Thesis of Doctor of Philosophy

The Study of Characteristics of Visual Attention in Depth of Drivers in Traffic Environment

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Abstract

The number of traffic accidents keeps increasing with increasing of the number of private cars and the improvement of road traffic environments although death number of traffic accidents keeps decreasing over the recent years. There were a lot of factors for the traffic accidents, those factors that are directly related to people-the so-called "human errors"-has been examined by considering a car to be a cooperative human-machine system and through the analysis of about 300 road traffic accidents by the Institute for Traffic Accident Research and Data Analysis (ITARDA). When human errors are grouped into three categories, namely, cognitive errors, judgment errors and operation errors, they are found to constitute 47%,40%, and 13 of the total, respectively, meaning that cognitive errors and judgment constitute about 90% of all human errors. In addition, a lot of death numbers in the twilight condition have been reported. There are several reasons for the human errors; one of the main reasons is the effect of traffic environment (including car exterior and interior environment) on safety driving. Another primary reason is the effect of the visual function of drivers on operations of drivers.

With the popularization of the information prompt instruments in the car interior like automobile navigation system and speedometer etc., drivers obtained more and more information from the screen display. It is important the effect of the expression color of the information prompt instruments in the car interior on the visual attention of drivers. So, it is very important to reveal the vision attentional characteristics of drivers. However, characteristic of depth attention of drivers remained unclear, only a few studies addressed the effect of the environmental illuminance in car exterior and the information prompt instruments in car interior on the visual attention of drivers. We designed an attention measurement system to conduct four experiments in order to research the attentional characteristics of drivers in the present study

The environmental illuminance in car exterior can be divided into three categories: The bright, twilight and dawn. There are various kinds of color combines between the information prompt instruments in car interior and the traffic environment in car exterior. In order to ensure traffic safety and to obtain more visual information, drivers have to switch continually their visual attention between the objects presented in front of drivers because various kinds of traffic environments are changing continually during driving. The present study consisted of the following four parts:

(1) A study on characteristics of attention in depth of young subjects in changing supposed environmental illuminance. The experimental environment illuminances were: bright (480-680 lx)

and twilight (95-135 lx) conditions. Subjects were fifteen students served as participants, whose mean year was 21.8 years old. The subjects must make a quick response according to the information presented beforehand at the targets location. Three within-observe variables were used: cue validity (Valid: V, Invalid: I, Neutral: N). 65% of all trials were Valid, 15% were Invalid and 20% were Neutral. The experimental results suggested that the attentional characteristics of subjects were influenced not only by the vision function of subjects, but also by cue validity. Reaction time was shorter in the valid, and longer in the invalid. In addition, there was an effect of environmental illuminance on response lag in low illuminance condition, and the response lag depended on the shifting distance of the attention in depth. (Bright: 480-680 lx, twilight: 95-135 lx and dawn: 5-8 lx)

(2) A study on characteristics of attention in depth of subjects simulated low-vision in changing supposed environment illuminance. The experimental environment illuminances were: bright (480-680 lx), twilight (95-135 lx) and dawn (5-8 lx) conditions. Subjects were fourteen students served as participants, whose mean year was 24.9 years old. The results suggested that the attentional characteristics of subjects were also influenced by the environmental illuminanc. In particularly, reaction time was shortest in the dawn condition than in the bright and twilight conditions, and showed that there is an effect of low environmental illuminance on response of subjects.

(3) A study on characteristics of attention in depth of older subjects in supposed bright condition. The experimental environment illuminance was: bright (480-680 lx) condition. Subjects were fifteen older peoples served as participants, whose mean year was 63.9 years old. The results suggested that their reaction times were obviously longer than young subjects.

(4) A Study on characteristics of attention in depth in changing cue duration and targets color in supposed traffic environment. The experimental cue durations were: 600 and 1000 ms, and color of cue and targets were red and green under two observing conditions (static and dynamic). The results suggested that it was evident the effect of color on the response lag when the color of cue and color of targets was not consistent.

