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Title: The effect of speed limit credibility on drivers' speed choice

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Abstract

Credibility of speed limits is a key factor affecting drivers' compliance with speed limits. Two experiments were conducted to investigate how credibility of speed limits affects judgments of appropriate speed. The first experiment aimed to establish speeds deemed appropriate by investigating Malaysians drivers' judgments of the appropriate speed to drive based on photographs of roads with the speed limit sign erased. Drivers chose speeds which correlated with but were higher than the actual speed limits of the roads. Analysis of road characteristics suggested they based their decisions mainly on features of the road itself rather than of the roadside. The second experiment tested the impact of credibility of speed limit information on the speed drivers judged appropriate. Drivers judged the appropriate speed to drive for the same photographs as in Experiment 1 with speed limit information provided. Four conditions were included: two conditions where the speed limit posted was 10% higher or 10% lower than the appropriate speed established in Experiment 1 (credible speed limits), and two conditions where the posted speed limit was 50% higher or 50% lower than the appropriate speed (non-credible speed limits). Posted speed limits did affect drivers' judgments about the appropriate speed to drive. Credibility also influenced judgments whereby drivers selected appropriate speeds consistent with the speed limits for the 10% lower condition, but not for speed limits that deviated highly from the appropriate speed judged in Experiment 1.

Keywords appropriate speed, credibility, judgment, Malaysian, drivers

1. Introduction

Speed is one of the most important factors which affect the safety of a driver (Elliot et al., 2005; Master, 1998; Nilsson, 2004). A number of studies have shown that increases in speed lead to increases in crash rates and crash severity. For example, Maycock et al. (1999) and Quimby et al. (1999) measured the traveling speed of vehicles on roads in the UK; Kloeden et al. (1997) used a case-control method to investigate the crash rate of 60km/h roads in Australia; and Kloeden et al. (2001) investigated the crash rate of 80km/h and 120km/h roads in Australia, all finding that increases in speed lead to increases in crash rates and severity. It has also been found that increasing one's speed decreases the available time to react to sudden changes on roads; it reduces manoeuvrability and the stopping distance is larger (Aarts & van Schagen, 2006).

Speed limits are regarded as a crucial part of effective speed management as they should prescribe speeds that are safe for drivers under typical conditions. It has been found that drivers whose speed deviates to a large extent from the speed limit set are most likely to be involved in accidents. Solomon (1964) investigated relationships between vehicle speed and collision rates on main rural highways in the USA using a case-control method. Vehicles that were moving 10km/h faster than the modus speed had the lowest collision rate and vehicles that were moving much slower or much faster than the modus speed were more likely to be involved in accidents. A recent review also showed that greater speed dispersion is associated with increased crash rate (Aarts & van Schagen, 2006). These findings suggest that some degree of compliance with speed limits is important to maximise safety, yet studies typically indicate that speed limits are not the sole factor which affects speed choice.

Perceptions of a safe speed to travel are affected by the environment, the geometry of the road, weather conditions and adjoining land use (Wilmot & Khanal, 1999). Travelling

speed choice was found to increase with wider roads, roads without curves, roads with a smooth surface, with the presence of road markings (Elliott et al., 2003; Martens et al., 1997) and with fewer buildings, trees and vegetation along the roads (Elliott et al., 2003). It has been suggested that the credibility of the speed limit also affects drivers' speed choice (OECD/ECMT, 2006; van Schagen et al., 2004). Goldenbeld and van Schagen (2007) argued that it is generally assumed people will comply with speed limits if they regard them as being reasonable or "credible". Conversely, if the limit is not consistent with what they deem to be reasonable based on the road characteristics, then they may well ignore that limit. Goldenbeld and van Schagen (2007) further speculated that if the speed limits in a system appear consistently unreasonable, road users may question the utility of and perhaps disregard the entire system. In support of this suggestion, they cited survey findings which suggest that drivers tend to rely on their own judgments of appropriate speed rather than the speed limit shown when driving past construction (Gardner & Rockwell, 1983). In agreement with this, Kanellaidis et al. (1995) asked drivers why they violate speed limits and their most frequently reported answer was that they do not regard the speed limits as being reliable.

While survey studies indicate that people cite credibility as a key reason for compliance with speed limits, few studies have aimed to directly assess the impact of speed limit credibility on speed judgments. Goldenbeld and van Schagen (2007) investigated whether different characteristics of the road affect judgments of the credibility of 80km/h rural roads in the Netherlands. Different photographs of 80km/h speed limit rural roads were shown to Dutch road users and they were required to judge their preferred speed and the safe speed limit of those roads. The credibility of the speed limit was operationalised as the difference between the actual speed limit (which was always 80km/h) and the participants' preferred speed and perceived safe limit. It was found that drivers preferred to drive at about 8km/h faster than the actual speed limit while they judged the safe speed to be 4km/h higher

than the actual speed limit. It was also found that a number of different environmental features affect drivers' judgments. Preferred speed was decreased with the presence of a curve, a short sight distance, presence of buildings along the side of the road and when there was little view to the right; whereas the absence of trees on the right hand side of the road increased perceived safe limit but not preferred speed (Goldenbeld & van Schagen 2007). Van Nes, Houtenbos, and Van Schagen (2008) found that participants selected lower speeds and engaged in less speeding for road sections with highly credible speed limits compared to road sections with less credible speed limits. Similarly, Van Nes, Brandenburg and Twisk (2010) reported that simulator participants drove at speeds closer to those which had previously been rated as reasonable for the roads, than those which had not.

