The effect of luminance on simulated driving speed

Sarah J. Pritchard and Stephen T. Hammett§

Dept of Psychology,

Royal Holloway University of London,

Egham, Surrey

TW20 0EX UK

Tel/Fax: +44 1784 443702

Email: s.hammett@rhul.ac.uk

§ Corresponding author

Abstract

Perceived speed is modulated by a range of stimulus attributes such as contrast, luminance and adaptation duration. It has been suggested that such changes in perceived speed may influence driving behaviour. In order to evaluate the effect of luminance on driving speed we have measured subjects' driving speed in a driving simulator for a range of luminance and speed over time. The results indicate that reducing luminance results in a decrease in driving speed for all speeds measured. This reduction in driving speed at low luminance is consistent with previous findings that perceived speed increases at low luminance. However, the results also indicated that driving speed remained stable over a 30 s period. The stability of driving speed over time is inconsistent with previous findings that perceived speed reduces exponentially as a function of adaptation duration. The results are suggestive of a scheme whereby driving speed is consistent with the known effects of luminance upon perceived speed but may also be modulated by higher order processes that serve to maintain a constant speed.

Keywords: perceived speed, luminance, driving, adaptation

1.0 Introduction

Whilst a number of relatively successful and physiologically plausible models of motion processing has been proposed (e.g. van Santen & Sperling, 1985; Adelson & Bergen, 1985; Watson & Ahumada, 1985), the precise mechanisms involved in encoding perceived speed are poorly understood. Perceptual judgments of speed are influenced by a range of stimulus attributes such as the size of the stimulus, the relative direction of motion, the size and homogeneity of the background, retinal location, adaptation and contrast (see e.g. Brown, 1931; Thompson, 1981, 1982). Early explanations of speed encoding relied on the notion that a representation of speed was contingent on the spike rate of speed-tuned neurones (Barlow & Hill, 1963), but whilst there is much psychophysical evidence consistent with this frequency-response class of model (e.g. Clifford & Langley, 1996; Bex, Bedingham & Hammett, 1999), the finding that perceived speed may increase after adaptation under certain conditions (Thompson 1981; Smith & Edgar, 1994; Hammett, Bedingham & Thompson, 2000) is inconsistent with such an encoding strategy. In order to accommodate this and other psychophysical results, a number of workers has proposed that the encoding of speed may be accomplished by taking the ratio of two populations of neurones whose speed tuning properties differ (see, e.g. Thompson, 1982; Smith & Edgar, 1994; Hammett, Champion, Morland & Thompson, 2005).

Recently Bayesian models of speed encoding have been proposed (Stocker & Simoncelli, 2006; Hürlimann, Kiper & Carandi, 2002; Ascher & Grywacz, 2000) which assume that perceived speed is encoded as the product of a prior distribution, centred on relatively slow speeds, and a likelihood distribution that is derived from sensory processes. This class of model fares well in explaining the well known reduction of perceived speed induced by reducing contrast (Thompson, 1982) since any degradation in stimulus information serves to increase the proportionate effect of the slow prior and thus lead to a reduction in perceived speed. However, the Bayesian class of model struggles to explain both the increases in perceived speed at higher speeds that have been found under reduced contrast conditions (Thompson, Brooks & Hammett, 2006) and the finding that reducing luminance leads to an increase in perceived speed (Hammett, Champion, Thompson & Morland 2007; Vaziri-Pashkam & Cavanagh, 2008). Both of these manipulations of stimulus attributes should lead to an increase in the proportionate effect of any slow prior and therefore a reduction in perceived speed. Thus there is currently no clear account of how speed is encoded in the human visual system. Indeed, Krekelberg et al (2006) reported that no current model of speed encoding is entirely consistent with the response properties of speed-tuned cells in Macaque MT.

Despite the lack of a complete understanding of how distortions in perceived speed may arise, such phenomena may have a weighty applied bearing. A number of groups has found evidence that distortions in perceived speed may directly influence driving behaviour. For instance, Denton (1980) reported that perceived speed in a driving simulator can be modulated by the spacing of patterns (and thus temporal frequency) in the visual field and that the placement of lines of exponentially increasing spatial frequency orthogonal to the approach to junctions appeared to reduce accidents. More recently, Manser and Hancock (2007) have shown that increasing the temporal frequency of patterns in a simulated driving environment reduces driving speed and, conversely, reducing temporal frequency increases driving speed. They conclude that manipulating the temporal frequency of road markings (and thus presumably perceived speed) may be an effective method for the control of road users' driving speed. Denton (1976) proposed that adaptation may also influence driving speed and Gray and Regan (2000) reported that following five minutes of adaptation to motion in a driving simulator, subjects initiated overtaking manoeuvres significantly later than in the absence of adaptation. Gray and

