

Reduction of perceived visual speed during walking: Evidence against the involvement of attentional or vestibular mechanisms

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Introduction

We reported previously (Thurrell et al. 1998) that perceived expanding optic-flow speed is reduced linearly with increasing walking speed on an exercise treadmill. Any movement of the eyes, such as that resulting from locomotion, has a profound effect on the images projected on the retinae. Thus, in any visual determination of the position or movement of an object, account must be made of the movements of the eyes in space. As it is rare to walk on a moving surface, we postulated that signals of eye motion relative to the support surface, i.e. of walking speed, could preserve perceptual constancy during normal self-motion. However, two alternative mechanisms were proposed to explain the data: changes in attentional load have been shown to modulate visual motion aftereffects (Chaudhuri, 1990) suggesting that attentional changes during walking at different speeds may be responsible; and vestibular stimulation has been shown to increase visual motion detection thresholds and latencies (Probst et al. 1986) and may, therefore, extend to reductions in perceived visual motion speeds via the 'bobbing' motion of the head during walking.

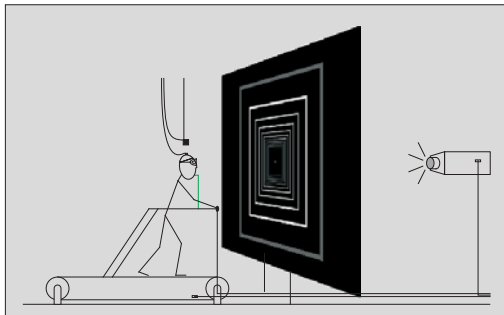


Figure 1. The experimental set-up. The bite-bar (green) was used to restrict head motion.

Methods

16 subjects between the ages of 19 and 24 were tested. Walking was performed on an exercise treadmill powered by the locomotion of the subject whilst holding the hand-rails, allowing subjects direct control of their walking velocity. Goggles were worn allowing vision only from the right eye and restricting peripheral vision. The visual stimulus consisted of a large screen (1.9m x 1.2m) directly in front of the treadmill on

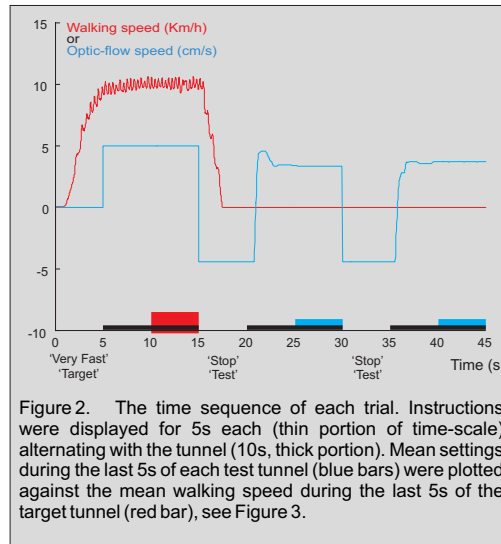


Figure 2. The time sequence of each trial. Instructions were displayed for 5s each (thin portion of time-scale) alternating with the tunnel (10s, thick portion). Mean settings during the last 5s of each test tunnel (blue bars) were plotted against the mean walking speed during the last 5s of the target tunnel (red bar), see Figure 3.

which was rear-projected a moveable tunnel composed of 15 bright squares on a dark background. A fixation point was also present at eye level in the center of the tunnel. The image resolution was 1024 x 768 refreshed at 35Hz, fully anti-aliased and tunnel components faded in and out of the background luminosity to reduce motion artefacts. Head position was monitored in all 6 degrees of freedom.

The order of the experiments was counterbalanced across the subjects, with 18 trials for each condition. Subjects adjusted the test tunnel velocity using a potentiometer placed near their right hand.

