Reduction of perceived visual speed during walking: Effect dependent upon stimulus similarity to the visual consequences of locomotion

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Introduction

Movement of the eyes 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. We reported previously (Thurrell et al. 1998) that perceived optic-flow speed is reduced linearly with walking speed. As it is rare to walk on a moving surface, we postulated this mechanism would preserve world constancy during normal self-motion. Previous findings that this effect is tuned to motor activities similar to natural locomotion (walking) support this hypothesis (Pelah et al. 2001). The hypothesis that this effect is due to mechanisms of perceptual constancy would be bolstered if the effect were also strongest for optic-flow patterns similar to those experienced during natural locomotion (walking). We therefore tested the effect on five optic-flow patterns progressively less similar to natural locomotion: an Expanding Tunnel, a Horizontal Grating, a Vertical Grating, a rotating Cartwheel and a Flashing Tunnel.

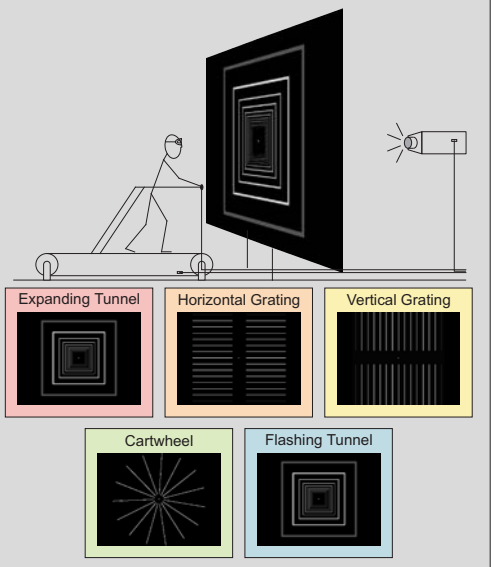

Figure 1. The experimental set-up and the 5 optic-flow patterns used.

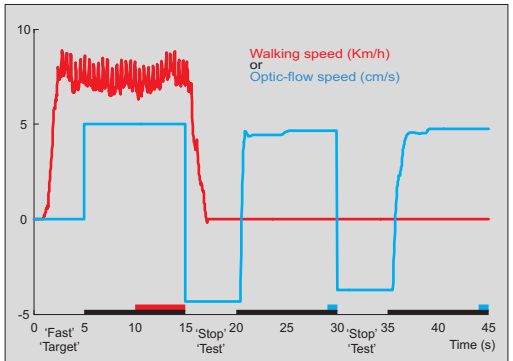

Figure 2. The time sequence of each trial. Instructions were displayed for 5s each (thin portion of time-scale) alternating with the tunnel (10s, thick portion). Mean settings during the last 1s of each test tunnel (blue bars) were plotted against the mean walking speed during the last 5s of the target tunnel (red bar), see Figure 3.

Methods

15 naïve subjects between the ages of 21 and 57 were tested. Walking was performed on an exercise treadmill powered by the locomotion of the subject whilst holding the hand-rails, allowing direct control of their walking velocity. Monocular goggles were worn also restricting peripheral vision. The visual stimulus consisted of a large screen directly in front of the treadmill on which optic-flow patterns were rear-projected. A fixation point was always present at eye level in the centre of the screen. The image resolution was 1280 x 1024 refreshed at 30Hz and fully anti-aliased to reduce motion artefacts.

The five conditions:

- The Expanding Tunnel consisted of 15 bright rectangles expanding and looming against the dark background.
- The Horizontal Grating consisted of 15 horizontal lines moving downward. Each line was masked in the central 20% of the screen to reduce cueing as each line passed the fixation point.
- The Vertical Grating was similar to the Horizontal Grating but rotated anti-clockwise (moving rightward).
- The Cartwheel consisted of 15 radial spokes rotating anti-clockwise around the fixation point. The innermost 10% of each line was masked for comparison to other stimuli.
- The Flashing Tunnel was similar to the Expanding Tunnel but stationary and with a sinusoidally varying luminosity.

