Effects of visual field on perceived speed of self-motion from optic flow

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We investigated effects of visual field on perceived speed of self-motion from optic flow in two experiments. The optic flow patterns were produced as if an observer moved through a cylindrical volume (3m in radius) of which surface was filled with random dots. Observers compared perceived self-speed with the test stimulus to that with the stimulus presented on a full screen by two-alternative forced-choice staircase algorithm. In experiment 1 the test stimulus was curtailed radially to examine the effects of stimulus area. The results showed that the perceived self-speed increased with stimulus area. In experiment 2 the stimulus was curtailed concentrically to examine the interactions between stimulus area and retinal position. The results showed that the perceived self-speed increased with average of retinal image velocity. We suggest that perceived self-speed from optic flow is affected by 2-D factors, stimulus area and retinal distribution and that distance perception error may elicit different self-speed as a function of retinal eccentricity.

Keywords: self-motion, visual field, optic flow, perceived speed.

Introduction

When we move around the environment, complex optic flow fields falls on the retina. This flow field has information for heading direction, heading speed, vection and postural adjustments. The self-motion information is processed in wide visual field, which has been shown physiologically and psychophysically(Berthoz, Pavard, & Young, 1975; Brandt, Dichgans, & Koenig, 1973; Burr, Morrone, & Vaina, 1998; Held, Dichgans, & Bauer, 1975; Lestienne, Soechting, & Berthoz, 1977; Tanaka, & Saito, 1989). Our concern here is to investigate effects of visual field on perceiving heading speed.

In order to investigate effects of visual field on perception of heading speed, we need to consider two factors, stimulus area and retinal position. About the first factor, the literature reported that visual performance based on optic flow improved with stimulus area(Burr, Morrone,M. & Vaina, 1998; Morrone, Burr, & Vaina, 1995). The second factor consists of two sub-factors. One is the retinal characteristics that visual performance usually deteriorates with eccentricity. The other is the retinal distribution that image velocity of radial flow on the retina increases with eccentricity.

Goal of this study is to clarify effects of three factors described above on perceived self-speed from optic flow. To do this, we conducted two experiments. In experiment 1, we measured effect of stimulus area. In experiment 2, we measured interaction between stimulus area and retinal position. In addition, we make a model equation that perceived self-speed is predicted by effects of three factors.

Experiment 1

<u>Stimulus & Method</u>

The observers viewed motion sequences that simulated translation (straight-line motion) through a cylindrical volume (3m in radius, 100m in depth) of which surface was filled with random dots. The simulated heading speed was either 18 or 72 km/h. Stimulus area was one of 5, 12, 25, 50 and 100% of whole screen and varied by changing an angle of each sector. The pattern was curtailed to 1, 2, 4, 8 sectors and maximally separated from the others. Temporal two alternative forced-choice algorithm were used to determine the perceived speed what they translate forward relatively to the stimulus. On each trial, observer saw two motion sequences, test and reference stimulus. Each stimulus appeared for 5 sec separated by an interval of 1 sec. Four observers in experiment 1 and five observers in experiment 2 participated.

<u>Results</u>

Fig.1 shows the results of perceived self-speed with one observer for numbers of the stimulus sectors as a function of stimulus area in 18km/h. Perceived self-speeds for all observers increase with stimulus area. For several observers, the perceived self-

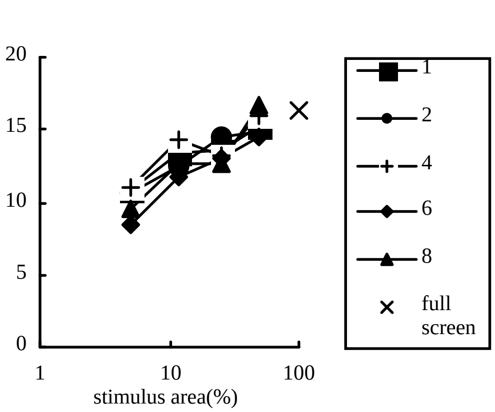

Fig.1 The results of perceived self-speed as a function of stimulus area in18 km/h(observse WT).

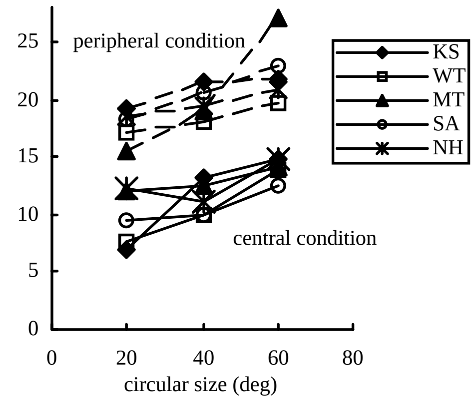

Fig.2 The results of perceived self-speed as a function of circular size in 18 km/h.

speed at identical stimulus area decreases with addition of numbers of the stimulus sectors especially when stimulus area is small. It is suggested that stimulus area strongly contributes to perceived self-speed.

Experiment 2

Stimulus & Method

Apparatus, stimuli and procedure were same except several points bellow. Stimulus configuration was varied concentrically in 6 stimulus conditions, 3 of them are peripheral sub-conditions, only dots outside the circular border were visible and another 3 are central sub-conditions, dots within a circular border were visible. The diameter of the circular border varied among 20, 40 and 60 deg.

Results

Fig.2 shows the results of perceived self-speed for central and peripheral conditions as a function of circular border size in 18 km/h. The results for all observers show that perceived self-speeds in central and peripheral conditions increase with circular border size. It is suggested that retinal image velocity strongly contributes to perceived self-speed.

Discussion

To clarify contribution of the three factors to perceived self-speed, we introduce a model equation consisted of these factors, which predicts perceived self-speed.

Perceived self-speed(Vpe) = Vsi{aA + b (PdPc)}

Vsi was simulated speed (km/h) and a,b were constant. A was normalized perceived self-speed against stimulus area, which was derived from results of experiment 1. Pd was physical dots velocity on the retina. Pc was normalized retinal characteristics as a function of eccentricity and was taken form the previous data, Tynan & Sekuler (1982). We also applied Pc as simply unity or one as a multiple factor. It means (Pd Pc) will be just Pd. (Pd Pc) was an average of perceived image velocity of the stimulus derived from (Pd Pc) for each corresponding eccentricity.

We calculated Vpe to fit to the results of experiment 2. In this calculation, the constants a and b are optimized by multiple regression analysis. The results show that the model equation fitted very well into the results of experiment 2 even when we neglected the effect of Pc as being one. (r^2= 0.851 in 18km/h and r^2= 0.922 in 72 km/h). This result reveals that that Pc doesn't affect Vpe. Therefore it suggests that two factors, stimulus area and retinal distribution, contribute greatly to perceived self-speed.

Our result suggests that 3-D scaling of self-speed perception from 2-D information may not be accurately occurred. We can consider a possibility that the observer perceives the tunnel as a cone but not a strict cylinder. Distance perception error may elicit different self-speed as a function of retinal eccentricity.

Conclusion

In summary, our results indicated that perceived self-speed from optic flow is affected by two 2-D factors, stimulus area and retinal distribution. Distance perception error elicit, at least a part of the difference in self-speed depending on retinal eccentricity.

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