Each trial was 45s long (see Figure 2):

- ⊙ An instruction denoting a target presentation and for the motor activity speed, either 'stop', 'very slow', 'slow', 'normal', 'fast' or 'very fast' was displayed for 5s giving the subject time to reach this speed.
 - ⊙ A target tunnel velocity (always expanding at 5cm/s at the mid-hemifield position) was presented for 10s.
 - ⊙ The tunnel was removed for 5s and replaced with instructions to stop walking and adjust the tunnel speed. The tunnel speed was to be adjusted to that perceived during walking.
 - ⊙ A test tunnel whose velocity was controlled by the subject was presented for 10s.
 - ⊙ A second test tunnel followed in an identical manner.
- The three different conditions were:

- ⊙ The control condition as above.
- ⊙ The attention condition, in which an auditory-verbal summing task of 5 single-digit numbers was presented concurrently with the target presentation.
- ⊙ The restricted head motion condition, in which subjects' head positions were fixed using a bite-bar rigidly attached to the treadmill.

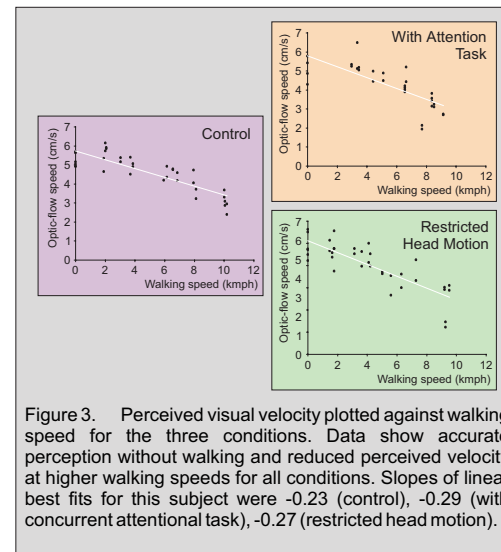


Figure 3. Perceived visual velocity plotted against walking speed for the three conditions. Data show accurate perception without walking and reduced perceived velocity at higher walking speeds for all conditions. Slopes of linear best fits for this subject were -0.23 (control), -0.29 (with concurrent attentional task), -0.27 (restricted head motion).

Results

- ⊙ 12 out of 16 subjects showed the previously reported effect of reduced perceived visual velocity due to walking in the control condition. The slope of line of best fit was taken as the effect strength (see Figure 3) for each condition. Remaining subjects produced anomalous results possibly due to misinterpretation of instructions or lack of immersion in the environment and were discarded.
- ⊙ In all conditions, the mean strength of the influence of walking speed on expanding optic-flow perception was significantly different from zero ($P < 0.05$).
- ⊙ In the attention condition, the average effect strength was lower (slope of 0.35 vs. 0.42), though not significantly so (Paired t-test, 2 tailed, $n = 10$), than during the Control condition.
- ⊙ In the restricted head motion condition, the average effect

strength was also lower than during the control condition (slope of 0.23 vs. 0.44), though this was not significant ($P < 0.05$, paired 2 tailed t-test, $n = 6$). During the restricted head motion condition, linear head motion was reduced by a factor of ~15 laterally and ~5 otherwise, whilst rotational motion was reduced by a factor of ~10 for yaw and roll, though pitch motion remained unchanged.

Discussion

Confirming previous findings, visual motion perception is influenced by walking in approximately three-quarters of subjects. Neither increasing the concurrent attentional load nor reducing the vestibular stimulation due to walking, significantly alters the influence of walking speed on expanding optic-flow perception. We suggest, therefore, that these findings support the hypothesis that this reduction in perceived expanding optic-flow speed functions to maintain

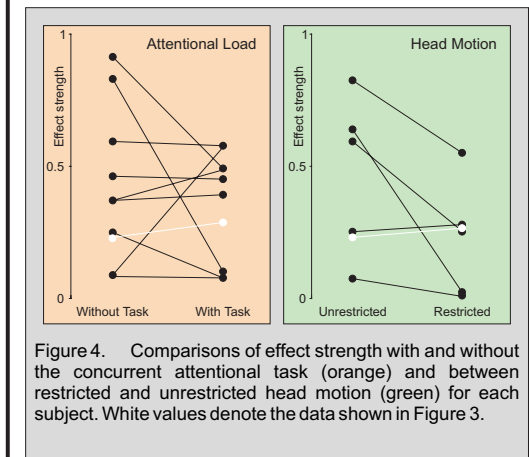


Figure 4. Comparisons of effect strength with and without the concurrent attentional task (orange) and between restricted and unrestricted head motion (green) for each subject. White values denote the data shown in Figure 3.

References

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