In the current study, we aimed to investigate how modifying the credibility of the speed limit of roads influences drivers' judgments of an appropriate speed to drive. The term 'appropriate speed' was used in both studies we report here because we aimed to elicit drivers' genuine views on a suitable speed for the road, rather than for them to try and guess the speed limit, and it has previously been suggested that this particular term emphasises the importance of participants using judgment based on their own criteria (Nunes & Recarte, 2005). In the first experiment, we aimed to establish the speed at which drivers judged it was appropriate to drive by viewing photographs of roads. This was done in order to establish a baseline for manipulations of speed limit information in the second experiment. Consistent with previous studies (e.g. Fleiter & Watson, 2006; Goldenbeld & van Schagen, 2007), we predicted that the drivers would deem a speed appropriate as higher than the actual speed limits of the roads. In the second experiment, for each of the roads shown in the first experiment speed limit credibility was either manipulated to be low or high. The low credibility was generated by a large discrepancy between the posted speed limit and the mean appropriate speed judged in Experiment 1; the high credibility was generated by a small

discrepancy between the posted speed limit and the mean appropriate speed judged in Experiment 1. New groups of drivers were again asked to judge the appropriate speed to drive on the roads. If assumptions about credibility are correct, we would expect to see judgments that are consistent with the displayed speed limit in road scenes where the speed limit was close to the previously identified appropriate speed (i.e. the speed limit appears credible) but not when the limit displayed was a much lower or much higher speed (i.e. the speed limit shown is not credible). Furthermore, in conditions where there is a large disparity between the appropriate speed and the speed limit posted, drivers may disregard speed limit information entirely in making their judgments and make judgments that are very similar to those made in Experiment 1.

2. Experiment 1:

2.1 Methods

2.1.1 Participants

Twenty-nine Malaysian drivers were recruited (19 female and 10 males). Their mean age was 21.21 years old (S.D. = 3.11) ranging from 17 to 31 years old and they had a mean of 2.74 years (S.D. = 1.93; ranging from 0.17 to 6 years) of active driving experience since getting their provisional driving license in Malaysia. All reported normal or corrected-to-normal vision.

2.1.2 Design

A within-participants design was used whereby all participants were presented with all stimuli.

2.1.3 Stimuli

A Panasonic SDC-900 video camera was mounted on the windscreen of a car using a Manfrotto Suction Pump mount. Videos were recorded from a driver's point of view while

driving on a variety of highways around Malaysia. Thirty-five images of roads where the speed limit sign was clearly visible were extracted from the videos to be used in the experiment. These pictures contained a range of speed limits, including 40km/h (5 images), 50km/h (4 images), 60km/h (6 images), 70km/h (5 images), 80km/h (5 images), 90km/h (5 images), 110km/h (5 images). The speed limit which was written on the sign was erased using Paint software. Pictures were presented with the resolution of 800x450 pixels. Figure 1 shows examples of the photograph stimuli.

Figure 1. Examples of road images with actual speed limits erased on the signs. Actual speed limits as follows: (a) 40km/h; (b) 50km/h; (c) 60km/h; (d) 70km/h; (e) 80km/h; (f) 90km/h and (g) 110km/h.

2.1.4 Procedure

The 35 images were presented in random sequence using E-prime software. Participants were required to judge the appropriate speed to drive on each road. Images were presented for an unlimited time and participants could use the time they wanted to key in the appropriate speed in the unit of km per hour. A fixation point '+' appeared in the middle of the screen between trials for 500ms. Participants were required to complete five practice trials before the 35 experimental trials in order to familiarise with the task. They were seated approximately 70cm from the screen with visual angle of approximately 28 x 21 degrees.

2.2 Results

A paired-samples t-test was carried out in order to compare the mean speed limit of the roads with the mean judged appropriate speed. This revealed that overall, the judged appropriate speeds (83.04km/h) were significantly higher than the actual speed limits (71.71km/h) of the roads, $t(35) = 3.24$, $p < .005$. Next we aimed to see whether there was any relationship between the actual speed limit and the judged appropriate speed. There was a significant positive correlation between the actual speed limit of the roads and the judged appropriate speed, $r(35) = 0.45$, $p < .01$, displayed in Figure 2.

