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The Sensory-Motor Coordination Measuring System Using Pointing Movements for the Evaluation of the Activities of Daily Living (ADL).

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In this paper, we aim to construct a system that measures older people's sensory, motor and cognitive functions related to spatial localization. We constructed an experimental system that could measure hand pointing movements to a light spot that was displayed for 200 ms. Experiment data show that older people frequently lose sight of a target presented at 80 degrees. This result suggests that the risk of traffic accident increases because of an oversight when older people go across a road. The experimental data show that significant differences between the older and young groups appeared in the localization angle. The average angle that older subjects pointed at was greater than the average angle of younger subjects. In order to analyze individual differences among the older subjects, we defined an evaluation scale, 'IEO,' from each subject's localization angle. The 'IEO' score and ADL (Activities of Daily Living) questionnaire score were highly correlated (0.95).

Key Words : Aging, Activities of Daily Living (ADL), Useful field of view, Pointing movements, Oversight, Traffic accident.

1. INTRODUCTION

In 2015, 25% of the Japanese population is projected to be 65 years old or older. Compared with other generations, the traffic accident percentage of older pedestrian is high. People cannot always recognize slight declines in the abilities of their sensory organs and cognitive functions in daily life. To prevent older people from experiencing a serious illness, falls, or traffic accidents, however, it is important for people to check for these changes themselves. If there were systems that could detect older people's slight declines in ability, it might be easier to offer rehabilitation therapy in order to improve and maintain their quality of life.

An Activities of Daily Living (ADL) scale is one of the tests that evaluates the sensory and cognitive abilities of older people with a written questionnaire. The ADL is used as certification for the need for long-term care in JAPAN. ADL scales are designed for patients or older people who may need nursing care [1-5]. Thus, the ADL may not be best suited to detect slight declines in sensory or cognitive functions among older people.

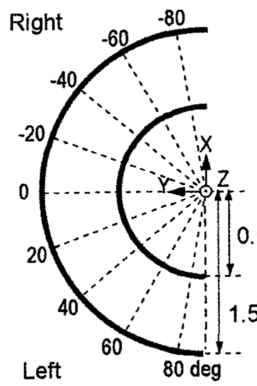
Another problem with the ADL scale is that the results are subjective, and it is difficult to detect slight declines in ability. If there were another way to measure people's sensory and cognitive functions as reliably as the ADL scale does, but as easily as people measure their blood pressure with a sphygmomanometer, then people could monitor themselves daily to detect changes.

Declines in visual function [6-10], motor function and somatosensory function [11] occur due to disease and as a consequence of normal aging. In this paper, we aim to construct a system that measures older people's sensory and cognitive functions. Adjustment in the coordination of visual and motor systems in the presence of deficit is crucial to an individual's ability to continue to function in the physical world. We pay attention to motion, especially visually induced pointing moments of the arm, because it is frequently used in daily life, and the ADL contains a number of questions relating to the ability to use one's hands. We also gathered ADL information from subjects with a questionnaire, and we investigated the relationship between the ADL questionnaire scores and experimental results.

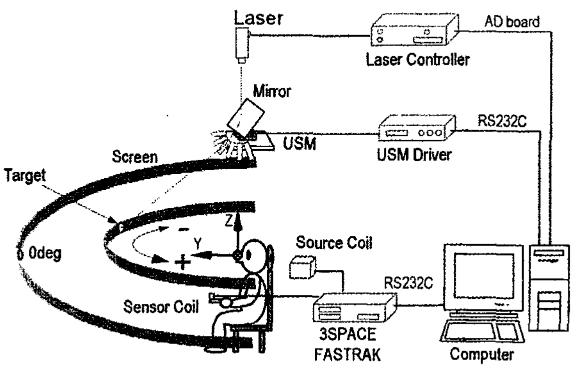
2. EXPERIMENTAL SYSTEM AND METHODS

We constructed a system that could measure a pointing movement to a flash target. Figure 1 shows the experimental system. Figure 1 (a) shows the layout dimension diagram of screens and the coordinate axes. Figure 1 (b) shows a block diagram of the experimental system. A carved semicircle of oblong screens was placed at a distance of 0.5 m and 1.5 m from the subject. The height of the screens was the same as the height of the subject's eyes. The target, a point of red light from a laser pointer, was projected onto the screen. The target position was controlled by the angle of a reflecting mirror mounted on an ultrasonic motor. The target appeared for only 200 ms, which is the same as the latency of saccadic eye movements ; therefore, subjects could not gaze at the target.