Regan proposed that this change in driving behaviour may be a direct result of perceptual changes induced by motion adaptation. Similarly, Snowden et al (1998) have previously reported that the reduction in contrast in a simulated foggy driving environment results in an increase in simulated driving speed. They reasoned that this increase in driving speed is due to the well-known reduction in perceived speed found at low contrast (e.g. Thompson, 1982). However, recently, Pretto et al (2010) have reported that both perceived speed and driving speed is reduced for more ecologically valid stimuli whose contrast is reduced in a distance-dependent manner. Additionally, Owens et al (2010) found subjects' driving speed was significantly slower under reduced contrast conditions in a real-world driving paradigm. Thus whilst stimulus parameters may be critical to both perceived speed and driving speed, well known psychophysical effects may not translate straightforwardly into real-life situations. Whilst a clearer picture of how contrast influences driving speed is now emerging, no previous study has measured the effect of luminance on driving speed. Gegenfurtner, Mayser and Sharpe's (1999) finding that rod-isolating stimuli appear to move more slowly prompted them to speculate that night time driving in poorly lit areas may "… lead to an underestimation of the speed of movement, which in turn might elicit a compensatory – and possibly fatal - increase in speed". However, more recently, both Hammett et al (2007) and Vaziri-Pashkam & Cavanagh (2008) have reported that the perceived speed of a low luminance stimulus is significantly higher than an otherwise identical high-luminance pattern. We reasoned that this striking increase in perceived speed at low luminance should result in a reduction in driving speed in dimly lit conditions, if driving speed is determined by perceived speed. Moreover, since adapting to motion is known to reduce perceived speed, we reasoned that driving speed should increase as adaptation duration increases. We have therefore measured the speed at which subjects drive in a simulated environment under a variety of luminance and speed conditions. Given previous findings of the influence of temporal frequency upon both driving speed and low-level motion judgments (e.g. Reisbeck & Gegenfurtner, 1999) we have also measured the effect of luminance upon driving speed as temporal frequency varies whilst speed is constant.

2.0 Experiment 1: The effect of luminance on simulated driving speed

2.1 Methods

2.1.1 Apparatus and materials

A simulated continuous straight rolling road was generated under computer control. Stimuli were scripted in Python and generated using Vizard (WorldViz LLC: Santa Babara) software that uses OpenSceneGraph libraries to present perspective correct 3D stimuli. This allows all stimuli to undergo the transformations that would occur during natural ego-motion at a speed specified in m s-1, with a pre-specified eye-height and observer position and field of vision that dictates the rendered frustum. Scene refresh was maintained at 60Hz and the scene was displayed on a Viewsonic G70fm CRT at a mean luminance of 59.95 cd/m^2. The active display subtended 32.4° x 24.3° at a viewing distance of 57cm. The road was a solid (black) with no texture, other than for white lines situated in the horizontal centre of the display. The white lines had an even duty cycle whose fundamental temporal frequency (but not duty cycle) was matched to that of one of two sets of UK road markings corresponding to speed limits above or below 40 mph (Department of Transport, 2003). The surrounding texture was green in colour, randomly interspersed with noise to simulate grass. A schematic of the stimulus is given in Fig 1. The position and speed along the road was controlled by a Trust GM-3200 steering wheel and accelerator (Logitech) respectively; the vibration feedback of the accelerator device was disabled.

