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CLINICAL INVESTIGATION

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Age-related deterioration of motion perception and detection

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Abstract ● Purpose: The purpose of this study was to evaluate the effect of aging on motion detection and perception. ● Methods: Forty-six subjects, ages 19–92 years, were asked to view a motion stimulus. Infrared oculography was used to objectively evaluate motion detection by documenting the presence of optokinetic nystagmus as the subjects viewed the stimulus. Subjective responses to motion perception were recorded using a computer joystick. ● Results: Optokinetic nystagmus was clearly detectable in all 46 subjects. Motion detection and perception thresholds showed age-related deterioration. No relationship was found to gender or age-gender interaction. ● Conclusion: The results indicate motion detection and perception thresholds deteriorate with age. This may reflect a susceptibility to age-related degeneration in specific cortical areas responsible for motion perception as well as neurodegeneration in the retinogeniculate pathway.

Introduction

Several studies have described a decline in the motion perception sensitivity of the visual system with aging [2, 11, 13], whereas others have reported that this decline occurs only in women [5]. Motion has been characterized as a function of the M-cell pathway [3]. For the present study, we evaluated the effect of aging on motion detection and perception by measuring thresholds in visually normal subjects from 19 to 92 years of age (n=46). We utilized a system which separately assessed the conscious perception of motion and the objective detection of motion as indicated by the onset of optokinetic nystagmus (OKN). In our study, we attempted to better elucidate the relative importance of higher cortical versus subcortical (or retinogeniculate) degeneration in the deterioration of the motion sensitivity that occurs with aging.

Material and methods

This research followed the tenets of the Declaration of Helsinki. The nature and possible consequences of the study were explained to each participant and informed consent was obtained from each. The research was approved by the University of Southern California's Internal Review Board.

Subjects

Forty-six visually normal volunteers (22 males, 24 females) aged 19–92 years were drawn from employes of the Doheny Eye Institute and the local community. All subjects had a best corrected visual

Table 1 Subject characteristics (*OKN* optokinetic nystagmus, *JOY* joystick response)

		Threshold of % coherence				Threshold of % coherence	
ID	Age (years)	OKN	JOY	ID	Age (years)	OKN	JOY
F01	19	6.47	5.81	M01	24	4.33	1.64
F02	25	2.07	1.21	M02	26	12.87	1.00
F03	28	6.08	1.54	M03	26	2.14	1.64
F04	29	7.75	1.21	M04	27	5.73	2.63
F05	29	9.64	2.43	M05	27	3.86	2.86
F06	30	7.39	1.78	M06	28	8.00	5.21
F07	31	18.19	1.54	M07	28	2.42	3.84
F08	32	7.45	3.51	M08	31	4.62	2.61
F09	33	6.49	3.13	M09	35	19.86	0.76
F10	36	13.76	2.42	M10	35	14.98	3.06
F11	40	4.74	4.74	M11	35	6.16	4.62
F12	43	4.47	4.21	M12	41	2.11	2.11
F13	46	12.43	3.67	M13	46	6.16	3.84
F14	48	7.03	5.51	M14	51	4.62	6.05
F15	51	19.88	5.74	M15	53	14.24	7.17
F16	53	3.60	5.48	M16	54	8.38	2.72
F17	59	19.34	2.95	M17	57	12.87	7.34
F18	60	9.70	6.35	M18	58	1.64	2.86
F19	64	16.56	7.63	M19	67	15.90	2.95
F20	69	15.52	9.48	M20	69	12.12	3.66
F21	69	16.81	4.21	M21	71	1.64	5.40
F22	69	8.61	3.13	M22	92	16.74	0.84
F23	75	6.30	4.97				
F24	86	13.38	2.63				

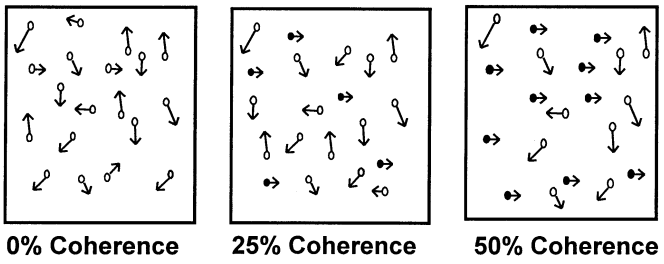

Fig. 1 Schematic representation of the motion stimulus. Display at *left* is perceived as random noise. Coherent motion signal is produced (*center* and *right*) by replotting a subset of dots at a fixed spatial offset in a common direction