In present study, the visual attention characteristics of young, low-vision and older subjects are examined by changing peripheral environmental illuminance and color combination of cue and targets. Four experiments are conducted. The results of the environmental illuminanc experiments suggest that reaction time of the subjects with high visual adaptability is shorter than the subjects with low visual adaptability in twilight condition, this results show that the subjects with low visual adaptability have a response lag in twilight condition, the direction of switching attention of subjects result in this orientation to response lag. Response of subjects with low visual adaptability is slower than subjects with high visual adaptability when the attention distance is greater. The results of the color combination experiments suggest that the asymmetry of attention is small in cue being red than that in cue being green, on the other hand, the reaction time is shorter in targets being red than that in targets being green in invalid condition.

In conclusion, danger tendency of drivers is exposed in traffic environmental illuminance change in this study. To be engaged in traffic safety education, according to those research results, we should expound visual attention characteristics to drivers, even try to append these finding into teaching pamphlet in order to ensure traffic safety and to decrease traffic accidents.

Keywords: Visual attention in depth, Traffic environment, Peripheral environmental illuminance, Cues and stimuli, Duration and color.

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Chapter 1 General Introduction

Motor cars are a very commonplace means of transportation, especially when compared to public transport. The number of private cars continues to increase, the numbers of people, who have access to their driving license, is getting more and more, however, road traffic accidents have become a problem. Thus, there is a need for a means of reducing the number of road traffic accidents without compromising the convenience that cars offer us. Many of researches are currently being done in the field of active safety. From analyses of drivers' mistakes, many traffic accidents referred to as "human errors", and have shown that drivers continue to make mistakes in the cognition of their external world and judging between safe/not safe. So, research into drivers' behavior and active safety is being performed to develop driver support technologies that take the characteristics of a driver's cognition, judgment, and actions into account.

When a driver is driving a car, the driver should attend objects to both near and far at the same time in order to ensure traffic safety, that is, feature information of objects presented in front of drivers will draw driver's visual attention in useful field of view. Driving behavior is the control of a vehicle through a process of drivers' recognition, judgment and operation based on environmental information input, a visual system of drivers receives massive amounts of information and prioritizes from frontal road signs and markings in traffic environment, so drivers have to switch continually their visual attention between the objects presented in front of drivers, such as shifting from near space to far space. The selection of information from the environment is accomplished by drivers' visual attention, in order to acquire significant information, drivers allocated selectively their attention, and drivers for driving tasks are required to make a quick response according to the feature information (location, color, shape, orientation etc.) of objects presented beforehand at the targets location. Although it is one of the most important issues to understand the relationship between our visual system and our driving behavior, we can not disclose the characteristics of visual cognition in three-dimensional space and the relationship between visual cognition and our driving behavior in actual situation.

1.1 Research background

1.1.1 Road traffic safety situations

1) Number of motor vehicles increases rapidly: In the past 10 years, with the continuous and rapid development of Chinese economy, the numbers of both motor vehicles and drivers increased sharply. The number of vehicles reached from 31.8 millions in 1995 to 127.3 millions

in 2007 (see Figure 1-1), and with an annual increase rate over 10%, which is remarkably higher than that of the GDP [1].