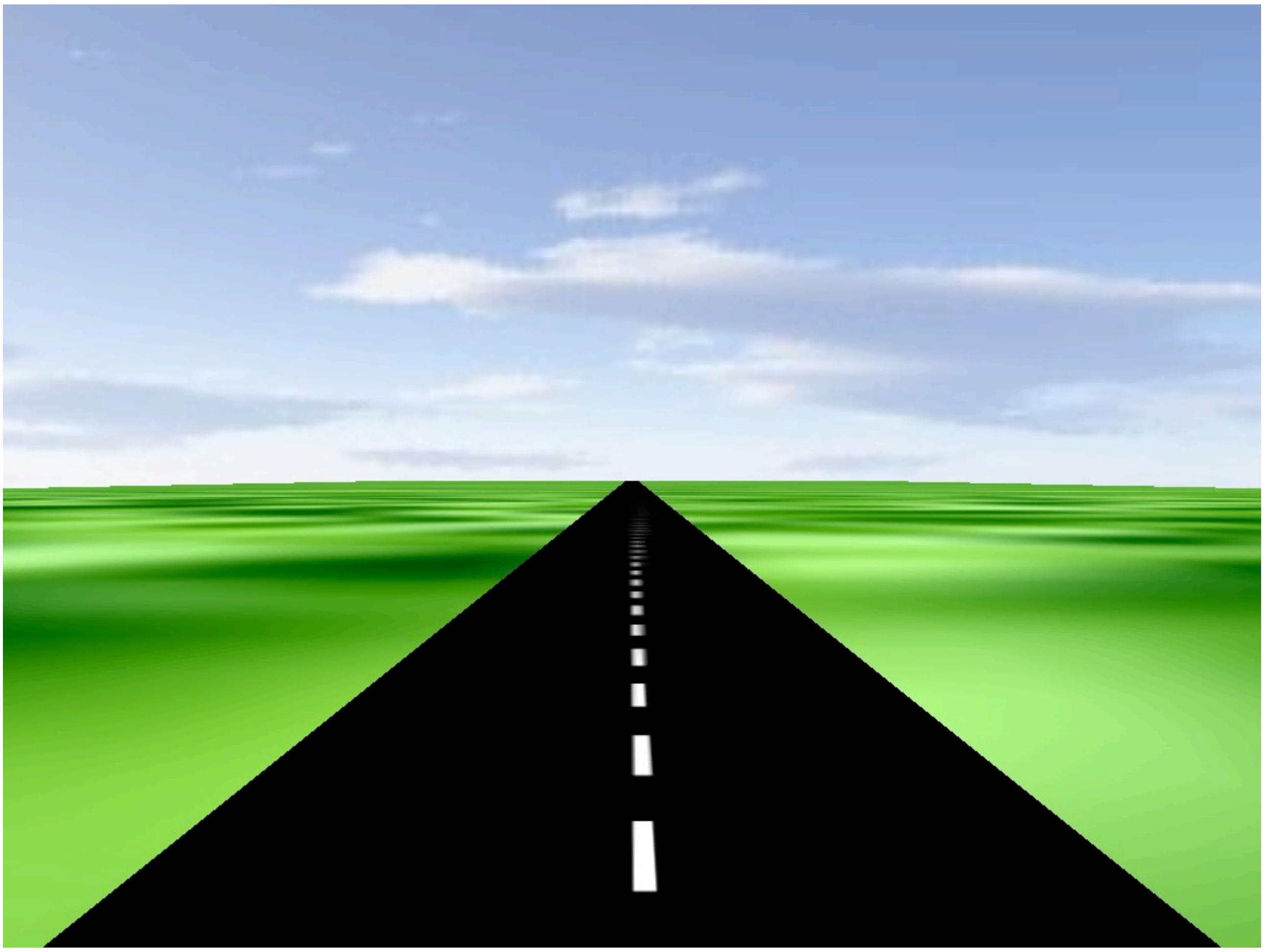

Fig 1 Schematic representation of the driving simulator.

Optical Drop Cell optician trial frames (Skeoch, Sussex) were worn continuously by the subjects throughout the trials. Luminance was reduced by inserting neutral density filters (NDF) (Thorlabs Inc.) into the lens slots of the trial frames. Three luminance levels of 59.95cd m-2 , 4.87 cd m-2 and 0.42 cd m-2 (hereafter nominally 60, 5 and 0.4 cd m-2) were obtained by introducing NDF's of optical density 0, 1 or 2 respectively into the trial frames. Luminance was measured using the Cambridge Research System Optical photometer (Rochester,UK).

All five subjects (4 males, 1 female) had normal or contact lens-corrected vision, had a full driving license and drove regularly. Viewing was binocular in a semi-darkened room and no head restraint was used. One of the subjects (SP) was an author; the other subjects were naïve as to the purposes of the experiment.

2.1.2 Procedure

At the start of each experimental session, subjects were dark adapted for 5 minutes. Whenever a change in luminance occurred, the subjects were first grey screen adapted (ambient lighting, no NDF) for 5mins and then adapted to a grey screen of the appropriate luminance for a further 5mins. The trials were segregated into blocks determined by the target speeds of 30 mph, 50 mph and 70 mph, with each block occurring on contiguous days. The presentation order of target speed and temporal frequency within each speed session was quasi-randomly determined for each subject.

There were four practice sessions at the beginning of each target speed trial; two of the practice sessions employed the stimulus whose temporal frequency of the road markings matched those found in zones with speed limits below 40 mph and two of the sessions had the stimulus where the temporal frequency of the road markings corresponded to those found in zones with speed limits greater than 40 mph. Each subject was given a target speed at the start of each session; they were then presented with the simulated continuous road and instructed to drive along the road using the accelerator at that target speed. Performance feedback was given by means of a speedometer situated in the top left corner of the display. The subjects were directed to fixate at the centre of the screen, where the white lines were situated. Each practice session lasted 30secs; all practice sessions were conducted without NDFs.

In the experimental conditions, the speedometer was disabled, subjects were instructed to achieve and maintain the target speed of the practice. Each trial lasted 30 seconds. At each speed, subjects completed the task for all three luminance conditions and for lines representing temporal frequencies for speed limits both above and below 40 mph. Subjects adapted to a grey screen of mean luminance for 1 minute between each individual trial. The luminance was altered by the insertion of NDF's into the optical frames. The mean of three trials per luminance condition, speed and temporal frequency condition was taken.

2.2 Results

During the practice sessions subjects achieved task performance that was within experimental error. The largest mean deviation from target speed in the practice trials was 1.6% at 30 mph for the lower temporal frequency. All other mean deviations from target speed were less than 1%. Average speed for each target speed and luminance is plotted in Fig 2. As luminance decreased, the subjects' driving speed reduced monotonically for all speeds and luminances tested. The greatest effect was observed at the highest speed tested: in the lowest luminance condition (0.4 cd m-2) average driving speed was 18% and 29% below target speed at 7 Hz and 10.5 Hz, respectively. At 30 mph, mean speed was 12% and 22% below target speed at 3Hz and 4.5Hz, respectively. Thus driving speed decreased as a function of decreasing luminance whilst higher temporal frequencies resulted in lower driving speed for the same target speed, independent of luminance.

A three-factor repeated measures ANOVA revealed a significant main effects of speed (F(2, 8) = 4.158, p<.001), luminance (F(2, 8) = 52.671, p<.001) and temporal frequency (F(1, 4) = 12.991, p<.025). Bonferroni corrected post-hoc analyses indicated that there were significant differences between all luminance conditions (p<.025). There was a significant interaction between speed and frequency (F(2, 8) = 9.791, p<.01) but no significant interaction between either speed and luminance (F(4, 16) = 1.686, p = .202) or luminance and temporal frequency (F(2, 8) = .358, p = .710).