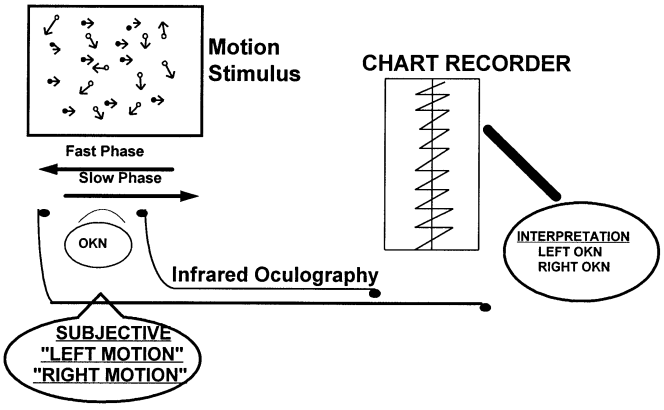

Fig. 2 Schematic representation of the testing protocol. Subjects binocularly viewed a random dot motion stimulus in a darkened room. Infrared oculography was used to monitor eye movements for the presence of optokinetic nystagmus (*OKN*) while the subjective perception of motion was recorded

acuity of at least 20/40, and all underwent a complete ophthalmic examination, including intraocular pressure measurement, pupillary response, optic nerve evaluation, and color vision, Subjects with evidence of any CNS or ocular disease, including clinically significant lens or optic nerve changes, were excluded (Table 1).

Apparatus

Motion stimulus

The motion stimulus was produced on a 25-in. Zenith cathode ray tube (CRT) under control of a 4.77- MHz IBM PC with software developed by one of the authors (S.E.S.). In the random dot display, an array of 100 randomly located dots was plotted in rapid succession (11.5 Hz) on a black background (contrast 99%). Individual dots subtended 14 min of field and moved at 2.5 deg/s, with an overall field size of 30°×30°. Subjects viewing this display perceive random motion noise (Fig. 1, left), as there is no net motion in the display. When a subset of the dots is replotted at a fixed spatial offset (0.5°) in a common direction (left or right), a coherent motion signal is produced, embedded within the background of random motion noise (Fig. 1, center and right). The proportion of dots in coherent motion can be varied between 0% and 50% in equal increments, thereby producing graded intensities of the motion signal. No position cues were embedded in the display. This technique has been shown to effectively isolate motion processing [8, 9].

Infrared oculography

Infrared oculography was utilized to record eye movements for the presence of OKN. Subjects wore plano spectacles fitted with infrared emitters and sensors. Sensors were adjusted so that they straddled the medial and lateral aspects of the corneal limbus of each eye. The amount of light reflected from each eye was converted into an electrical signal and was electronically subtracted (lateral from medial sensor) in each eye to give a horizontal eye position. This position was plotted on a six-channel oscillographic recorder (Gould 2600) for later analysis.

Testing procedure

Testing was performed in a darkened room. Each subject binocularly viewed the CRT display at 64 cm (Fig. 2). Initial practice trials were presented at a 40% coherence level. The subjects were given specific instructions to respond to the direction of motion (left or right) on each trial with the computer joystick. This forced response was necessary before the initiation of the next trial. The subjects continued these practice trials until they correctly discerned the directions of motion for six consecutive trials. Once the subjects fulfilled these criteria and felt that they understood the objective of the test well, the test was begun. The test consisted of 80 randomly ordered trials with ten trials, presented at each of eight coherence levels, ranging from 0% to 50%. The stimulus was presented for a duration of 10 s in each trial, after which the screen was blank before the next trial. A two-alternative (left or right) forced choice procedure was used. There was a 1-s pause between trials; the entire test took approximately 10 min. Possible effects of an age-dependent de-