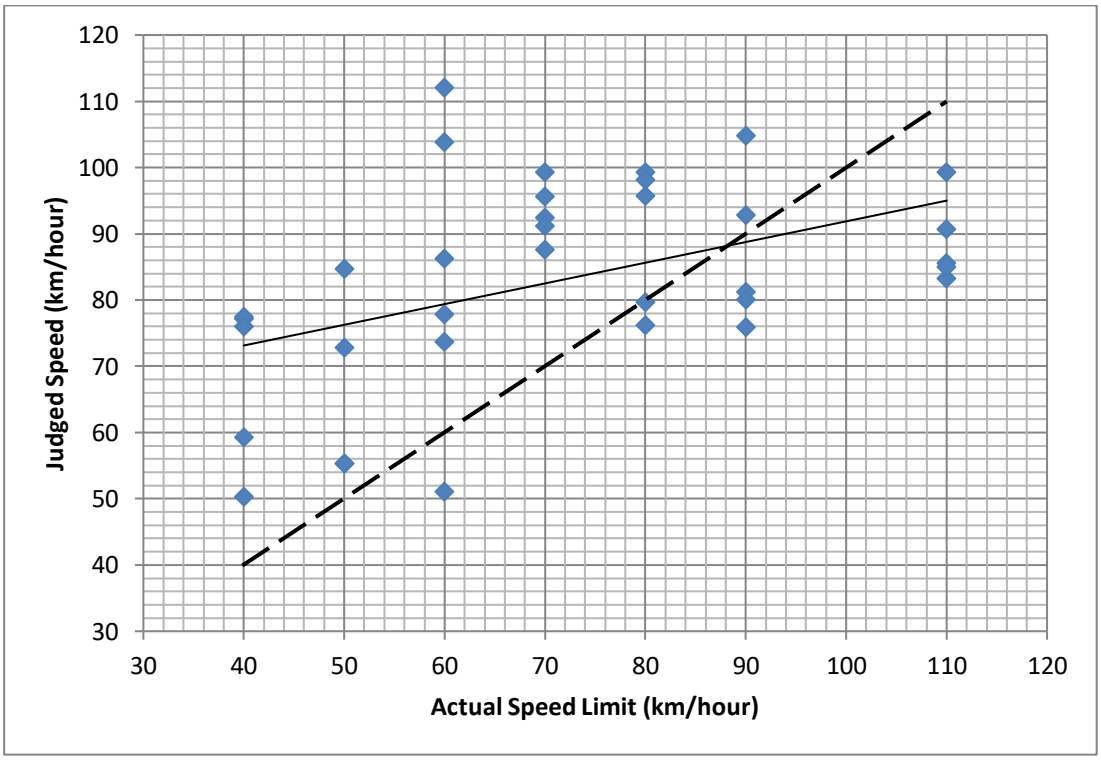

Figure. 2 Actual Speed Limit vs Judged Appropriate Speed in km/h (individual points represent each road). The dotted line indicates the actual speed limit of each road.

Seven one-sample t-tests were carried out in order to compare the actual speed limit of the roads with the judged appropriate speed for each speed limit category, with a Bonferroni corrected alpha level of .007. This revealed that the judged appropriate speed was significantly higher than the actual speed limit of the roads, for 40 km/h roads, $t(28) = 10.52$, $p < .001$; 50km/h roads, $t(28) = 5.81$, $p < .001$; 60km/h roads, $t(28) = 4.91$, $p < .001$; 70km/h roads, $t(28) = 10.50$, $p < .001$; and 80km/h roads, $t(28) = 3.64$, $p = .001$. Judged appropriate speed (86.93km/h) was not significantly different as compared to the actual speed limits of the 90 km/h roads, $t(28) = 1.52$, $p > .05$. Judged appropriate speed (88.76km/h) was significantly lower than the actual speed limits of the 110 km/h roads, $t(28) = 8.43$, $p < .001$.

The mean judged appropriate speed for each participant across the 35 images was calculated in order to identify whether there were individual differences in the judgments made by the participants. The lowest mean judged appropriate speed was found to be 58km/h, whereas the highest mean judged appropriate speed was 103.14km/h. Further analyses were conducted to investigate whether male and female drivers and drivers with varying levels of experience differed in mean judgments. An independent samples t-test revealed that there was no difference between the judgments of male (82.92km/h) and female participants (76.72km/h), $t(27) = .07$, $p > .05$. Also, there was no significant correlation between driver experience in years and mean judged appropriate speed $r(27) = .22$, $p > .05$.

Besides the association between the actual speed and judged speed, we also investigated the association between individual road characteristics and drivers' judged speed. The 35 images were coded independently by five judges on 16 road characteristics, the first 14 of which were taken from Goldenbeld & van Schagen (2007). The 16 road

226 characteristics include (1) Presence of a curve: yes/no; (2) Road width: average/wider than
227 average; (3) Sight distance: average/more than average; (4) Clarity of situation: average/more
228 than average; (5) View to the right: little/average/large; (6) View to the left:
229 little/average/large; (7) Presence of buildings alongside the road: none/few; (8) Presence of
230 lighting poles: yes/no; (9) Presence of trees at the right: yes/no; (10) Presence of trees at the
231 left: yes/no; (11) Presence of vegetation at the right: yes/no; (12) Presence of vegetation at
232 the left: yes/no; (13) Presence of traffic on same carriageway: yes/no; (14) Presence of traffic
233 on opposite carriageway: yes/no; (15) Presence of intersections (junctions, exits, emerging
234 lane): yes/no; (16) Number of lanes. Presence of intersections and number of lanes were
235 added for this study because they are other features that have previously been suggested to
236 affect speed choice (e.g. Edquist, Rudin-Brown & Lenne, 2009; Elliot et al., 2003).

237 Paired-samples t-tests and one-way ANOVAs (for variables with more than two
238 levels) along with Bonferroni post hoc tests were carried out to compare drivers' judged
239 speeds on each characteristic. Results are shown in Table 1.

240 Table 1. Mean appropriate speeds and associated inferential tests for judged speed according
241 to road characteristics; significant results in bold ($p < .05$).

