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Original Paper

The Relationship between Aging and the Detection of Dynamic Movement in Drivers' Visual Functions

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Abstract

Elderly drivers over the age of 75 have been required to attend traffic safety courses since January 1999. In the courses, visual acuity tests for motion are performed as a part of the aptitude tests, and about 80% of the subjects show scores of 0.1 - 0.2, which is the lowest boundary level. This result raises doubts about the effectiveness of the visual acuity tests for motion in elderly people. A further problem is that the test method and the results obtained with this method have not been fully evaluated.

In this study, dynamic moving detection, misses(non-responses), false alarms, and delayed responses were measured in 518 drivers between the ages of 10 and 90 using a dynamic vigilance checker (DVC), which was developed to solve the problems of the conventional visual acuity tests of motion. The changes in visual acuity of motion with aging were evaluated.

The decrease in dynamic moving detection and the increase in misses were significant in those in their 60's and 70's. The number of false alarms and delayed responses was dependent on the eye movement requirements of the task. Reduction of visual functions in subjects over 75 years of age depended on the individual, showing the validity of DVC.

This study showed that the DVC for visual function tests of motion was suitable for drivers of different ages, indicating that it can replace the ineffective visual acuity tests of motion used for elderly drivers at present.

Introduction

In traffic safety courses for elderly drivers, visual acuity tests for motion are performed as a part of the aptitude tests. Suzumura[1] noted that visual acuity for motion was considerably reduced in elderly people. However, because methods for testing visual acuity for motion and the results of such tests have not been fully evaluated, it was considered necessary to approach the problem from the viewpoint of traffic psychology.

A number of optical physiological and sensory psychological studies have been done on recognition and processing of objects and phenomena in space by the visual system. The ability of the eye to perceive still objects without moving the eye is explained by comparing the eye to a camera, and visual function capacity is represented by "static visual acuity (SVA)". SVA means the just noticeable difference (JND),

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i.e., a limen or threshold of recognition of 2 points or 2 lines as separate, and it is expressed as a reciprocal of the minimum separable visual angle.

With regard to perception and judgment of moving objects, Ludvigh[2], Miller[3], and Burg[4] performed various experiments pertaining to the ability to distinguish moving objects on a plane, "dynamic visual acuity (DVA)". However, these results have been inconsistent due to difficulties in control of conditions such as direction, velocity, and brightness of moving objects and interaction with background factors.

In 1956, Hagino and Suzumura started ophthalmologic studies on visual acuity of motion at the Institute of Environmental Medicine in Nagoya University[5]. Initially, they called moving objects flying objects using foveal vision. With the development of various measurement apparatus, they developed a KVA tester, which is in general use today and has contributed to the development of this study. Hagino called the ability to perceive approaching visual targets "kinetic visual acuity (KVA)"[6], which was defined by Suzumura as the "ability to clearly see an object approaching linearly from the front when the object or a person is watching it"[7]. Thus, the idea that visual acuity of motion is equivalent to KVA became generally accepted, and KVA began to be used in the field of traffic studies (Type AS-4C by Suzumura [7]).

Because the concept of visual acuity of motion contains different visual functions, DVA and KVA, it is necessary to evaluate the meaning of separately measuring DVA and KVA. First, DVA reflects conjugate eye movement, while KVA is disjunctive eye movement (Saida[8]). From the viewpoint of daily cognitive activities in visual space, danger can only be avoided with good DVA and KVA, for example in traffic driving situations. However, DVA is rarely measured except in studies of sports vision, and it is a problem that only KVA is considered important. Second, the validity of the concept of the limen or threshold of recognition of small differences in visual targets as a variable of the detection of moving objects should be reconsidered when measuring visual acuity of motion. This is because what matters when one is watching a moving object is to recognize what it is rather than to accurately understand its motion. Also, as Atsumi has pointed out, the functions of the retina in visual acuity of motion is not foveal vision but parafoveal vision [9,10]. Furthermore, although thresholds are often measured, involvement of the response latency factor cannot be ignored. If delay of reaction directly reduces visual acuity, measurement of thresholds themselves will be meaningless. If delay of response time which is generally observed in elderly people results in a reduction of visual acuity, that is a serious problem. In fact, KVA scores for elderly drivers measured in traffic safety courses are at nearly the lowest level in about 80% of the subjects (Fig. 1 by Kanemitsu and Kimura[11]).