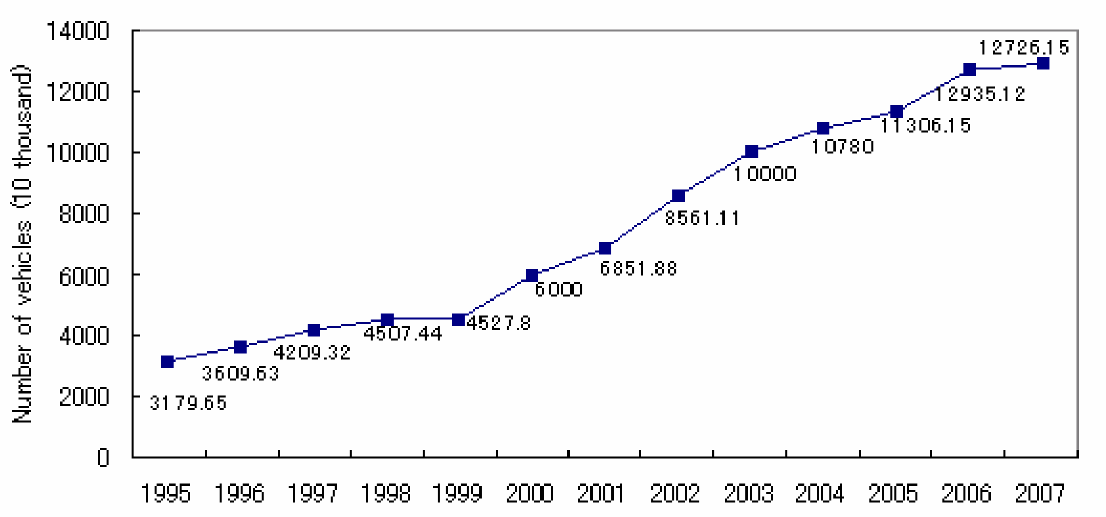


Figure 1-1 Statistic of motor vehicle numbers during 1995-2007 in China
(From China Annual Report on Automobile Industry, 2005, 2006, 2007)

2) The number of vehicle drivers increases rapidly: The number of drivers grew rapidly along with the growth of the vehicle number. Till the end of 2006, there are 1108.9 millions drivers nationwide, and with an annual increase rate over 10%.

3) Road traffic death number increased sharply: The number of traffic accidents kept relatively high over the last years, the road traffic death number increased sharply also (see Figure 1-2). Traffic accidents mainly occurred on highways in 2004, highway accident death accounts for 76.8% of total traffic accident death, with accidents numbers 1.4 times of that of urban road and death numbers 3.3 times of that of urban.

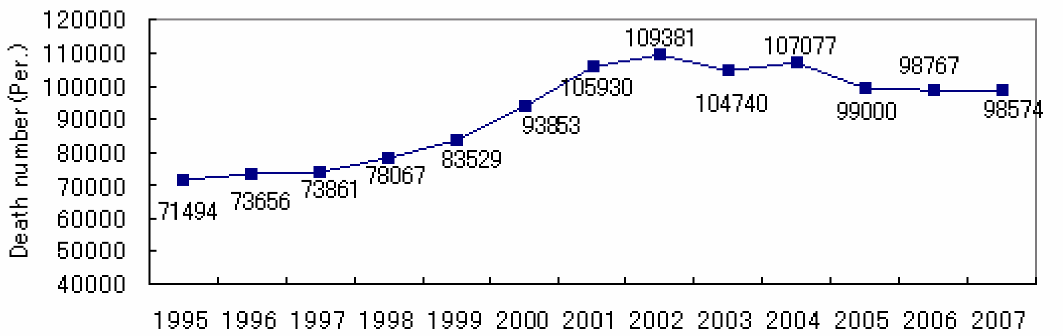


Figure 1-2 Death numbers of traffic accidents during 1995-2007 in China
(From China Annual Report on Automobile Industry, 2005, 2006, 2007)

1.1.2 Human error and road traffic accidents

Let's consider the factors that contribute to the occurrence of accidents. Those factors that are directly related to people-the so-called "human errors"- has been examined by considering a car to be a cooperative human-machine system and through the analysis of about 300 road traffic accidents by the Institute for Traffic Accident Research and Data Analysis (ITARDA). When human errors are grouped into three categories, namely, cognitive errors (ex. Errors caused by oversights), judgment errors (ex. wrongly judging that the other vehicle will stop) and operation errors (ex. failing to apply the brakes strongly enough in an emergency), they are found to constitute 47%, 40%, and 13% of the total, respectively, meaning that cognitive errors and judgment constitute about 90% of all human errors. When the reasons for cognitive and judgment errors are analyzed, we find that about half of the cognitive mistakes are caused by “carelessness” and “mistaken assumptions”, while about half of the judgment mistakes are caused by “mistaken assumptions”. Watanabe et al. investigated the visual checks made by drivers to ensure that it was safe to cross an intersection without traffic signals. It was found that, in the case of about half of the 172 observations, the driver failed to check the conditions adequately or was too late. Such drivers seem to assume that there will be no other vehicles in the intersection, so do not confirm that the conditions are safe. Figure 1-3 shows relation among cognition and judgment as well as operation of drivers during driving in traffic environment.

