feel you would gain or lose.” (Emphasis as presented on original questionnaire).

### Questions asked

- Q39 You are driving along an open road. How much time do you feel you would gain if you drove for 10 miles at 40mph instead of 30 mph?
- Q40 You are driving along an open road. How much time do you feel you would gain if you drove for 10 miles at 70mph instead of 60 mph?
- Q41 You are driving along an open road. How much time do you feel you would lose if you drove for 10 miles at 20mph instead of 30mph?
- Q42 You are driving along an open road. How much time do you feel you would lose if you drove for 10 miles at 50mph instead of 60mph?



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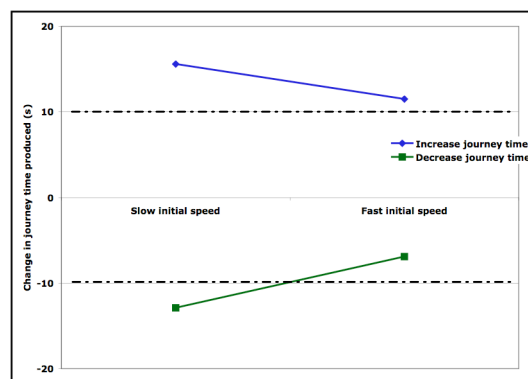
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**Captions**

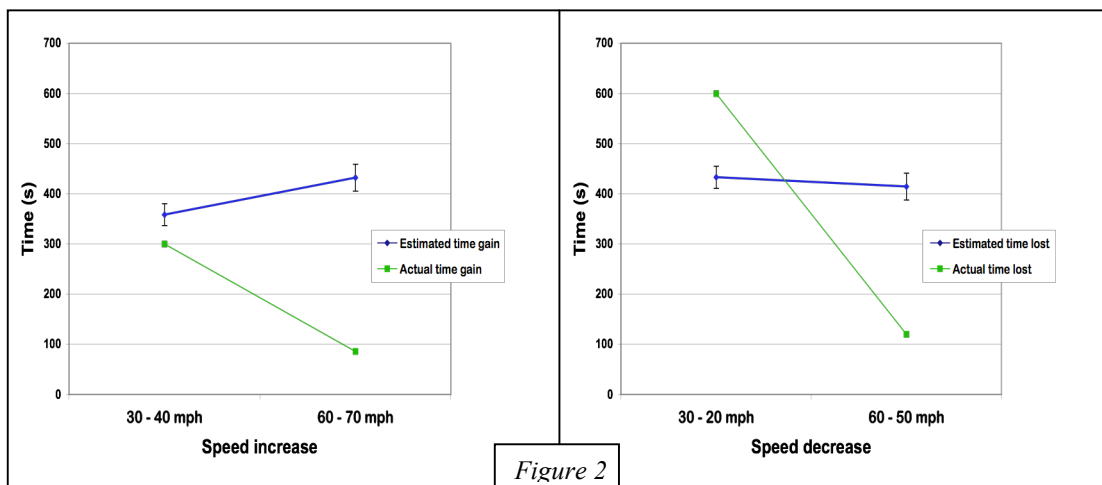
- Figure 1 Change in journey time according to starting speed and instruction to either increase or decrease journey time by 10 seconds
- Figure 2a Estimated and actual time saved when speed is increased by 10 mph
- Figure 2b Estimated and actual time lost when speed is decreased by 10 mph

**Figures**

*Figure 1*



*Figure 2*



*Figure 2*