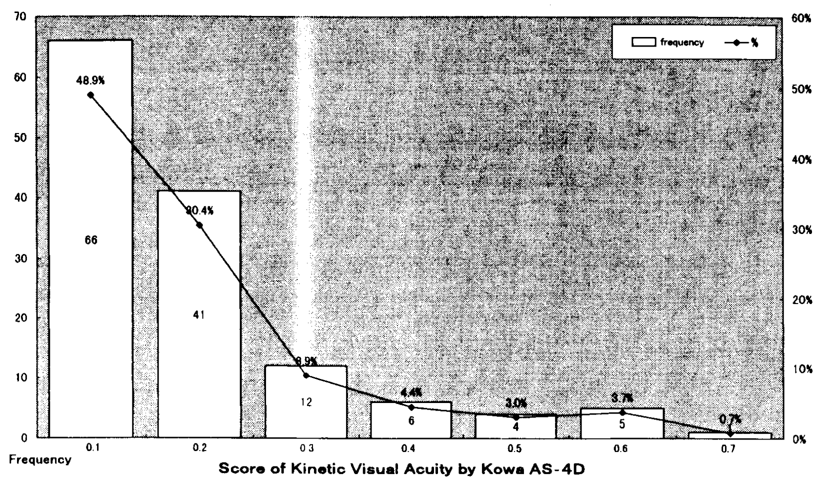

Fig. 1 Histogram of elderly drivers' KVA scores (n=135)

Table 1 Combinations of stimulus situation and response type by Signal Detection Theory

Stimulus situation	Response	
	"Yes" : go	"No" : no-go
Correct target presentation "Signal"	Correct response "Hit"	Incorrect response "Miss"
Incorrect target presentation "Noise"	False response "FA" ; False Alarm	Correct no response "CR" ; Correct Rejection

These problems need to be recognized and it is necessary to develop a new measuring method of dynamic vision which will solve them. In the present study, the results of visual-cognitive tests of motion were analyzed in people of different ages using a measuring apparatus of dynamic vision developed by Kanemitsu[12,13], and the reduction of visual functions in elderly people was confirmed.

According to the criteria of DVA, Kanemitsu[12,13] introduced "dynamic moving detectability (DMD)", which is defined as rapid and accurate detection of changes in moving objects beyond expectations in the total visual field. Ophthalmologically, DMD takes into account smooth eye movement and saccadic eye movement, and it can be used to examine the visual acuity of elderly people independently of the variable of response time [14]. Furthermore, it has been confirmed in elderly people that the ability to detect danger in traffic situations can be evaluated by DMD. In measuring DMD, the "signal detection theory" proposed by Green and Swets[15] was adopted, and "vigilance tasks" for detection of signals in noises were introduced. As shown in Fig. 2, signals (regular octagon target) and noises (irregular octagon target) were spatio-temporally displayed at random on the CRT of a computer, and the subjects were directed to push the "go" button for signals or "no-go" for noises. Table 1 shows the combination of the stimulus situations and responses.

The DMD ratio as a variable of measurement was calculated by dividing the total number of "go" responses to signals and "no-go" responses to noises by the total number of signals and noises displayed, as shown below.

$$DMD\ ratio = \frac{No.\ of\ correct\ \text{“go”}\ responses + No.\ of\ correct\ \text{“no-go”}\ responses}{No.\ of\ total\ stimulus\ presentations\ (signal + noise)}$$

In addition, the miss ratio (ratio of non-responses), FA ratio (ratio of error responses), and ratio of delayed responses (ratio of correct responses requiring more than a certain time) were calculated.