We defined 0 degrees as directly in front of the subject. We showed each subject a target from −80 deg to 80 deg in 20 deg intervals. Subjects were instructed to point at the target with their arm using a pointer that they held in total darkness. The pointers were small wooden sticks equipped with sensor coils measuring 15*20*15 mm. Subjects were asked to place a finger on a sensor coil on the pointer. These sensor coils were light and small, so subjects could move their arms freely. Subjects were instructed to point with their right arm when a target appeared on the right side, and to point with their left arm when a target appeared on the left side. The loci of pointing movements were measured by 3SPACE FASTRCK. It calculates three-dimensional positions and orientations from the relative position of a source coil and a sensor coil. The source coil was fixed on a wooden pole. The spatial resolution of the signals between the sensors on the pointers and the source coil was better than 0.5 deg. The sampling frequency of the experimental system was 60 Hz. The calculated data were sent to a computer by RS-232C.



(a) Layout dimension diagram of screens and coordinate axis.



(b) Block diagram of the experimental system.

Figure 1 The sensory-motor coordination measuring system using pointing movements. The experimental system was constructed using two carved semicircles of oblong black screens, a light source from a semiconductor laser, an ultra sonic motor with a reflecting mirror, a device controller unit, a computer, and 3SPACE FASTRAK, which digitizes the distance between a source coil and sensor coils. This experimental system can automatically measure a subject's pointing movements toward a red flash point (a target) on the screen.

Figure 2 diagrams the experimental procedure. At the start of each experimental trial, the LED at zero deg was turned on for 3.0-5.0 s, and then one of the targets was turned on for 0.2 s. Measurement was performed in a dark room with a brightness of 10^{-6}cd/m^2 so that subjects could not see their hands ; thus, subjects couldn't use visual feedback. Subjects had 3.0 s to point at the target, and then the next trial began. Each session consisted of sixteen trials. The sequence of target presentation was randomized in such a way that each position was presented twice. Four (two) separate sessions were carried out with each young (older) subject.

We gathered ADL information with a written questionnaire. Seven older subjects completed the questionnaire. Those questionnaires are based upon the standard of the HQL (the Research Institute of Human Engineering for Quality Life) in Japan. Table 1 contains the list of items asked from the ADL questionnaire. Subjects were given one point for each affirmative response and could earn a maximum score of 31.

Table 2 displays information about the subjects. There were seven older subjects, ranging in age from 63 to 72, and seven young subjects, ranging in age from 22 to 23. All subjects were right-handed.

3. RESULTS

Figure 3 shows the relationship between the target angle and oversight ratio in older people. The horizontal axis displays the target angle, and the vertical axis shows the oversight ratio. The depth of the figure shows the distance between the subject and the target. The oversight ratio was calculated by dividing the number of oversights by the number of trials. These data show that older

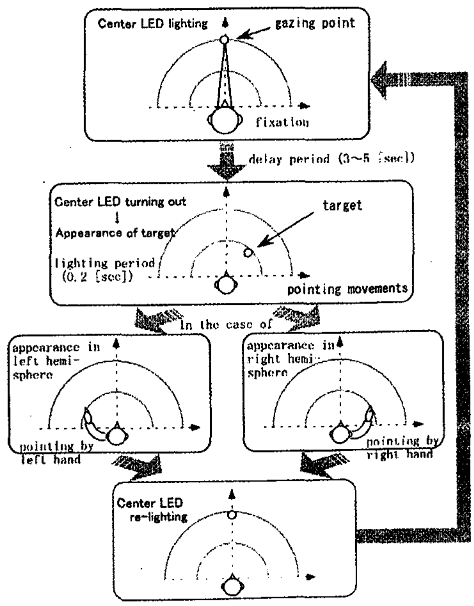


Figure 2 The experimental procedure. First, an LED at zero deg was lit for 3.0-5.0 s as the signal to start a session, and then one of the targets was turned on for 200 ms. Subjects were instructed to point at a target using their hand. Measurement was performed in a dark room with a brightness of 10^{-6}cd/m^2 so subjects could not see their hands. After 3.0 s of total darkness, the second session began.