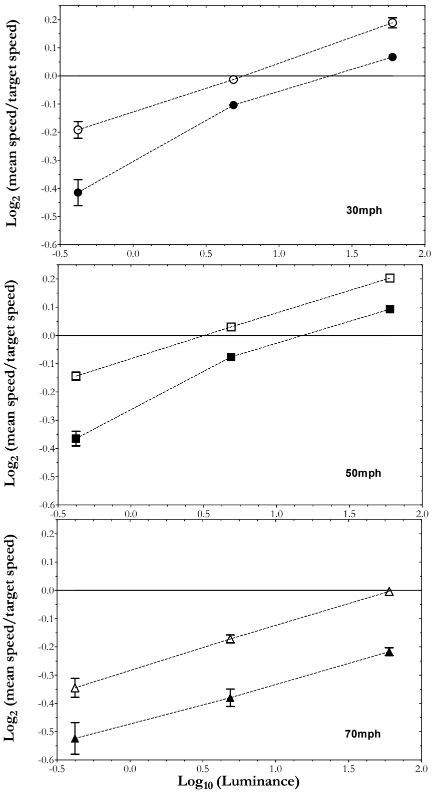

Fig 2 Log2 of the ratio of mean speed to target speed as a function of log10 luminance for lower (open symbols) and higher (closed symbols) temporal frequency spacing of road markings at 30 mph (circles), 50 mph (squares) and 70 mph (triangles). Values greater than zero represent driving speeds faster than the target speed; values below zero represent driving speeds slower than the target speed. Error bars indicate ±1 SEM.

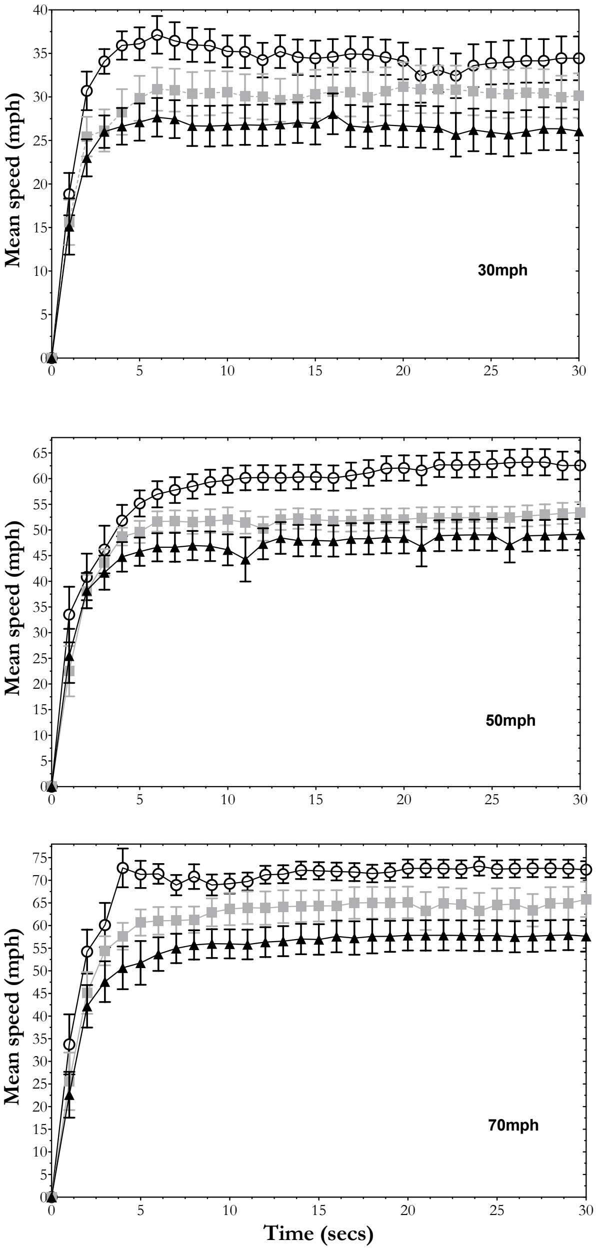

Fig 3 Mean driving speed as a function of time at 30 mph (upper panel), 50 mph (centre panel) and 70 mph (lower panel) and at 60 cd m-2 (circles), 5 cd m-2 (squares) and 0.4 cd m-2 (triangles) luminance conditions, error bars indicate ± 1SEM.

Fig. 3 plots mean driving speed (averaged across subjects) as a function of time for the lower temporal frequency condition. There is no evidence of an increase in speed as a function of time. In all cases, mean speed plateaus after around five seconds, with little evidence of any systematic drift in speed thereafter. Linear regression of each function (the first four seconds having been discarded) resulted in a mean slope of 0.09 (standard error = 0.04). A single sample t test revealed no significant difference between these slopes and zero ($t(8)=2.296$, $p>0.05$; observed power = 0.67). Qualitatively similar results were found in the higher temporal frequency condition (not shown).