The apparatus developed for measuring DMD was named the "dynamic vigilance checker (DVC)", and

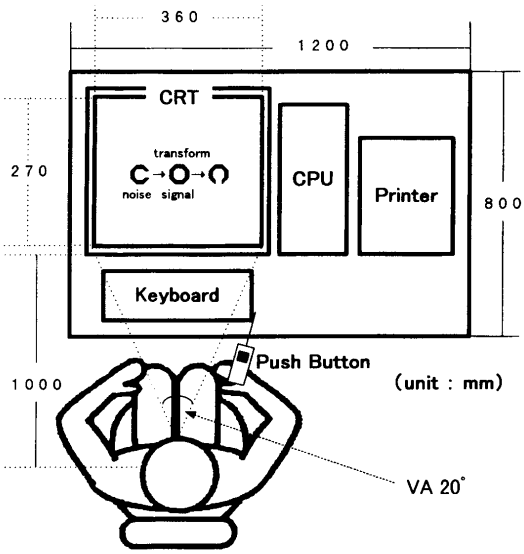

Fig. 2 Schematic outline for measuring DMD by DVC device

was introduced by Kanemitsu and Kimura[16] at the 59th Congress of the Japanese Traffic Psychological Society in 1999 (Fig. 2). Subsequently, a large number of subjects were tested using DVC, and the data were analyzed. The purpose was to confirm the general functional decrement of dynamic vision with aging and external validity of DVC testers.

Methods

The relationship between aging and DMD as determined by DVC was analyzed by the following procedures.

(1) Subjects: Five hundred eighteen subjects were tested, including 148 drivers over the age of 75 in traffic safety courses for elderly drivers in Okayama Prefecture, 124 members of clubs for elderly people, and 246 teenagers and adults, most of whom were attending driving schools. The age distribution was : under 20 years of age (25), in the 20's (88), in the 30's (36), in the 40's (49), in the 50's (48), in the early 60's (29), in the late 60's (29), in the early 70's (66), in the late 70's (120), and over 80 years of age (28).

(2) DVC measurement: Measurements were performed using pursuit tasks and unexpected tasks corresponding to the 2 kinds of eye movement. The subjects of the study were instructed in the operation method of the DVC apparatus.

(3) Measurement time: It generally took 7 - 8 min. for the entire test.

(4) Processing of the results: All measurement results were saved in a computer, and statistically analyzed by SAS program. The DMD ratio, miss ratio, FA ratio, and ratio of delayed responses, as subvariables, were statistically analyzed.

Results

Table 2 shows the means of the DMD ratio, miss ratio, FA ratio, and ratio of delayed responses classified by age. Table 3 shows the results of analysis of variance of the parameters using the age factor. Because analysis of variance on the single factor with respect to age showed significance , multiple comparisons of

Table 2 Average ratio of each DVC index by age for two kinds of tasks

		Pursuit task(smooth eye movement)				Unexpected task(saccadic eye movement)			
Age		DMD	Miss	False alarm	Delayed response	DMD	Miss	False alarm	Delayed response
10	Mean	97.4	4.7	1.8	26.9	98.2	1.3	2.1	2.8
N = 25	SD	3.0	8.2	1.5	12.0	1.4	1.8	1.7	2.9
20	Mean	97.8	3.6	1.7	29.6	97.8	1.9	2.3	2.9
N = 88	SD	2.2	5.2	1.5	11.7	2.9	5.4	2.6	4.2
30	Mean	98.4	2.6	1.2	35.2	98.6	0.9	1.7	3.5
N = 36	SD	1.9	5.4	1.0	10.1	2.7	3.0	2.7	5.9
40	Mean	96.8	5.8	2.3	45.1	98.0	1.5	2.2	5.2
N = 49	SD	3.3	8.7	2.2	12.9	2.7	4.4	2.8	6.7
50	Mean	96.3	6.8	2.6	50.6	96.5	4.4	3.0	10.9
N = 48	SD	3.8	9.3	2.4	13.5	3.8	8.4	4.0	13.6
60 – 65	Mean	93.4	11.7	4.7	56.6	96.1	5.6	3.0	14.4
N = 29	SD	4.1	9.7	4.0	15.1	3.4	8.2	3.5	13.7
66 – 69	Mean	92.9	16.3	3.7	62.6	93.4	13.3	3.2	15.7
N = 29	SD	5.4	16.8	2.2	16.1	7.5	21.0	2.4	19.1
70 – 75	Mean	90.7	22.2	4.6	67.4	92.3	15.5	3.8	29.0
N = 66	SD	5.3	16.6	2.7	13.5	5.8	15.7	3.7	20.7
76 – 79	Mean	90.3	24.1	4.5	67.7	90.9	19.2	4.1	32.1
N = 120	SD	6.3	19.2	2.9	14.7	7.3	19.6	3.7	21.2
80	Mean	88.8	27.0	5.5	68.4	87.6	24.4	6.4	30.2
N = 28	SD	6.4	18.4	5.0	11.6	9.7	20.1	7.6	14.2

N = 518

the parameters between the age classes were performed, using the Bonferroni test. There were statistically significant combinations, which are marked with asterisks in Table 4-a and Table 4-b. To evaluate the changes in DMD with aging, the means of the parameters according to age classes are shown in Figs. 3-6.