Road Characteristics	Mean appropriate speed (km/h)	Appropriate speed		
		d.f.	F/ t	p
Road width	Ave, 80.41; >ave, 84.94	**28**	**2.31**	**0.028**
Presence curve	Yes, 80.17; no, 85.90	**28**	**3.27**	**0.003**
Sight distance	Ave, 78.03; >ave, 90.72	**28**	**6.12**	**<0.001**
Clarity of situation	Ave, 88.46; >ave, 79.09	**28**	**5.30**	**<0.001**
View to the right	<Ave, 86.12; ave, 81.09; >ave, 83.63	2,56	2.86	0.066
View to the left	<Ave, 77.35; ave, 83.86; >ave, 97.79	**2,56**	**44.77**	**<0.001***
Buildings alongside the road	Yes, 83.01; no, 83.39	28	0.15	0.885
Presence of lighting poles	Yes, 82.02; no, 94.71	**28**	**6.83**	**<0.001**
Presence trees right	Yes, 83.03; no, 83.58	28	0.38	0.706
Presence trees left	Yes, 82.66; no, 86.86	28	0.69	0.496
Presence vegetation right	Yes, 83.46; no, 82.95	28	0.26	0.795

Presence vegetation left	Yes, 84.61; no, 82.45	28	1.11	0.276
Traffic same carriageway	Yes, 84.02; no, 82.26	28	0.81	0.425
Traffic opposite carriageway	Yes, 85.03; no, 81.86	28	1.91	0.066
Presence of intersections	Yes, 74.96; no, 85.89	**28**	**7.39**	**<0.001**
Number of lanes	One, 63.25; two, 80.98; three, 88.69; four, 82.06; five, 87.59	**4,112**	**15.90**	**<0.001***

* Bonferroni Post Hoc for view to the left revealed differences between all three pairs. Bonferroni Post Hoc for number of lanes revealed differences between one lane compared to all others; and between three lanes and four.

2.3 Discussion

The purpose of this experiment was to determine the mean judged appropriate speed for each road photograph as a basis for the manipulations carried out in Experiment 2. However, general analyses conducted on participants' responses produced a few results for comment. There was a moderate positive correlation between the actual speed limit of the roads and the appropriate speed to drive that was judged by drivers. Apparently, the photographs provided sufficient visual information about road and environmental features to enable drivers to make appropriate speed judgments that systematically varied with actual speed limits.

To identify which environmental features participants used as a basis for their judgments, a series of analyses was conducted to investigate how these characteristics affected drivers' judged speed. Results suggest that drivers are more affected by the characteristics of the road (such as road width, presence of curve, sight distance, clarity of situation, presence of lighting poles, presence of intersections and number of lanes), than features of the road side (such as buildings alongside the road, presence of trees and vegetation on the right and left). This may be because the features of the road have a more direct impact on driver safety, although it could also be due to the road side features in the pictures being relatively uniform, limiting the impact on drivers' judged speed. As we did not

match the stimuli for variability in road versus road side characteristics it could be that the greater impact of features of the road is a consequence of the particular stimuli chosen. Traffic on the same and opposite carriageway did not affect drivers' judgments about the appropriate speed, which concurs with the findings of Goldenbeld and van Schagen (2007). Perhaps this is because drivers consider the state of traffic situation as temporary and therefore not relevant to general judgments about appropriate speed to drive. Although we asked drivers about the appropriate speed to drive instead of their preferred speed or safe speed as was done in Goldenbeld and van Schagen (2007), overall the effects of road(side) characteristics on drivers' judged speed are very similar. Unlike Goldenbeld and van Schagen (2007), the current study did not find an effect of the 'view to the right' and instead found an effect of 'view to the left', but this is presumably due to the differing traffic systems: in Malaysia there is left hand traffic as compared to right hand traffic in the Netherlands. Future studies could use eye tracking to investigate what information drivers focus on while making judgments.

The judged appropriate speed tended to be higher than the actual speed limit of the roads, a finding which is consistent with previous research which suggests people prefer speeds faster than the actual speed limit of roads when in ignorance of the actual speed limit (e.g. Fleiter & Watson, 2006; Goldenbeld & van Schagen, 2007). This did not prove to be the case for the roads with the highest actual speed limits, for which participants either selected a speed similar to or lower than the actual speed limit of the road. This suggests that drivers saw the appropriate speeds as forming a narrower range than the actual speed limits of the roads, with the majority of their judgments having a mean falling in the 70-100 km/hr range. One possible explanation for this is that the photographs made the roads look more uniform than the actual roads do in real life, leading participants to choose a narrower range

of speeds. Another possibility is that drivers genuinely do believe that speeds within a certain range are preferable for driving and hence claim speeds as appropriate within that range.

Males and females did not differ in their judgments of appropriate speed. This finding is consistent with earlier findings of Stradling et al. (2003) and Goldenbeld and van Schagen (2007) who found no gender differences in preferred speed to drive, although it should be noted that those studies asked for one's own preferred speed rather than general views on appropriateness. Other studies have reported that males do drive faster than females (SIRC, 2004; McKenna et al., 1998) although gender differences in preferred speed may have decreased over time (Stradling et al., 2003). Goldenbeld and van Schagen (2007) argued that in their study quiet roads with fewer vulnerable road users were shown and this reduced females' safety perspective. A similar explanation could perhaps be applied in our study where all of the photographs were taken on highways.

There was also no correlation between driver experience and judged appropriate speed, at least with drivers in this sample, who had a range of less than one year to six years of driving experience. The results suggest that drivers of the varying levels of experience considered in this study utilise similar cues to inform their decisions on how fast it is appropriate to drive. Nevertheless, the drivers' age range in the current study was much narrower than in Goldenbeld and van Schagen (2007) who found that preferred speed decreased with age (and presumably experience). Therefore, we may have found effects of experience if a wider age range had been considered.