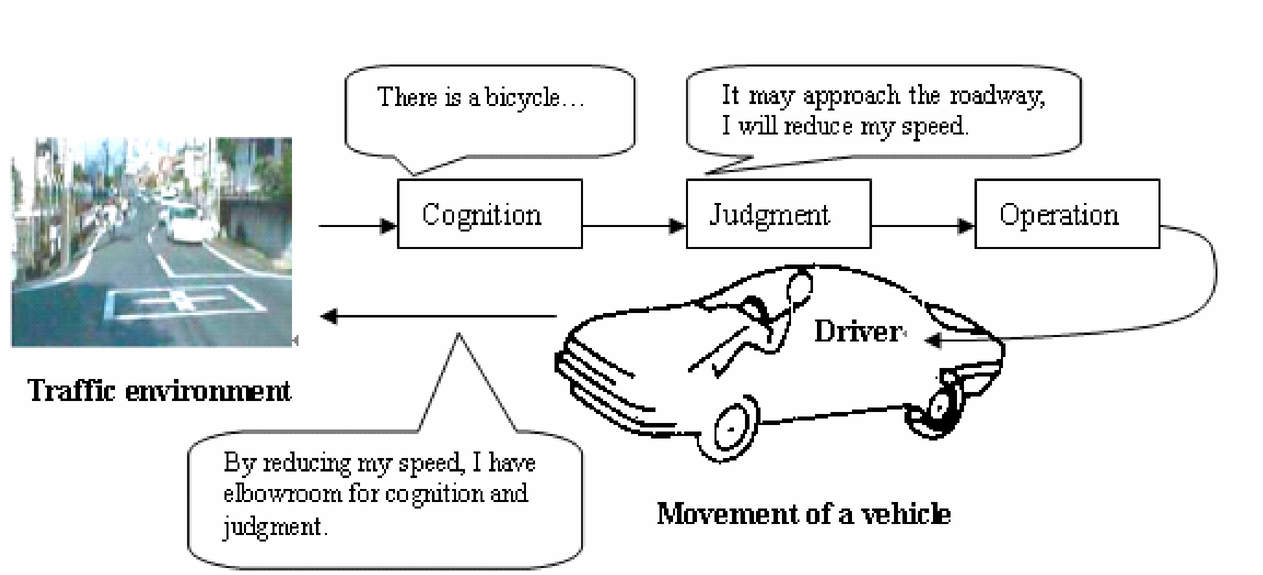


Figure 1-3 Block diagram of a vehicle regarded as a human-machine cooperative system

1.1.3 Cause analysis of road traffic accident proneness

There were a lot of reasons for the traffic accidents, such as road status, law-breaking and anti-regulation behaviors of drivers, time of driving and age of drivers etc. Figures1-4 and 1-5 illustrated the status of traffic accident with different age and different time in driving.

One of reasons was visual attention of the driver. During driving, the drivers must accurately distinguished from frontal road signs and markings in various conditions, such as in daytime, twilight, night, foggy day and in rainy day etc., and visual attention of the drivers was under influence of many factors, such as luminance environment, self-visual function, and the location of vision objects etc.. Many of traffic accidents happened in twilight condition. Traffic accidents rate was 22.71% in twilight (18:00 to 20:00 hour) based on the investigations.