3.0 Experiment 2: Randomising accelerator gain

The results of Experiment 1 indicate that driving speed is reduced at low luminance, consistent with previous reports that perceived speed increases at low luminance (Hammett et al, 2007; Vaziri-Pashkam & Cavanagh, 2008). However, if the reduction in perceived driving speed were due to a change in perceived speed then one may expect other dynamic changes in driving speed to be attendant. For instance, adaptation to a drifting pattern is known to reduce its perceived speed exponentially over time (Bex et al., 1999, Hammett et al., 2000, Hammett et al., 2005). Thus whilst the overall reduction in driving speed at low luminance is consistent with the previously reported effect of luminance upon perceived speed, the absence of any change (increase) in driving speed over time is inconsistent with known dynamic changes in speed perception. One possibility is that subjects simply used visual information to set a target speed and subsequently maintained that accelerator position regardless of any changes in perceived speed. In order to investigate whether subjects' stable driving performance was due to the use of proprioceptive feedback we therefore repeated our measurements for a subset of conditions but varied the gain of the accelerator pedal randomly at six second intervals. Thus in order to maintain a constant driving speed, subjects were required to adjust the accelerator position every six seconds and could not do so upon the basis of previous knowledge of pedal position.

3.1 Methods

The stimuli and apparatus used were essentially the same as those described for Experiment 1 with the exception that the scene was presented on a Samsung SyncMaster 910N LCD display with a mean luminance of 56.42 cd m-2 (hereafter nominally 56 cd m-2). The active display subtended 32° x 24°, at a viewing distance of 65cm. The stimuli and apparatus used were essentially the same as those described in Experiment 1, but only one luminance condition was employed and the gain of the accelerator was randomly altered within a ±50% range every 6 seconds. Therefore, to achieve the same target speed, subjects had to regularly physically alter the position of the accelerator. All five subjects (three males, two females) had normal or contact lens-corrected vision, held a full driving license and drove regularly. The experimental protocol was essentially the same as the prior experiment; however the gain of the accelerator was randomly altered under computer control throughout the trial after every 6 seconds. The trial ended at 50 seconds. The mean of four trials per target speed was taken.

3.2 Results

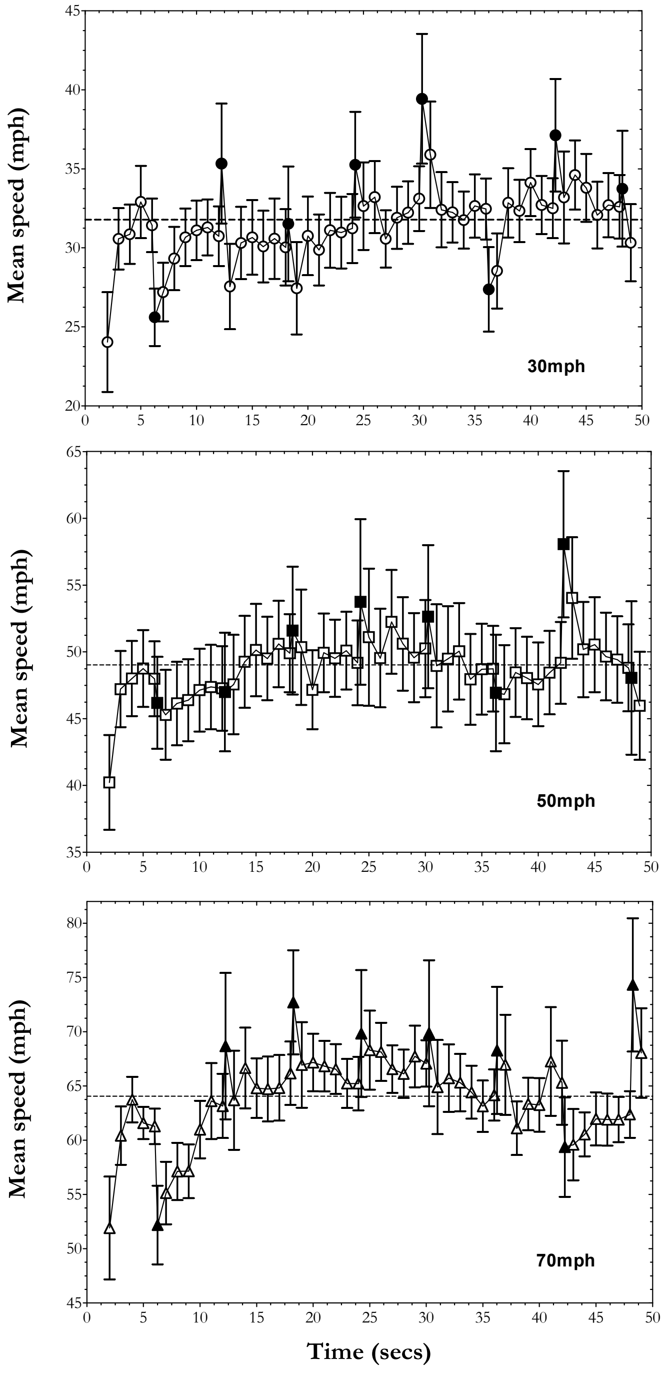

Fig 4 Speed, averaged across subjects and trials as a function of time for target speeds of 70mph (triangles), 50mph (squares) and 30mph (circles). Error bars represent ± SEM. Closed symbols indicate points of accelerator gain change. Broken lines represent mean speed.