3. Experiment 2:

The previous experiment established what judgments drivers made about appropriate speeds to drive when they were not given any speed limit information. This experiment aimed to investigate how the credibility of speed limit information affects judgments about the appropriate speed to drive. The same photographs from Experiment 1 were presented to

new groups of drivers, this time with speed limits posted on traffic signs. Posted speed limits were either 10% lower or higher than the appropriate speed from Experiment 1 or 50% lower or higher than the appropriate speed. 10% was chosen based on the fact that a tolerance of around 10% deviation from speed limits is frequently regarded as acceptable (Ng, 2012) – hence, a speed limit 10% from the judged appropriate speed from Experiment 1 would likely appear fairly credible. The 50% value was selected as a striking contrast, and thus likely to be perceived as not credible. Based on Goldenbeld and van Schagen (2007), we predicted that drivers would be more likely to suggest an appropriate speed that is in line with the posted speed limit if it is credible, that is, close to the appropriate speed indicated in Experiment 1 (i.e. 10% lower or 10% higher) than if it substantially deviates from the appropriate speed (i.e. 50% lower or 50% higher). Furthermore, we predicted that where the speed limits consistently and substantially deviate from the appropriate speed (i.e. the 50% lower and 50% higher conditions), drivers would disregard the speed limit information altogether and make judgments consistent with those in Experiment 1 (where no speed limit information was available).

3.1 Methods

3.1.1 Participants and Design

In total, 109 Malaysian drivers were recruited. Although Experiment 1 suggested driver experience has no impact on judgments of appropriate speed within the range of driver experience selected, participants in each of the four conditions were matched closely with those in Experiment 1 in terms of driving experience. A between-participants design was used whereby participants were assigned to one of the four conditions on an alternating basis (displayed in Table 2) while ensuring the conditions were balanced in their gender composition and driver experience since getting their driving license in Malaysia.

337 Table 2. Demographic details of participants in each condition.

Condition	Number of drivers (female, males)	Age (years)		Active driving experience (years)	
		Range	Mean (s.d.)	Range	Mean (s.d.)
10H (10% higher)	26 (13,13)	18-26	21.27 (2.39)	0.17-6.17	2.8 (1.77)
10L (10% lower)	28 (15,13)	18-25	20.14 (2.17)	0.08-7.00	2.41 (2.00)
50H (50% higher)	28 (15,13)	18-25	20.93 (2.39)	0.17-7.00	2.64 (2.00)
50L (50% lower)	27 (13,14)	18-27	20.70 (2.22)	0.25-6.17	2.63 (1.81)

338

339 All participants reported normal or corrected-to-normal vision. A one-way ANOVA
340 was conducted to compare the experience level for the four conditions and the drivers in
341 Experiment 1. This found no difference between conditions in number of years of active
342 driving experience, $F(4,133) = 0.16$, $p > .05$. Similarly a one-way ANOVA was conducted to
343 compare the driver age for the four conditions and the drivers in Experiment 1. The test found
344 no difference between conditions in drivers' age, $F(4,133) = 0.93$, $p > .05$.

345 **3.1.2 Stimuli**

346 The mean judged appropriate speeds for each of the images from Experiment 1 were
347 used as a baseline for creating the stimuli for Experiment 2. The same set of 35 photographs
348 from Experiment 1 was used. However, these images were edited to display various different
349 speed limits on the speed limit sign. Four conditions were created which included a condition
350 where the speed limit display was 10% higher than the judged appropriate speed (10H), a
351 condition where the speed limit display was 10% lower than judged appropriate speed (10L),
352 a condition where the speed limit display was 50% higher than judged appropriate speed

(50H), and a condition where the speed limit display was 50% lower than judged appropriate speed (50L). For each individual photograph the mean judged appropriate speed from all participants in Experiment 1 was subjected to an increase of 10% or 50%, or a decrease of 10% or 50%. Due to the implausibility of a speed limit sign displaying a number which is not a multiple of 10, the calculated values were rounded to the nearest 10. These whole numbers for each image and each condition were edited onto the speed limit sign using Paint software.

To determine the effect of the rounding of the individual numbers on the manipulations created for the four conditions, the mean percentage difference between the mean judged appropriate speed from Experiment 1 and the mean posted speed was calculated for each condition (displayed in Table 3).

Table 3. The mean percentage difference between mean judged appropriate speed from Experiment 1 and the mean posted speed for each condition.

Condition	Adjusted Percentage
10H	10.23% higher
10L	9.31% lower
50H	50.69% higher
50L	48.49% lower

3.1.3 Procedure

Participants experienced the exact same procedure as in Experiment 1. They were required to judge the appropriate speed to drive on each road in the 35 images. Images were presented randomly for an unlimited time and participants could use the time they wanted to key in the appropriate speed in the unit of km per hour. A fixation point '+' appeared in the

middle of the screen between trials for 500ms. Participants experienced 5 practice trials before the 35 experimental trials. They were seated approximately 70cm from the screen with visual angle of approximately 28 x 21 degrees.