Table 3 Results of analysis of variance on each index

Task of DMD	Index	F value	p
Pursuit DMD	DMD ratio	31.25	.0001
	Miss	26.18	.0001
	Error (FA)	15.98	.0001
	Delayed response	32.72	.0001
Unexpected DMD	DMD ratio	22.80	.0001
	Miss	20.62	.0001
	Error (FA)	5.50	.001
	Delayed response	39.02	.0001

df = 9

Table 4-a Statistical results of multiple comparison among age variables on pursuit task of DMD

Age	Index	< 19	20-29	30-39	40-49	50-59	60-64	65-69	70-74	75-79	80 <
< 19	DMD							***	***	***	***
	Miss								***	***	***
	FA						***		***	***	***
	Delay				***	***	***	***	***	***	***
20-29	DMD						***	***	***	***	***
	Miss							***	***	***	***
	FA						***	***	***	***	***
	Delay				***	***	***	***	***	***	***
30-39	DMD						***	***	***	***	***
	Miss							***	***	***	***
	FA						***	***	***	***	***
	Delay					***	***	***	***	***	***
40-49	DMD							***	***	***	***
	Miss							***	***	***	***
	FA						***		***	***	***
	Delay								***	***	***
50-59	DMD								***	***	***
	Miss								***	***	***
	FA						***		***	***	***
	Delay										
60-64	DMD										***
	Miss								***	***	***
	FA										
	Delay										
65-69	DMD										***
70-74											
75-79											
80 <											

N=518

Table 4-b Statistical results of multiple comparison among age variables on unexpected task of DMD

Age	Index	< 19	20-29	30-39	40-49	50-59	60-64	65-69	70-74	75-79	80 <
< 19	DMD								***	***	***
	Miss								***	***	***
	FA						***				***
	Delay						***		***	***	***
20-29	DMD							***	***	***	***
	Miss							***	***	***	***
	FA									***	***
	Delay					***	***	***	***	***	***
30-39	DMD							***	***	***	***
	Miss							***	***	***	***
	FA									***	***
	Delay						***		***	***	***
40-49	DMD							***	***	***	***
	Miss							***	***	***	***
	FA										***
	Delay								***	***	***
50-59	DMD								***	***	***
	Miss								***	***	***
	FA										***
	Delay								***	***	***
60-64	DMD									***	***
	Miss									***	***
	FA										***
	Delay								***	***	***
65-69	DMD										***
	Miss										
	FA										***
	Delay								***	***	***
70-74	DMD										***
75-79											
80 <											

N=518

The results demonstrated a reduction of DMD with aging with distinct differences between juveniles, adults, and elderly subjects. In the pursuit tasks, a decrease in the DMD ratio and an increase in the miss ratio started with those in their 60's, and increased markedly with those in their 70's. Increases in the FA ratio and the ratio of delayed responses started in the younger age groups. A tendency of delayed responses was observed in the 40's group. On the other hand, in unexpected tasks, a decrease in the DMD ratio and increases in the miss ratio and ratio of delayed responses were observed in those in their 60's and early 70's, while the increase in FA ratio was marked in those in their late 70's.