Table 1 List of items from the ADL questionnaire [16].
(Translated from Japanese)

1. Can you stand up by yourself from a chair and from a bed without support?
2. Can you sit up straight (in Japanese, sit in a correct manner)?
3. Can you stand up by yourself from the position of sitting up straight without support?
4. Can you stand up by yourself from the position of lying on your back?
5. Can you operate the TV correctly with a remote control?
6. Do your fingers feel weak when fastening buttons of your clothes?
7. Can you fasten your buttons quickly?
8. Do your fingers feel weak when you are tying shoes or boots?
9. Can you tie your shoes quickly?
10. Can you wink?
11. Can you put on your skirt or pants while standing?
12. Can you pull on socks while standing?
13. Can you tie your shoes or boots while standing?
14. Can you change your clothes quickly?
15. Can you open a can of soda with your finger?
16. Can you open a bag of candy without ripping it?
17. Can you put a futon away into a wall-cupboard?
18. Do you feel comfortable when you walk with a cane?
19. Do you think you don't have to use a walking stick?
20. Do you run with short steps sometimes?
21. Can you follow on the heels of people in a crowd?
22. Do you prefer walking to taking a bus when you need to go about 100 yards?
23. Can you walk for 30 minutes without rest?
24. Can you walk for two hours without rest?
25. Do you feel comfortable without a handrail when you go up or down stairs?
26. Do you use a handrail when you go up or down stairs?
27. Do you sometimes dash up steps?
28. Can you stand in a train for 15 minutes without holding on to a strap?
29. Do you find it easy to board (or get out) a bus from the entrance to the platform?
30. Do you infrequently slip in places that are slippery (e.g., a waxed floor)?
31. Do you rarely fall down in places that are slippery?

Table 2 Subjects

		Name						
		AH	FN	HO	MT	NI	YA	YH
Age		21	23	21	20	21	21	20
Sex		M	F	M	M	M	M	M
Vision	right vision	1.0	1.2 c	1.0 c	1.0 c	1.0 c	1.5	1.0
	left vision	1.0	1.2 c	1.0 c	1.0 c	1.0 c	1.5	1.0
Dominant arm		R	R	R	R	R	R	R
Dominant eye		R	R	R	R	R	L	R

		Name						
		KN	KSk	KSs	TI	TS	YO	YT
Age		70	70	63	70	72	66	69
Sex		M	F	F	F	M	M	M
Vision	right vision	1.0	0.6	0.6	0.7 g	0.8	0.7	1.0 g
	left vision	0.6	0.6	0.6	0.7 g	0.8	1.0	1.0 g
Dominant arm		R	R	R	R	R	R	R
Dominant eye		R	R	R	R	L	R	R

people frequently lose sight of a target presented at 80 degrees. The oversight ratio increased from 26% to 73% depending on the distance between the subject and the target. All targets were of equal brightness. On the other hand, retinal illumination from the target decreased depending on the distance between the subject and the target. In a previous study [12], the oversight ratio of older people was 89.6% against a target presented at 80 degrees at a distance of 1.5 m. We consider that the oversight ratio in this study differed because of the brightness of the target, retinal illumination, and the contrast of the target with the backdrop.

Figure 4 defines the pointing angle error. In this study, the pointing angle was defined as the angle between the x-axis and a line from the nasal bone to a finger position. The error is defined as the difference between the pointing angle and the target angle.

Figure 5 shows the relationship between the pointing angle and the error. Figures 5 (a) and (b) show the error for depth distances of 1.5 m and 0.5 m. The horizontal axis shows the target angle, and the vertical axis shows the error. Each mark represents a subject. The experimental data show that significant differences appeared in the localization angle between the older and young groups ($P < 0.005$). The average angle that older subjects pointed at was greater than the average angle of younger subjects ; older people's orientation had a tendency to shift to the outside as compared with younger people. The standard deviation among older people is also larger than that among younger people. This result shows that individual differences among older people were greater than those among younger people.

Figure 6 shows the pointing angle error of each older subject. Figures 6 (a) and (b) show that the depth distance is 1.5 m and 0.5 m. The horizontal axis shows the target angle, and the vertical axis shows the error. The solid line and the dotted line display the average pointing angle among older subjects and younger subjects, respectively. In spite of changing from D = 0.5 m to D = 1.5 m, the pointing angle of each subject showed the same tendency.

In order to analyze individual differences among older subjects, we defined an evaluation scale, the 'Integrated Error of

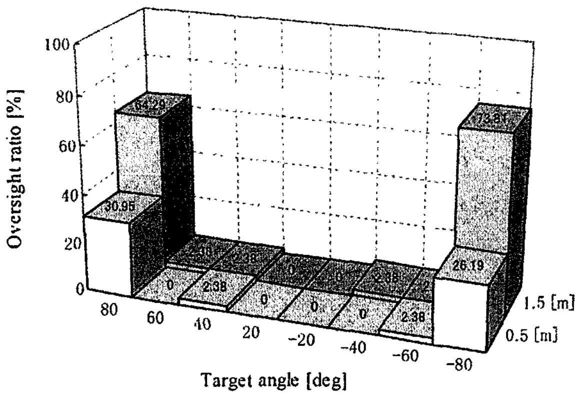


Figure 3 The relationship between the target angle and the oversight ratio in older people. The horizontal axis displays the target angle, the vertical axis displays the oversight ratio, and the depth shows the distance between a subject and a target. The oversight ratio was calculated by dividing the number of oversights by the number of trials.