3.2 Results

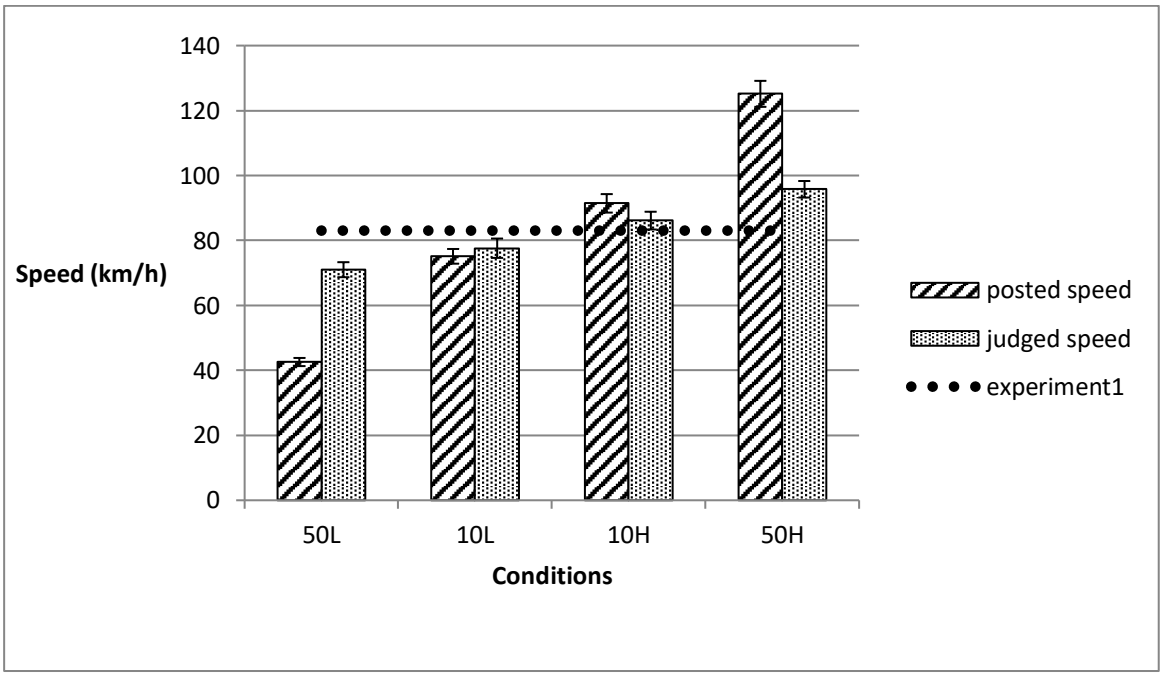

Figure 3. Mean posted speed and judged appropriate speed for each condition. The dotted line indicates the average judged appropriate speed in Experiment 1.

Figure 3 shows the mean posted speed and judged appropriate speed for all four conditions (50L, 10L, 10H and 50H), and Table 4 offers a summary of the analyses carried out. A one-way ANOVA revealed that there was a significant difference between conditions in judged speed, $F(3,136) = 16.32$, $p < .001$. Bonferroni post-hoc tests showed the judged appropriate speed was significantly higher for 50H (95.77km/h) than 50L (71.00km/h), $p < .001$; judged appropriate speed was significantly higher for 50H (95.77km/h) than 10L (77.61km/h), $p < .001$; judged appropriate speed was significantly higher for 10H (86.11km/h)

than 50L (71.00km/h), p =.001. The mean judged appropriate speed did not differ between 50H and 10H; 50L and 10L; and 10H and 10L, all p > .05.

The next analysis investigated whether the judged speed differed significantly from the speed posted. In order to do this, for each trial the posted speed was subtracted from the judged speed, creating difference scores. A positive difference score would reflect a tendency to judge a higher speed than the posted speed while a negative score would indicate a tendency to judge a lower speed than posted. Mean difference scores were calculated for each participant and then four one-sample t-tests were conducted (one for each condition) comparing the mean difference scores with 0 (with a Bonferroni-corrected alpha level of .0125). Difference scores were significantly less than 0 for the 50H, $t(34) = 14.97$, $p < .001$ ($M = -29.37$, S.D. = 11.61), and 10H conditions, $t(34) = 7.54$, $p < .001$ ($M = 5.32$, S.D. = 4.17),. The difference scores were significantly larger than 0 for the 50L condition, $t(34) = 19.66$, $p < .001$ ($M = 28.43$, S.D. = 8.55), while the difference scores did not differ from 0 in the 10L condition, $t(34) = 1.81$, $p > .05$ ($M = 2.50$, S.D. = 8.18).

The next analysis aimed to determine how participants' judgments related to the appropriate speed for the roads, as determined in Experiment 1. The dotted line in Figure 5 shows the mean appropriate speed for the roads from Experiment 1. Four paired-sampled t-tests were carried out comparing the judged appropriate speed from Experiment 1 with judged appropriate speed in Experiment 2 in each condition (with a Bonferroni-corrected alpha level of .0125). These revealed that for all four conditions, the judged appropriate speed in Experiment 2 was different from in Experiment 1. The judged appropriate speed in Experiment 2 was significantly lower than the judged appropriate speed in Experiment 1 (83.04km/h) for the 50L condition (71km/h), $t(34) = 11.12$, $p < .001$ and the 10L conditions (77.61km/h) n, $t(34) = 4.26$, $p < .001$. The judged appropriate speed in Experiment 2 was significantly higher than the judged appropriate speed in Experiment 1 for the 10H condition

(86.11km/h), t(34) = 4.26, p <.001 and the 50H conditions (95.77km/h), t(34) = 12.65, p <.001.