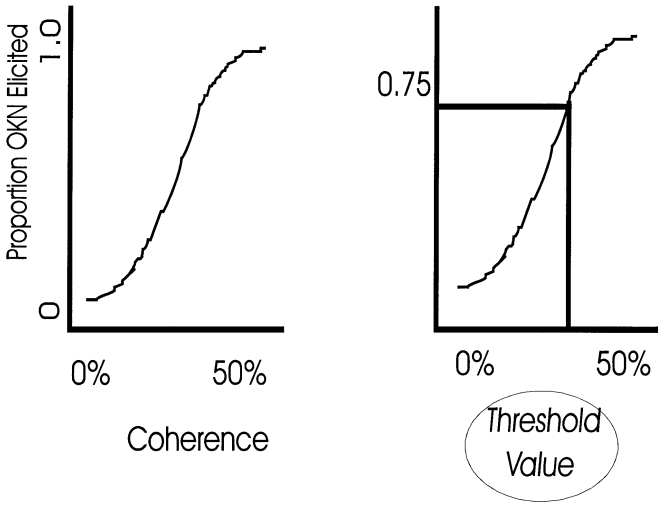

Fig. 3 Determination of motion detection threshold. The proportion of time an optokinetic nystagmus (*OKN*) was elicited was plotted against the percent motion coherence. The motion threshold was extrapolated from a probit analysis curve fit to the data

crease in attention span were alleviated through random presentation of stimuli, constant observation of subject by test administrator, and the forced choice methodology. Further details of the methodology have been previously reported [12].

Data interpretation

The subjective responses were recorded by joystick response and stored to the computer for later analysis. OKN was recorded on the chart recorder (Fig. 2). Tracings were later analyzed by one of the authors (D.B.T.) to determine the presence and direction of OKN. The author was masked to the true motion direction and the subjective response. Both the perception of motion and the direction of OKN were compared to the actual direction of the motion stimulus on a trial-by-trial basis. The motion detection threshold was defined as the coherence needed to produce an OKN in the corresponding direction 75% of the time. The motion perception threshold was similarly defined as the coherence needed to elicit a correct subjective response 75% of the time. Motion perception and detection thresholds were calculated by a probit analysis best fit to the data (Fig. 3). Since the motion perception thresholds were determined in a two-alternative, forced-choice procedure (producing a correct subjective response 50% of the time by chance alone), they cannot be directly compared to the motion detection thresholds, which were determined by the direction of OKN only when present. The relationship of each of the sets of thresholds to age and gender were assessed using least-squares multiple linear regression techniques.

Results

All 46 subjects were able to complete the motion perception task with adequate infrared oculography tracings for motion detection analysis. Optokinetic nystagmus was clearly detectable in all of these subjects. The average motion detection threshold was 9.24 (SD 5.5); the average motion perception threshold was 3.70 (SD 2.0). Both the motion detection and perception thresholds showed an age-related deterioration (Figs. 4, 5). The motion detection threshold increased with age (1.1% per decade; r=0.37, P<0.01). Similarly, the motion perception threshold increased with age (0.4% per decade; r=0.35, P<0.01). Neither threshold showed any relationship to gender or age-gender interaction when analyzed separately. Furthermore, there was no correlation between perception and detection thresholds for all ages (r=0.09).

Discussion

Neuropathologic studies have shown an age-related degeneration in the distal retina [7], proximal retina [14], optic nerve [1, 6] and visual cortex area [4]. In the present study, we found an age-related linear decrease in the objective motion detection sensitivity as evidenced by the onset of