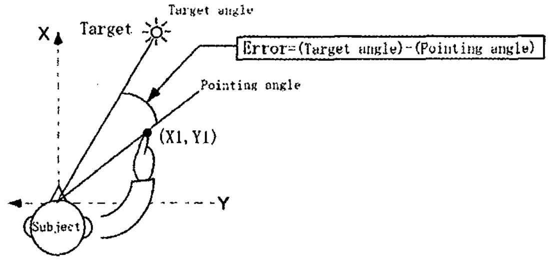


Figure 4 The definition of pointing error. The difference between the angles of the target direction and the pointing direction was defined as "Error".

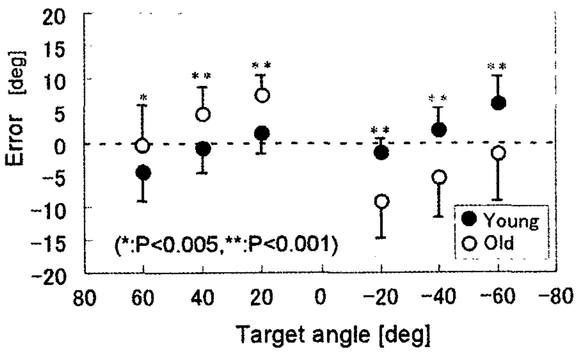
Orientation : IEO,' from each subject's orientation angle. Figure 7 shows the relationship between the IEO and ADL questionnaire scores. The horizontal axis displays the ADL questionnaire scores, and the vertical axis represents the IEO scores. The 'IEO' and ADL questionnaire scores were highly correlated ($R^2=0.95$ in case of $D=0.5$ m and $R^2=0.75$ when $D=1.5$ m). This result shows that the ADL score depends heavily on people's manual dexterity and visual orientation within the distance that their hand reaches.

4. DISCUSSION

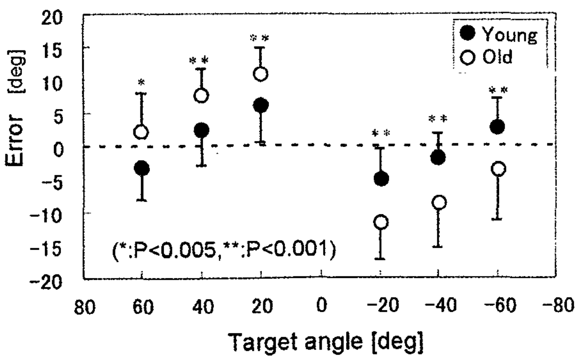
Existing studies report that there are no differences between older people and younger people in a horizontal field of vision. On the other hand, our results show that older people frequently failed to notice a target that appeared momentarily in peripheral vision. In this condition, age differences were significant. In our experimental condition, the significant difference by age appeared in the oversight ratio. This result suggests that it is dangerous to evaluate older people's visual function only by the width of the visual field or by visual acuity. Since older people with many oversights will require time to notice a car approaching from the edge of a visual field, if they cross a road in a low contrast environment, such as at twilight, it is possible that the risk of a traffic accident increases.

We think that it is necessary to verify the significant differences between younger people and older people by increasing the number of subjects. Nevertheless, it is clear from the difference in the standard deviation between younger people and older people that elderly people's individual differences are large. It is important to note, however, that there exist older people who show the same characteristics as younger people.

Our experimental system yielded a high correlation between the subjective evaluation and the ADL questionnaire scores. Skeletal muscles and skeletal structure decline gradually with age. However, the declines in ability can't be felt in daily life. Adjustment in the coordination of visual systems and motor systems is crucial to an individual's ability to continue to function in the physical world. If there is a mismatch between the motor system and the body image constructed in the central nervous system (CNS), the difference between the goal and the end point increases when there is no visual feedback. In daily living, we can correct for the difference because there is a great deal of visual feedback. If the chance is low that the CNS adjusts the body image using visual feedback, then we cannot correct for the difference, so the difference does not decrease. This mismatch between the motor system and the body image is one of the reasons for the decreased ADL scores. In studies of visual-motor rearrangement using visual displacement prisms, there was no statistically significant difference in measures of visuo-motor plasticity with