Table 4. Summary of results of statistical tests conducted in Experiment 2

Comparisons	Statistic
	F(3,136) = 16.32, p <.001, Bonferroni post-hoc tests as follow:
judged speed 50H vs judged speed 50L	<0.001
judged speed 50H vs judged speed 10L	<0.001
judged speed 50H vs judged speed 10H	> 0.05
judged speed 10H vs judged speed 50L	0.001
judged speed 10H vs judged speed 10L	> 0.05
judged speed 50L vs judged speed 10L	> 0.05
difference between 50H judged and posted speed vs 0	t(34) = 14.97, p <.001
difference between 10H judged and posted speed vs 0	t(34) = 7.54, p <.001
difference between 50L judged and posted speed vs 0	t(34) = 19.66, p <.001
difference between 10L judged and posted speed vs 0	t(34) = 1.81, p >.05
judged speed from Experiment 1 vs 50H	t(34) = 12.65, p <.001
judged speed from Experiment 1 vs 10H	t(34) = 4.26, p <.001
judged speed from Experiment 1 vs 50L	t(34) = 11.12, p <.001
judged speed from Experiment 1 vs 10L	t(34) = 4.26, p <.001

It may be the case that for those conditions where the posted limits lack credibility, the participants gradually learned that the speed limits were not credible and therefore initially judged speeds consistent with the posted limits but came to disregard them over time. A further analysis was conducted to address this possibility. This analysis focused on the 50H and 50L conditions only, as these conditions involved the non-credible posted limits. The average judged speed and average posted speed for the first five trials and last five trials each were calculated for each participant. The average posted speed was subtracted from the average judged speed for the first and last five trials for each participant. Again, this yielded

difference scores where a positive value reflected a tendency to judge a higher speed than the posted speed while a negative value indicated a tendency to judge a lower speed than posted. Four one-sample t-tests (50H and 50L for first five trials and 50H and 50L for last five trials) were conducted to compare the differences to zero (a difference score of 0 reflects judged speeds being equivalent to the posted speeds. For the first five trials, the difference between judged and posted speed was significantly different from 0 in both the 50H condition, $t(27) = 9.28$, $p < .001$ ($M = -24.92$; S.D. = 14.21) and the 50L condition, $t(26) = 6.68$, $p < .001$ ($M = 24.15$; S.D. = 18.79). Similarly for the last five trials, the difference between judged and posted speed was significantly different from 0 for the 50H condition, $t(27) = 10.28$, $p < .001$ ($M = -30.96$; S.D. = 15.93) and the 50L condition, $t(26) = 8.08$, $p < .001$ ($M = 29.90$; S.D. = 19.24). Two paired-samples t-tests were conducted to compare the difference scores for the first and last five trials in each condition. There was no significant difference for the 50L condition, $t(27) = 1.48$, $p > .05$ or the 50H condition, although there was a trend towards the difference score becoming increasingly negative for the 50H condition, $t(26) = 1.80$, $p = .084$.

3.3 Discussion

The information displayed on speed limit signs does at least to some extent modify drivers' judgments of the appropriate speed. This is supported by the finding that in all four conditions, drivers' judgments of the appropriate speed differed from those made in Experiment 1 - in all cases consistent with the direction of the displayed speed limit. This is further corroborated by the fact that there were differences between some of the conditions in the judged appropriate speed. Taken together these findings indicate that drivers do take the information displayed on the speed limit sign into account when deciding about the appropriate speed to drive.

However, it was clearly not the case that drivers always selected the speed shown on the speed limit signs as for three of the four conditions the mean judged appropriate speed differed from the speed displayed on the signs. For the conditions where the limit posted was 50% lower or 50% higher than the appropriate speed as identified in Experiment 1, people did not give speed judgments in line with the speed on the sign (they selected higher and lower speeds respectively). This was also the case for the condition where the speed limit signs displayed a speed only 10% higher than the appropriate speed chosen in Experiment 1, wherein people tended to select lower speeds. However, in 10% lower condition, where the displayed speed limit was 10% below that identified as appropriate in Experiment 1, there was no difference between judged appropriate speed and posted speed. This suggests that when the speed limit is similar to but slightly lower than a speed drivers believe to be appropriate in the absence of speed limit information, they will modify their judgments about appropriate speed in line with the speed limit provided. These findings are broadly consistent with previous simulator studies which found that drivers were more likely to comply with speed limits rated as credible (van Nes et al., 2008; 2010).

In order to compare results of Experiment 1 and Experiment 2, it is important to know whether possible sample differences may have played a role. Participants in both studies were recruited from the same population, and none of the groups differed significantly in age or experience. There was a slightly larger number of females than males in Experiment 1 but not Experiment 2; however, Experiment 1 showed no gender difference in judgments about appropriate speed. Therefore, it is highly unlikely any differences in performance between the two experiments could be accounted for in this way. It can be asked whether these effects are driven by performance of just a few drivers in the sample. It could be the case that some drivers always judge the speed displayed on the speed limit sign as appropriate, while others disregard the speed limit entirely. If this were the case, the means for the conditions would

reflect the combination of these two distinct response strategies. However, this interpretation seems unlikely because no driver in any of the four conditions consistently picked the speed shown on the speed limit signs throughout the thirty-five trials.

There are two further points which should be noted. Firstly, driver's judgments of appropriate speed did not differ between the 10% higher and 50% higher conditions, and did not differ between the 10% lower and 50% lower conditions. This suggests that drivers may only adjust their judgments of appropriate speed to a certain extent in light of speed limit information. This would imply that setting speed limits that differ greatly from the speed which drivers think is appropriate for the road is unlikely to result in dramatic changes in their views on the right speed. Second, while drivers did pick speeds consistent with the speed limits in the 10% lower condition (i.e. their chosen speed was not significantly different), they did not in the 10% higher condition. This asymmetry might imply that drivers are more prone to adjusting their judgments towards a lower speed than towards a higher speed when faced with speed limit information. This perhaps suggests that drivers are more comfortable revising their judgments to a safer speed than a speed that could be seen as more risky. Although this might appear to contradict other research suggesting that drivers are happy to exceed the speed limit and/or speeds they consider to be safe (Goldenbeld and Schagen, 2004), this may not be the case. In this study the speed limits posted were deliberately chosen to be above speeds the participants believed to be appropriate (not just above the actual speed limit), and this may explain the reluctance to pick the speeds posted. It could also be argued that the asymmetry could be due to a social desirability bias. If social desirability bias was a major factor in responding one might expect participants to judge appropriate speeds consistent with the speed limits across all the conditions, which did not happen. On the other hand it could still be argued that drivers might think that they ought to pick speeds below and not above the posted limits, which cannot entirely be ruled out.