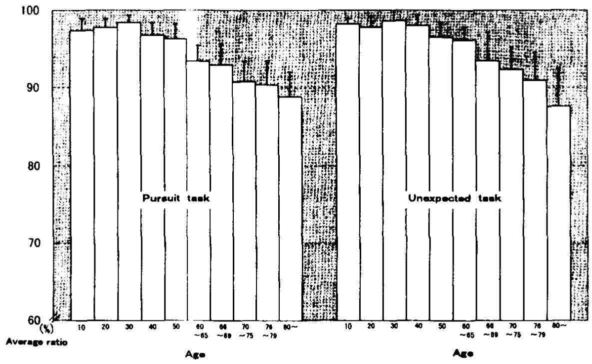

Fig. 3 Average DMD ratio by age for two kinds of tasks

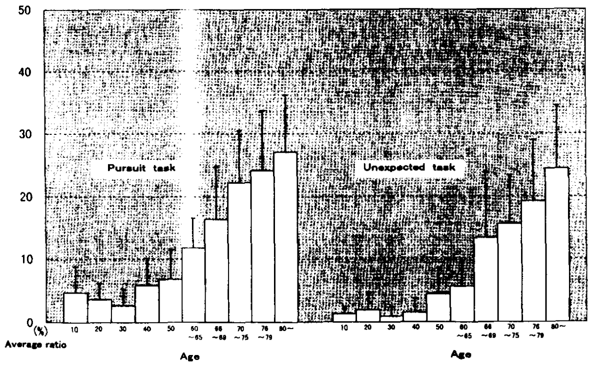

Fig. 4 Average ratio of Miss by age for two kinds of tasks

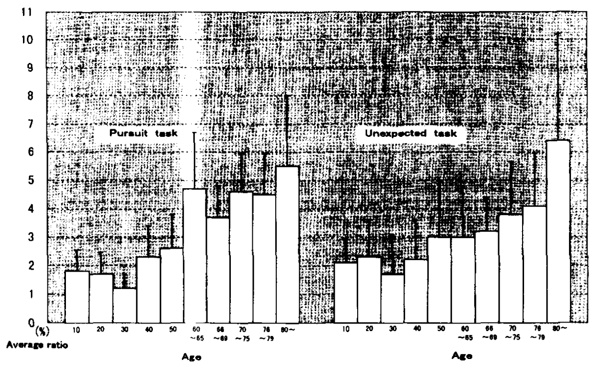

Fig. 5 Average ratio of false alarm(FA) by age for two kinds of tasks

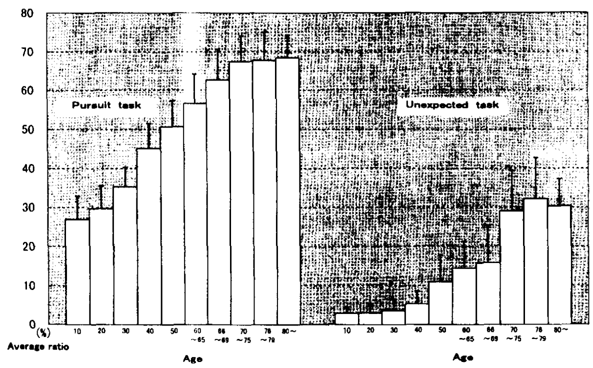

Fig. 6 Average ratio of delayed response by age for two kinds of tasks

Discussion

The main purpose of this study was to elucidate the changes in visual acuity of motion with aging using DVC, which was developed by the author [12,13]. Statistical analysis of the results demonstrated the effects of aging, and the relationship of visual acuity of motion between different age groups was validated by multiple comparisons. The DMD ratios in the 60's and 70's age groups were clearly different from those of other age groups, and those in the over 70 group were extremely low. Analyses of the results of false responses and delayed responses as subindices of DVC verified the validity of the DVC procedure. DVC was developed to solve problems with the KVA test, which is based on the threshold concept and is still in general use [13]. This new DVC procedure will become widely used for examination of visual functions of motion in elderly people[17].

There are several problems with the visual acuity tests of motion performed in traffic safety courses for elderly drivers, as mentioned in the beginning of this article. In studying visual acuity of motion in traffic situations, the apparatus for KVA tests has become a standard piece of equipment. However, it is necessary to reconsider its usage because its use implies that only visual acuity of moving objects is very important. Because elderly people cannot be properly tested with KVA, it will be a big problem if elderly people who take the test are disappointed with the inappropriate use of the apparatus and their irrational low scores. Therefore, it is important to investigate the mechanisms of vision in the perception of moving objects and to determine appropriate and effective parameters in traffic situations.

Taking the above problems into consideration, we have developed DVC based on the concept of DMD, but further studies are required to establish that DVC is truly effective in tests involving traffic situations. Visual functions of motion in traffic situations will be studied further, and more effective measurement apparatus will be developed and improved.

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