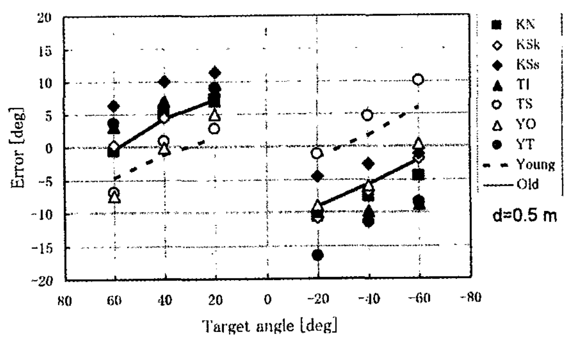


(a) D = 0.5 m

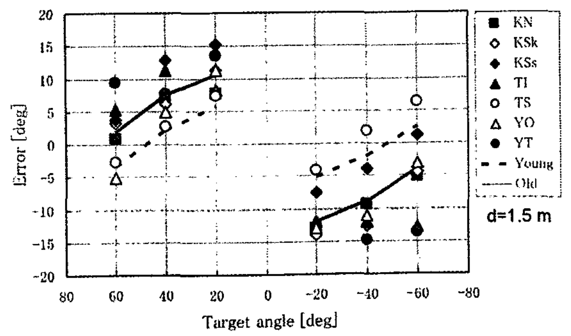


(b) D = 1.5 m

Figure 5 The relationship between the target angle and error. The horizontal axis shows the target angle, and the vertical axis shows the error for each subject group. A black dot shows the averaged error of younger subjects, a circle shows the averaged error of older subjects.



(a) D = 0.5 m



(b) D = 1.5 m

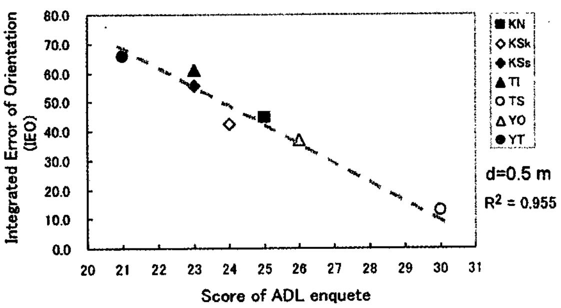
Figure 6 The pointing angle error of each subject. The horizontal axis shows the target angle, and the vertical axis shows the error for each subject group. Each mark shows the averaged error for each older subject. The dotted line shows the averaged error for younger subjects, and the solid line shows the averaged error of older subjects.

advancing age [13]. This result shows that the mismatch may be reduced if older people receive rehabilitation therapy.

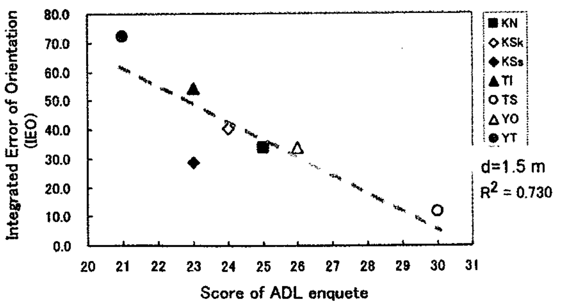
In a study that investigated reaction time and moving time related to the motor control of target-oriented arm movements, the quality of older people's control of rapid aiming arm movements showed regression, resulting in greater use of visual feedback during movement execution [14-15]. The strategy of target-oriented arm movements divides broadly into two categories. In one a hand is moved using visual feedback so that the distance between a goal and an end point may become small. In another a hand is moved by open loop control without visual feedback. It seems that many older people use the first strategy and many younger people use the second strategy.

5. CONCLUSIONS

In this paper, we constructed an experimental system that could measure the movements of hands pointing to a light spot that was displayed for 200 ms. The pointing differences between old people and young people were investigated. We also obtained information from a questionnaire related to the ADL scale. The experimental data show that significant differences appeared in the localization angle between the older and the younger groups. Older people frequently lose sight of a target presented at 80 degrees. The average angle that older subjects pointed at was greater than the average angle of younger subjects.



(a) D = 0.5 m



(b) D = 1.5 m

Figure 7 The relationship between the IEO and ADL questionnaire scores. The horizontal axis shows the score from the ADL questionnaire, and the vertical axis shows the value of the IEO score. Each mark represents an older subject. The dotted line shows the linear expression that was calculated by a least mean squares approximation.

In order to analyze the individual differences among the older subjects, we calculated an evaluation scale, 'IEO,' from each subject's localization angle. The 'IEO' score and ADL questionnaire score were highly correlated.

Understanding the property of human pointing movements is also useful for constructing human-machine interfaces, and important for preventing older people from traffic accidents. In the future if the devices that can measure the pointing accuracy in the daily life are developed, we can easily know the decline of the ADL using these data from this paper.

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