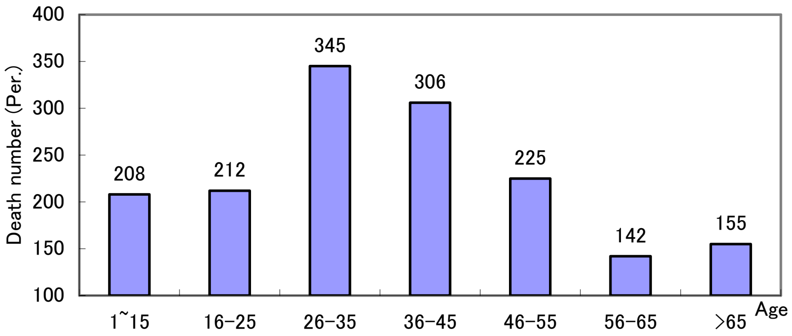


Figure 1-4 Death number with different age during 2000-2003, Henyang City

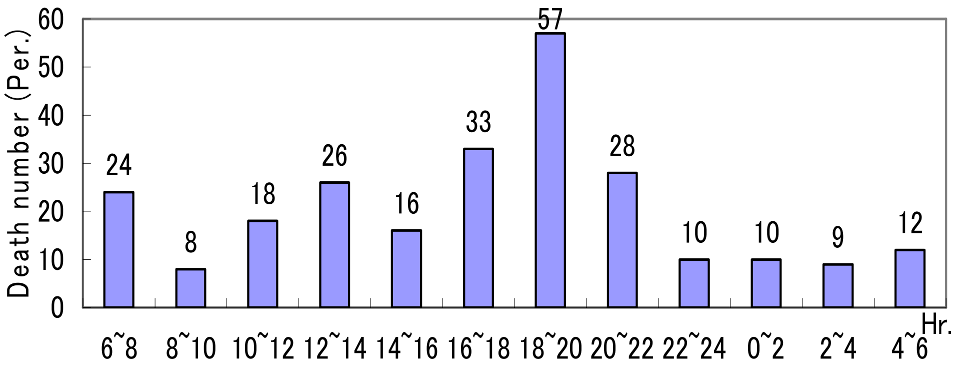


Figure 1-5 Death number with different time in2004, Hangzhou City
(From Report of Statistic Analysis of Traffic Accidents in Hangzhou City, 2004)

1.2 Connotation of visual attention

Attention has a complex meaning in psychology. In its early history, it was described closely related to subjective awareness of the world around us. As James said [James 1890]: "***Everyone knows what attention is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. ....***"

In recent years the concept of attention has refined its meaning in contrast to the idea of a purely automatic processing that occurs without attention. In cognitive neuroscience, it is now probably viewed as a neural system for the selection of information similar in many ways to the visual, auditory, or motor systems (Posner 1994)[2]. According to the evidence from neuroscience, an attention system can be divided into separate subsystems performing independent but interrelated functions interacting with other domain-specific systems. Attention is carried out by a network of anatomical areas and is therefore neither the property of a single center nor a function of the brain as a whole. Attention mechanism of human vision system has been applied to serve machine visual system for sampling data nonuniformly and utilizing its computational resources efficiently (Ballard 1991) [3]. The fundamental work on and the critical role of attention in vision have been described by Yarbus (1967), Neisser (1967), Richards and Kaufman (1969) and many other researchers. Further work on attention can also be found in (Posner 1980) [4], (Kosslyn 1980) [5] and (Treisman 1980) [6]. The visual attention mechanism may have at least the following basic components (Tsotsos, et. al. 1995) [7]:

(1) the selection of a region of interest in the visual field;

(2) the selection of feature dimensions and values of interest;

(3) the control of information flow through the network of neurons that constitutes the visual system;

(4) the shifting from one selected region to the next in time.

There are many ways that can be used to classify the attention system according to its various aspects. In a stimulus' point of view, the stimulus may attract attention by exogenous or endogenous methods. The exogenous components are mainly determined by external stimulus characteristics, whereas the endogenous components mostly depend on the subject's intentions and actions. In a subject's point of view, the subject can actually switch the gaze fixation point to the point being attended to (i.e., overt attention). On the other hand, it can also shift the attentional processing or gaze to a new location in the visual field for foveating without any a fixation shift or motor action (i.e., covert attention). As described by Treisman et al. (1984) [8], the features that are attractors of covert visual attention are those parts of an image that differ from all the other parts by a single aspect. And an object's shape, degree of symmetry, and the spatial distribution of objects in a scene are the important features for overt attentional stream. In the view of the route of information processing and attentional control, there are two kinds of execution methods: one is bottom-up or stimulus-driven, such as exogenous attention; another is top-down or goal-directed, such an endogenous attention. Combining some neurological models of attention, Perry and Hodges (1999) [9] have divided attention into three broad categories:

(1) Selective attention and shifting

Its defining characteristics are focusing on single relevant stimulus or processing at one time while ignoring irrelevant or distracting stimuli;