Fig. 4 plots mean driving speed as a function of time. Following each change in accelerator gain (indicated by closed symbols), driving speed typically returns to a stable quiescent speed in around 2-3 seconds. A repeated measures ANOVA revealed no significant difference between the driving speed reached immediately before each gain change (F(7,28)= 1.107, p>0.05, (30mph), F(7,28)=0.846, p>0.05, (50mph), F(7,28)=1.672, p>0.05 (70mph); observed power = 0.88). Thus following the initial correction after gain change, there is no evidence of a systematic change in speed.

4.0 Experiment 3: Motion after effects

The results of Experiment 2 revealed no evidence for a velocity after effect. In order to establish whether the experimental protocol induced other forms of adaptation, we measured the duration of the motion after effect (MAE) after adapting to the same stimuli used in Experiments 1 and 2.

4.1 Methods

4.1.1 Apparatus and materials

The stimuli and apparatus were essentially the same as those described for Experiment 2. Two luminance conditions, 56 cd m-2 and 0.4 cd m-2 were employed. All six subjects (4 males, 2 females) had normal or contact lens-corrected vision, a full driving license and drove regularly. Viewing was binocular in a semi-darkened room and no head restraint was used. One of the subjects (SP) was an author; the other subjects were naïve as to the purposes of the experiment.

4.1.2 Procedure

A similar experimental protocol was employed to that described for Experiments 1 and 2, but exclusively using the stimulus where the temporal frequency of the road markings corresponded to those found in zones with speed limits above 40 mph. At the start of each trial a “go” message appeared centrally at the top of the screen, prompting subjects to begin the trial. After 22 seconds subjects were instructed to stop and simultaneously fixate on a central cross that appeared in the static, simulated road. Subjects were instructed to press a mouse button when the perception of motion was abolished. At each speed, subjects completed the task for both luminance conditions. Subjects adapted to a grey screen of mean luminance for 1min between each individual trial. The mean of five trials per luminance condition was taken.

4.2 Results

Results from this experiment are qualitatively consistent with Experiments 1 and 2. After the initial acceleration period, driving speed stabilised with little drift thereafter. All subjects reported a motion after effect for all speeds and luminance conditions tested (Fig. 5). Mean duration of the MAE was 5.6 seconds for the high luminance condition and 4.96 seconds for the low luminance condition. One sample t tests revealed that both durations were significantly different from zero (t(2) = 9.466, p<0.025 for high luminance and t(2) = 49.27, p<.001 for low luminance). A repeated measures ANOVA revealed no significant difference in duration for luminance (F(1,4)=.368, p>0.05) or speed (F(2,8)=.496, p>0.05). Bonferroni corrected post-hoc tests revealed no significant difference in duration across speed (p > 0.05).

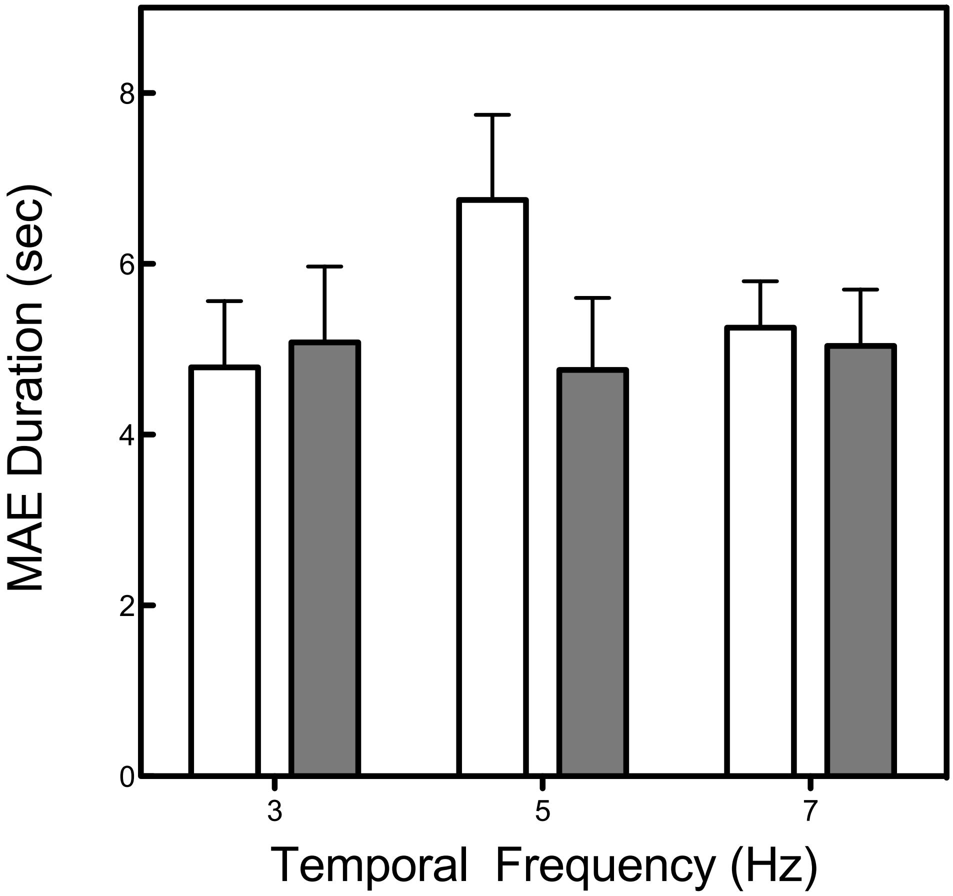

Fig 5 Mean duration of the MAE averaged across 6 subjects is plotted for high (open columns) and low (grey columns) luminance. Error bars represent 1 SEM.