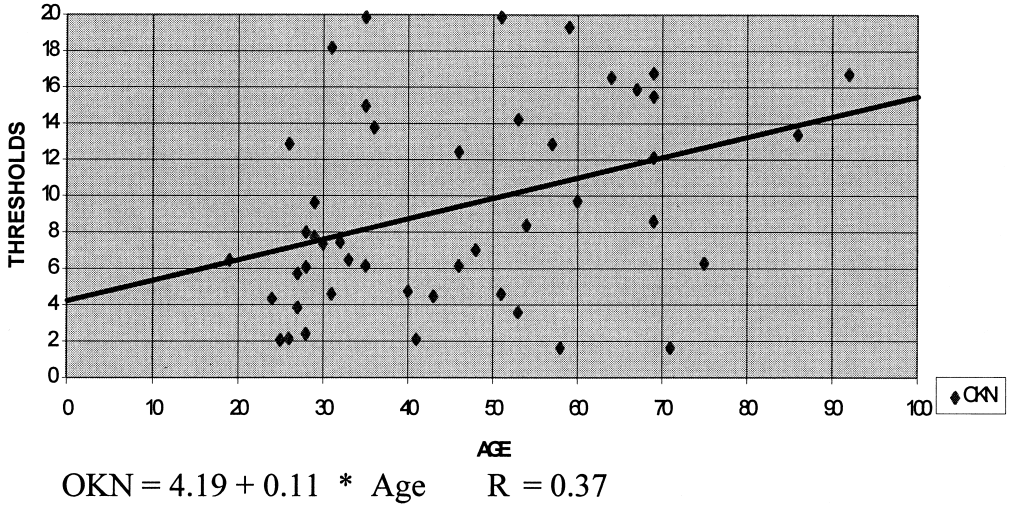

Fig. 4 Objective motion detection threshold was plotted against age. A linear regression analysis was performed and the equation was superimposed on the plot. *OKN* Optokinetic nystagmus, *R* correlation coefficient

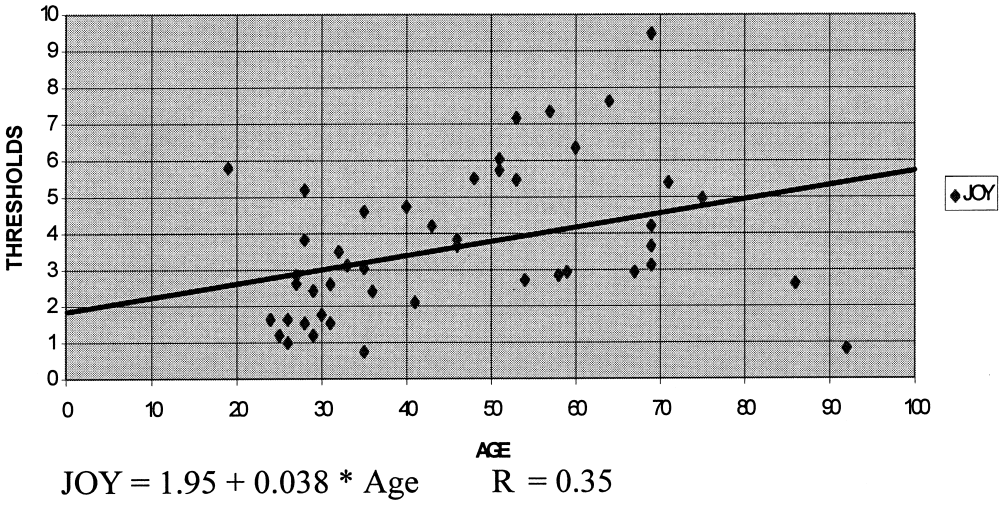

Fig. 5 Subjective motion perception threshold was plotted against age. A linear regression analysis was performed and the equation was superimposed on the plot. *JOY* Joystick, *R* correlation coefficient

OKN in the observed population (n=46). Similarly, the subjective motion perception sensitivity in the observed population (n=46) showed a decline with age. In a recent study, Gilmore et al. [5] found a similar decrease in motion sensitivity as a function of age in females. In a separate gender-specific analysis of our results, we found both the detection and perception sensitivity were generally lower in females than males. This relationship, however, was not statistically significant when examined by multiple linear regression analysis. This study did not have high statistical power to detect small or moderate effects of gender.

In previous studies, Trick and Silverman [13] found a linear decline in motion sensitivity of about 1% per decade that could not be attributed to optical changes. In particular, optical defocus (blurring) worse than 20/100 had no effect on motion thresholds (a 6+ lens was put over the eye and thresholds were unchanged; cataract would cause a similar type of blurring). It was suggested that the observed decrease in motion sensitivity resulted from age-related neurodegeneration in the retinogeniculate pathway. Our present data support these findings. The measurement of the perception of motion may assess different components of the motion pathway than the detection of motion as signaled by the OKN response. Our study did not find a relationship between perception and detection thresholds, suggesting that these two neural pathways are distinct. Though not well defined, the OKN pathway appears to have cortical and subcortical loops. The conscious perception of motion appears to be largely dependent on the middle temporal (MT) area of the visual cortex [10, 15]. We found age-related deterioration of visual function attributable to both of these pathways. This may reflect a susceptibility to age-related degeneration in specific cortical areas responsible for motion perception (i.e. MT area) as well as the neurodegeneration in the retinogeniculate pathway.

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