Each trial was 45s long (see Figure 2) and repeated 18 times for each pattern:

- An instruction denoting a target presentation and for the walking speed, either 'stop', 'very slow', 'slow', 'normal', 'fast' or 'very fast' was displayed for 5s giving the subject time to reach this speed from rest before…
- A target pattern (moving at 5cm/s at the mid-hemifield position or flashing at 2Hz) was presented for 10s.
- The pattern was removed for 5s and replaced with instructions to stop walking and to adjust the optic-flow speed, using a potentiometer placed near their right hand, to the target speed perceived during walking.
- A test pattern whose velocity was controlled by the subject was presented for 10s.
- A second test pattern followed in an identical manner.

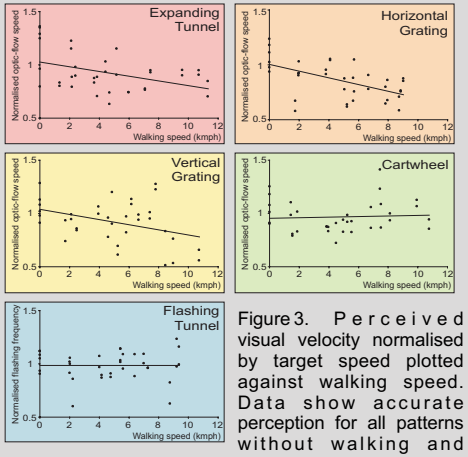

Figure 3. Perceived visual velocity normalised by target speed plotted against walking speed. Data show accurate perception for all patterns without walking and reduced perceived velocity at higher walking speeds for the Expanding Tunnel and both gratings for this subject, but not for the Cartwheel or the Flashing Tunnel. Slopes of linear best fits were 0.023 (Expanding Tunnel), -0.031 (Horizontal Grating), -0.025 (Vertical Grating), -0.0025 (Cartwheel) and 0.00039 (Flashing Tunnel).

Results

- 9 out of 15 subjects showed the previously reported effect of reduced perceived optic-flow speed during walking.
- The effects of walking speed on the perceived Expanding Tunnel and Horizontal Grating speeds were significantly different from zero ($P < 0.05$), but not from each other.
- The effect of walking speed on the perceived Vertical Grating and Cartwheel speeds and the perceived Flashing Tunnel frequency were not significantly different from zero.

Discussion

Confirming our previous findings, expanding optic-flow perception is influenced by walking. Downward linear motion was also significantly affected by walking speed. Linear sideways motion, rotation and flashing perception were not found to be significantly affected by walking speed. This trend may be explained by the similarity of the optic-flow pattern to that experienced during natural locomotion: Expansion as the 'gold standard' would be the most common optic-flow pattern generated by walking. Downward linear motion may correspond to motion of a ground surface while reducing conflict with an apparently non-moving sky. However, sideways linear motion, rotational motion and flashing do not normally result from walking. These results are therefore consistent with the hypothesis that non-visual signals of walking are used to disambiguate optic-flow perception.

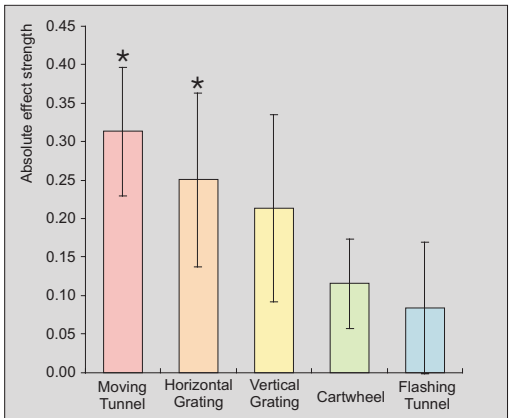

Figure 4. Intersubject mean (± s.e.m.) of absolute slopes for each optic-flow pattern showing the trend in effect magnitude from the Expanding Tunnel to the Flashing Tunnel. Asterisks denote values significantly different from zero.

References

A. Pelah, A.E.I. Thurrell and M.Berry (2001) Reduction of perceived visual speed during locomotion: Evidence for quadrupedal perceptual pathways in humans? Journal of Vision 1 (3), 307a.

A.E.I. Thurrell, A. Pelah and H.K. Distler (1998) The influence of non-visual signals of walking on the perceived speed of optic flow. Perception 27, 147.