5.0 Discussion

The results indicate that driving speed decreases monotonically as a function of decreasing luminance. The results also indicate that higher temporal frequencies with the same target speed resulted in a lower driving speed at all luminance levels tested. This interaction between temporal frequency and speed is consistent with Reisbeck and Gegenfurtner's (1999) finding that separable mechanisms interact with velocity tuned mechanisms in a motion discrimination task and with Manser and Hancock's (2007) finding that increasing temporal frequency patterns reduce driving speed. The results are also consistent with previous reports that the effect of luminance upon perceived speed is not restricted to mesopic light levels; just as Hammett et al (2007) found an increase in perceived speed for lower luminance patterns in both the photopic and mesopic range, so driving speed reduces in both ranges. Similarly, the range of driving speed reductions found here is consistent with the reduction in perceived speed at unequal luminance reported by Hammett et al (2007). Fig 6 plots the results of Hammett et al's (2007) measurements of perceived speed at unequal luminance (averaged across subjects for a luminance reduction of 1.3 log units), alongside the present results (Experiment 1) for driving speed (averaged across log 1 and log 2 luminance reduction conditions).

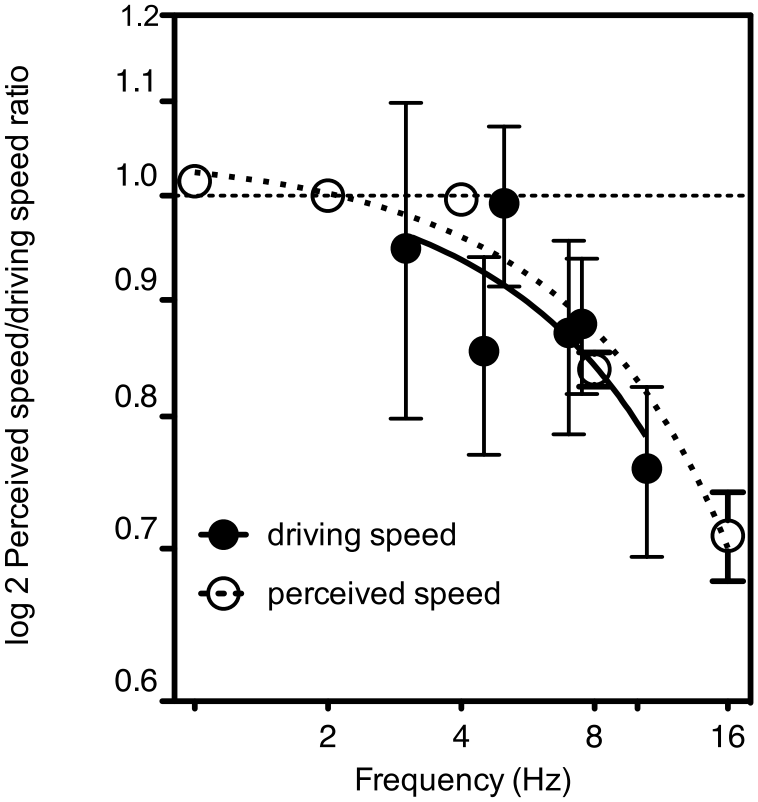

Fig 6 Driving speed (filled symbols) averaged across the 1 and 2 log unit reduction in luminance of the present results, is plotted alongside perceived speed (open symbols) at a log 1.3 reduction in luminance reported by Hammett et al (2007). Error bars represent ± 1 SEM. The broken and solid lines represent the linear regression through the perceived speed and driving speed data respectively. Note the y axis is of log 2 scale.

In summary, we have found that luminance, temporal frequency and speed all appear to influence driving speed. Each of these attributes of stimuli has previously been found to influence speed judgments in lower level motion tasks (e.g. Thompson, 1982; Reisbeck and Gegenfurtner, 1999; Hammett et al, 2007). As such, the results are suggestive of a scheme whereby driving speed is modulated by an increase in perceived speed at low luminance (Hammett et al, 2007; Vaziri-Pashkam & Cavanagh, 2008). However, such an interpretation of the effect of luminance on driving speed is predicated upon the assumption that driving speed is determined by perceived speed. Our results provide only limited support for such a direct linkage. If driving speed is directly related to perceived speed, one would expect it to also increase exponentially over time in a manner inversely proportional to the known exponential reduction in perceived speed found during motion adaptation (Bex et al., 1999; Hammett et al, 2000; Hammett et al, 2005). Indeed, Gray and Regan (2000) find indirect evidence that overtaking in a driving simulator is influenced by motion adaptation. Our results demonstrate that driving speed effectively plateaus after initial acceleration and remains stable over 30 sec. Gray and Regan's task involved estimating when to overtake, not maintaining a target speed, after 5 minutes adaptation. Thus their task required estimating something akin to time-to-collision to an object moving at a slower speed. It may be that the very long adaptation durations used by Gray and Regan are required to elicit adaptation effects. However, this seems unlikely given the relatively fast (ca 8 sec) reduction in perceived speed previously reported. Alternatively, it may be that adaptation effects are enhanced by eccentric viewing (their stimulus was much larger). However, this also seems unlikely since they find that "… peripheral changing-size mechanisms contribute only minimally to these effects". A more likely explanation of the difference between our findings and theirs is that adaptation does affect our ability to make time-to-collision judgments but not judgments of perceived speed per se. This is entirely consistent with Gray and Regan's proposal that the effects they report are due to adaptation of changing size detectors rather than speed tuned mechanisms.