However, previous research suggests that drivers are frequently willing to say that they would exceed the speed limit (e.g. Goldenbeld, van Schagen, & Drupsteen, 2005; SARTRE 3, 2004) and indeed they chose speeds well above the posted limits in some conditions of this study raising doubt over the role of social desirability here.

A further analysis investigated whether participants in the two conditions with non-credible speed limits (the 50% higher and 50% lower conditions) started off by judging speeds consistent with the limits posted but gradually disregarded the limits over time due to their persistent lack of credibility. Participants did not make judgments consistent with the limits posted in the first five trials in either condition. The magnitude of the discrepancy between the posted speed limit and the participants' judgments of appropriate speed did not change significantly over time for the 50% lower condition or the 50% higher condition. However, for the 50% higher condition there was a trend towards the discrepancy between posted and judged speeds increasing across the experiment. This is potentially consistent with a slightly greater tendency to disregard the posted speed over time in this particular condition.

4. General Discussion

Previous researchers have argued that one of the key reasons why drivers speed is because they do not regard the speed limits which are set as being credible (Goldenbeld & van Schagen, 2007; Kanellaidis et al., 1995). Two related suggestions are that a) drivers are more likely to be influenced by speed limits which are credible than those which appear unreasonable and b) if speed limits are frequently non-credible then drivers may doubt the entire system and no longer consider speed limit information when selecting an appropriate speed (Goldenbeld & van Schagen, 2007).

In the first experiment, drivers' judgments of the appropriate speed to drive in the absence of any provided speed limit information were higher than the actual true speed limits

of the roads. Although our study recruited Malaysian drivers, the findings in this respect are broadly consistent with previous studies conducted in other parts of the world regarding speed choice whereby participants on average preferred a speed about 10% higher than the actual speed limit of the roads (Fleiter and Watson, 2006; Goldenbeld & van Schagen, 2007). This similar trend in speed choice across studies is interesting given that Malaysia has a much higher crash and fatality rate than countries where research has previously taken place (23.8 deaths per 100,000 inhabitants in 2009, IRTAD, 2011). In addition, this experiment found that some characteristics of the environment (e.g. road width, presence curve, sight distance, clarity of situation, presence of intersections, number of lanes, view to the left, presence of light poles) have an effect on drivers' judged speed but not others (e.g. view to the right, buildings alongside the road, presence of trees and vegetation on both sides of the road, traffic on the same and opposite carriageway). While it is possible that this particular pattern of results is a consequence of the magnitude of variability in these features within the particular stimulus set, the features that did affect judgments were overall similar to those identified in Goldenbeld and van Schagen's (2007) study in the Netherlands. This suggests that in some domains drivers' decision-making processes may be fairly similar across cultures, contrasting with previous research which implies there are cultural effects on drivers' judgments (Lee et al., 2015; Lim et al., 2013; 2014).

In Experiment 2, we also find support for point a) above - namely that if a posted speed limit is close to but 10% lower than the speed drivers believe to be appropriate for the road (i.e. the speed limit is credible) this can lead to selection of speeds consistent with the limit posted. In contrast, when the speed limit shown was 50% higher or lower than the appropriate speed, drivers' judgments about appropriate speed deviated from the speed limit posted. However, our data appear to contradict point b). If b) is correct then we would expect that in conditions where the speed limits differ greatly from the appropriate speed (the 50%

552 higher and 50% lower conditions) drivers would disregard the limits altogether and should
553 consequently make judgments consistent with the judged appropriate speed from Experiment
554 1. This does not appear to be the case. Instead, drivers' judgments are of appropriate speeds of
555 similar magnitude to the 10% higher and 10% lower conditions respectively. If b) is correct
556 we might also have expected drivers' judgments to change over time for the non-credible
557 speed limit conditions, as drivers experience persistent non-credible limits and increasingly
558 disregard them. Our findings concerning this are somewhat mixed, as even within the first
559 five trials of the 50% higher and 50% lower conditions, drivers did not select speeds
560 consistent with the posted limits. However, there was a trend towards the discrepancy
561 between the judged appropriate speed and posted speeds increasing over time, which could
562 reflect an increasing disregard of the posted limits with greater exposure to non-credible
563 speed limits. As mentioned previously, it seems reasonable to suggest that there are certain
564 limits within which drivers will modify their judgments of an appropriate speed to drive
565 based on speed limit information provided. At the very least, the findings here suggest that
566 people do take account of speed limit information when choosing an appropriate speed to
567 drive. However, those who determine speed limits should take account of what drivers regard
568 as appropriate and understand that it may be difficult to modify drivers' views on how fast
569 one should drive beyond certain limits.

570 In summary, our findings suggest that drivers' views of an appropriate speed are
571 influenced by characteristics of the road itself. Drivers' views can be modified in light of
572 speed limit information but they are unlikely to select speeds consistent with speed limits
573 which are radically different from the speed they deem appropriate in the absence of speed
574 limit information. This suggests that speed limit credibility is likely to be a crucial factor in
575 speed limit compliance and those responsible for setting speed limits may need to consider
576 the match between the road characteristics and the speed limit set.

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