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VISUAL CONSTANCY DURING MOVEMENT: 2. SIZE CONSTANCY USING ONE OR BOTH EYES OR PROPRIOCEPTIVE INFORMATION

R. L. GREGORY AND HELEN E. ROSS[1]

University of Cambridge, England

Summary.—A method for estimating constancy during motion, described in a previous paper, is used to find the effect of proprioceptive information of *O*'s movement on visual size constancy. *Os* were carried in darkness backward and forward on a swing, while their constancy was estimated. It was found that constancy was improved when *Os* received proprioceptive information of their movement. Constancy was greater for binocular than monocular viewing of the self-luminous display; and constancy was greater for forward than backward movement.

It was shown in the preceding paper by Gregory and Ross (1964) that, when *O* was moving forward on a swing in the dark, visual size constancy was better than during backward movement. In that experiment *O* used only one eye, the other being covered. Further experiments were performed using a similar procedure to determine whether: (1) the use of both eyes gave better size constancy than use of one eye; (2) size constancy was better during forward than backward movement of the observer using both eyes; (3) the addition of a fixation line in the display improved size constancy with both eyes; and (4) the addition of proprioceptive information, by means of swinging on the hands, improved size constancy. It was thus hoped to elucidate further some of the factors involved in size constancy during movement of *O*.

METHOD

Apparatus and procedure.—Except where otherwise stated the apparatus and general procedure were the same as those in the preceding paper by Gregory and Ross (1964). For Exps. 2 and 3 a vertical fixation line was added through the centre of the display circle. This was provided by the second oscilloscope trace, so that this fixation line varied in size with the display circle.

For Exp. 4 hand rails were added on both sides of the swing. These were made from rope covered with rubber tubing and tied tightly to the metal supports of the swing. *O* grasped the centres of the ropes and swung himself backward and forward with his hands but without allowing his hands to slip. Care was taken that the amplitude of swing was the same with this method as it was when *O* swung himself by pressing his feet on the ground. Unlike the previous method, *O* never allowed himself to swing passively but always pulled and pushed himself on his hands while making judgments.

Subjects.—44 *Os* were research students, undergraduates, and students from the technical college and language schools. They were of both sexes, with an age range between 17 and 30 yr.

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EXPERIMENT 1

The aim of this experiment was to find out whether the use of both eyes gave better size constancy than the use of one eye only, using the simple circle display, *O* swinging passively in the dark.

Method.—Seven *O*s were tested under the same general procedure as before (Gregory & Ross, 1964). They were tested under binocular and monocular viewing. In the monocular condition one eye was covered with a shield. In both conditions only forward movement was used. The orders of testing for the two conditions were alternated between *O*s. The brightness of the display was reduced for the binocular condition in order to keep apparent brightness constant.

Results.—The results are shown in Table 1. It is clear that two eyes give better size constancy than one, the difference being significant by the Walsh test

TABLE 1

MEAN CONSTANCY SCORES ($\pm SD$) FOR ONE OR BOTH EYES DURING FORWARD MOVEMENT

O	Sex	One eye	Both eyes	*O*	Sex	One eye	Both eyes
1	F	0.21±0.12	0.50±0.06	5	M	0.32±0.04	0.41±0.18
2	M	0.04±0.15	0.39±0.15	6	M	0.00±0.26*	0.12±0.11
3	M	0.11±0.12	0.19±0.14	7	F	0.13±0.14	0.23±0.15
4	M	0.23±0.06	0.28±0.12	*M*		0.13±0.12	0.28±0.14

Note.—Asterisks indicate the number of extra SVC settings used.

($p = .01$, one tail). This result was expected since it is very well known that, when *O* is stationary two eyes gives better constancy than one. As found previously for one eye, the display was perceptually ambiguous and was sometimes seen to advance or retreat as well as expanding and contracting. The addition of a second eye did not remove the ambiguity, and two *O*s gave more varied binocular perceptions than monocular.

EXPERIMENT 2

The purpose of this experiment was to discover whether constancy is different for forward and backward movement when both eyes are used. To make sure that convergence was given adequately by the display, a visual fixation line was added to the circle although this was later found to be unnecessary (Exp. 3).

Method.—12 *O*s were tested under our previous procedure, but using both eyes. Half were tested first for forward movement, the other half for backward movement. *O*s were instructed to fixate upon the vertical fixation line while making their judgments.

Results.—The results are shown in Table 2. Even when both eyes are used, forward movement gives significantly better size constancy than backward movement (Walsh test, $p = .01$, two tails). Nine of 12 *O*s interpreted the display as advancing or retreating in space as they moved on the swing. One *O* saw only movement of the display and no size change, so that her results were calculated from the direction of the apparent movement instead of from the apparent size change (as described in the preceding paper).