In experiment 2 we investigated whether the stability of driving speed over time was due to subjects setting an initial accelerator position and maintaining it regardless of any subsequent change in perceived speed. Subjects were required to change accelerator position every six seconds in order to maintain target speed. Since the gain of the accelerator was randomly changed every six seconds, subjects could not employ prior knowledge of accelerator positions and speeds to maintain target speed. The results indicate that subjects could maintain target speed under these conditions with no evidence of any change in driving speed over time. We cannot entirely rule out the possibility that subjects could achieve a constant speed under these conditions due to a disruption of speed adaptation induced by the physical change in speed that accompanied each gain change. However, this seems very unlikely given that the time course of speed adaptation is fast (see e.g. Hammett et al (2000) who show 20 – 25 % reduction in perceived speed after 8 sec adaptation) and therefore would yield evidence of adaptation within each six second epoch. Moreover, at least for those instances where physical speed was reduced after gain change, the adaptation effect should have been even more evident since adaptation to higher speeds is known to reduce the perceived speed of slower stimuli more than same-speed adaptation (Smith & Edgar, 1994; Hammett et al, 2005). Thus a straightforward account of the stability of driving speed in terms of proprioceptive cues appears unlikely.

The absence of any evidence of speed adaptation may simply be due to the stimulus not inducing adaptation. However, the results of Experiment 3 vie against this since the same stimuli and task do result in a motion after-effect. Whilst the existence of a motion after-effect is not direct evidence of a velocity after-effect, there is good electrophysiological, imaging and psychophysical evidence that the MAE is the result of modulation of relatively early motion sensitive processes (e.g. Hammond, Mouat & Smith, 1985; Nishida, Ashida & Sato, 1994; Tootel et al, 1995). For instance, evidence for a direct correlate of the MAE in speed-tuned cells of visual area MT has been reported by Kohn and Movshon (2003) and Huk, Ress & Heeger (2001) have reported population level response imbalances in human MT+ that underlie the MAE.

In summary, we find that reducing luminance leads to a reduction in perceived speed, consistent with the notion that driving speed is determined by perceived speed. However, we also find that driving speed is stable over 30 seconds. Two possible interpretations of these findings are (1) perceived speed guides driving speed and no velocity after-effect exists in more complex visual tasks, or (2) the effect of luminance is mediated by higher-order cognitive mechanisms and a tight linkage between driving speed and perceived speed simply does not exist. It may be that the reduction in driving speed we have found is due to higher-level processes that serve to slow down driving speed in conditions of lower visibility. Our subjects were experienced drivers and we cannot rule out the possibility, for instance, that they have learned to slow down in dim conditions. Alternatively, it may be that velocity after-effects are not induced in more complex visual tasks either due to attentional or other cognitive modulation of the effect or to a lower level mechanism that only yields velocity after-effects under certain conditions. Previous findings of a reduction in perceived speed after motion adaptation have relied upon subjects' comparisons of perceived speed across adapted and unadapted parts of the visual field (e.g. Thompson, 1981). Indeed, direct measurement of the effect of adaptation upon perceived speed can only be made using such protocols. As such, it is not known whether velocity after-effects are induced by stimuli that adapt all of the visual field. It may be that velocity after effects are mediated by a mechanism that is sensitive to spatial disparities in adaptive state, for instance by normalising local speed signals over space (cf Heeger, 1992). In the case of the present experiment the entire visual field (involved in the task) was adapted and it may be that under such conditions the visual system dynamically recalibrates the effective code for speed in light of adaptive processes in order to provide a constant signal for visually guided behaviour. (See Harris, Morgan & Still (1981) for a qualitatively similar proposal regarding the reduction of the motion after-effect in the presence of consistent vestibular cues).

A number of psychophysical studies of perceived speed have possible implications for driving behaviour (e.g. Thompson 1982; Gegenfurtner et al, 1999; Hammett et al, 2007). These studies invariably use tasks that require relative judgments about the speed of stimuli that are either spatially or temporally discrete. One of our prime motivations for conducting these studies was to investigate whether previous psychophysical reports using tasks that require such relative judgments were consistent with driving behaviour under conditions where mean luminance is constant across space and time. Given the consistency of the present results with those previously reported for perceived speed and previous studies consistent with a direct link between perceived speed and driving speed (e.g. Denton, 1976, 1980; Manser & Hancock, 2007) we favour an interpretation whereby driving speed is indeed modulated by perceived speed but is immune to previously reported velocity after-effects, possibly because such after-effects are mediated by spatially localised changes in gain. We cannot, however, rule out the possibility that driving speed is mediated by higher-level cognitive processes. Either way, the results indicate that caution should be taken in extrapolating from the (often striking) results of low-level psychophysical motion tasks to visually guided behaviour.

5.0 Acknowledgements

Sarah Pritchard is supported by an EPSRC scholarship; many thanks to Jonas Larsson, Emma McHarg, John Wann and the anonymous referees for their helpful advice and suggestions.

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