TABLE 2

MEAN CONSTANCY SCORES ($\pm SD$) FOR FORWARD AND BACKWARD MOVEMENT USING BOTH EYES

O	Sex	Forward	Backward	*O*	Sex	Forward	Backward
1	M	0.17±0.09	0.19±0.07	8	M	0.41±0.11	0.38±0.32*
2	M	0.41±0.09	0.40±0.09	9	M	0.43±0.12	0.28±0.10
3	M	0.24±0.20	0.11±0.15	10	M	0.26±0.16	0.04±0.09
4	M	0.38±0.11	0.19±0.19	11	M	0.32±0.15	0.17±0.11
5	M	0.13±0.11	0.16±0.07	12	M	0.30±0.12	0.26±0.05
6	M	0.16±0.12	0.01±0.19	*M*		0.31±0.12	0.19±0.11
7	F	0.37±0.15	0.22±0.33**				

Note.—Asterisks indicate the number of extra SVC settings used.

EXPERIMENT 3

To discover whether the addition of the vertical fixation line, presumably improving convergence, improved size constancy during movement of the observer using binocular viewing, 9 *O*s were tested. Under the usual procedure, using both eyes, constancy was compared with and without the fixation line. Half the *O*s were tested first with the line present, the other half without.

TABLE 3

MEAN CONSTANCY SCORES ($\pm SD$) WITH AND WITHOUT A FIXATION LINE, USING BOTH EYES, AND SWINGING FORWARD

O	Sex	With line	No line	*O*	Sex	With line	No line
1	M	0.24±0.13	0.12±0.08	6	M	0.28±0.18*	0.24±0.12
2	M	0.34±0.17	0.37±0.18*	7	M	0.13±0.16	0.19±0.18
3	M	0.18±0.16	0.20±0.17	8	M	0.30±0.14	0.28±0.17
4	M	0.41±0.10	0.38±0.06	9	M	0.39±0.15	0.45±0.12
5	M	0.23±0.09	0.21±0.08	*M*		0.28±0.15	0.24±0.12

Note.—Asterisks indicate the number of extra SVC settings used.

In Table 3 the *M*s and *SD*s give no suggestion of a difference between the two conditions. Thus a fixation line seems unnecessary in using this technique for estimating constancy during movement.

EXPERIMENT 4

Method.—To discover whether the addition of proprioceptive information from the arms improved size constancy during movement, 16 *O*s made judgments, using one eye only during forward movement. Two conditions were compared: one was the usual procedure of swinging passively (after starting the swing by pressing on the ground with the feet), while in the other procedure *O* swung himself while judging by holding the side ropes firmly and pulling and pushing on them. Half the *O*s were tested first under each condition, and care was taken that the amplitude of swing was the same.

Results.—As shown in Table 4 size constancy was better with proprioception from the arms, the difference being significant (Wilcoxon test, $p = .01$,

TABLE 4

MEAN CONSTANCY SCORES (±SD) FOR PASSIVE AND ACTIVE SWINGING, USING ONE EYE AND SWINGING FORWARD

O	Sex	Passive	Active	*O*	Sex	Passive	Active
1	F	0.08±0.21*	0.00±0.15	10	F	0.23±0.20	0.32±0.20*
2	M	0.20±0.15	0.02±0.05	11	M	0.28±0.09	0.37±0.08
3	M	0.30±0.10	0.38±0.10	12	F	0.14±0.16	0.23±0.08
4	M	0.15±0.08	0.22±0.09	13	M	0.15±0.08	0.23±0.07
5	F	0.07±0.10	0.07±0.20	14	M	0.08±0.08	0.26±0.12
6	M	0.00±0.30*	0.22±0.10	15	M	0.09±0.12	0.19±0.10
7	M	0.11±0.20	0.27±0.12	16	M	0.12±0.09	0.23±0.12
8	M	0.19±0.12	0.34±0.05	*M*		0.13±0.12	0.23±0.10
9	M	0.11±0.32**	0.32±0.08				

Note.—Asterisks indicate the number of extra SVC settings used.

two tails). Thus, proprioceptive information can add to visual information in the determination of size constancy during *O*'s active movement. This result is of some interest in considering visual performance in driving, flying, or space travel for in such situations *O* is denied proprioceptive information from his movement, as unlike walking or running his limbs are carried with him. It also suggests that proprioceptive neural activity unrelated to velocity through space might give rise to visual errors, prejudicing judgment of speed and distance. In this experiment there was a slight indication of a sex difference in the use of proprioceptive information: the mean constancy index for the males was 0.25 and for the females, 0.16. This difference is not significant but agrees with the findings of Witkin (1949, 1952) who showed that, when postural and visual cues conflict, men make more use of postural cues than women.

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