(2) Sustained attention

Its defining characteristics are the maintenance of abilities to focus attention over extended periods of times;

(3) Divided attention

The defining characteristics are sharing of attention by focusing on more than one relevant stimulus or process at one time. However, all the above classifications are interweaved with both active (or voluntary) and passive (or involuntary) attention. The division of active and passive attention switch was proposed by James (1890). The findings from neuroscience indicate that the separate attentional resources exist for different stages of processing and distinct parallel neural pathways (Mishkin 1983, Posner 1994, Michie 1999). The following model (see Figure 1-6), SCAN, was proposed by Postma et.al. (1997) [10]:

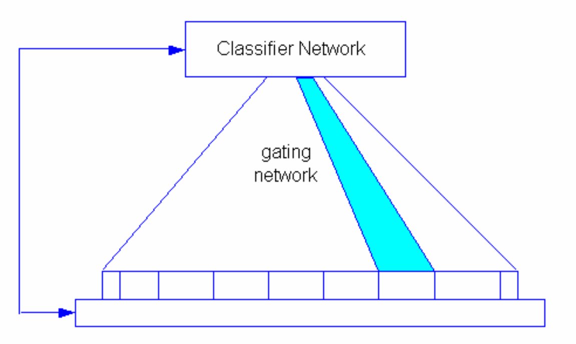


Figure 1-6 Attentional model: SCAN

SCAN consists of three main components: an input image, a gating network, and a classifier network. Given an expectation pattern E, the best-matching part of the input image is selected as the attended pattern and channeled by the gating network towards the output which serves as input for the classifier network. The shaded area represents the attentional beam. Another model (see Figure 1-7) SLAM was proposed by Phaf, et.al. (1990) [11]:

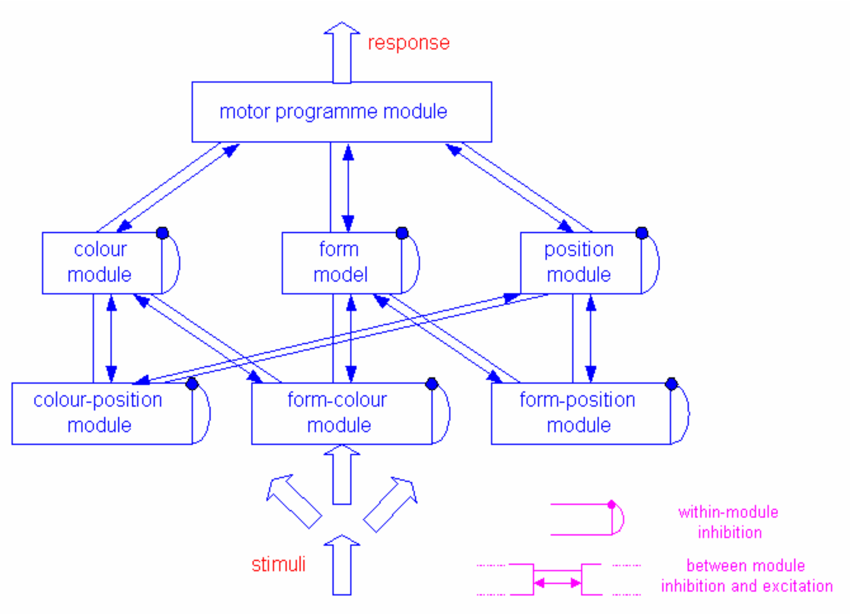


Figure 1-7 Attentional model: SLAM

SLAM uses two main procedures to select visual stimuli, within-module competition and precueing of behaviourally relevant attributes.

There are still some other typical models, listed as following:

a). A feature-integration theory

b). SERR (Humphreys, et.al. 1993) [12]

c). Guided search (Wolfe 1994) [13]

d). VIST (Ahmad 1992) [14]

e). Dynamic routing circuits (Olshausen, et.al. 1993) [15]

f). What-and-where filter (Carpenter, et.al. 1998) [16]

g). Active vision (Aloimonos 1988[17], Bajcsy 1988, Ballard 1991)

Overt and covert attention: Attention may be differentiated according to its status as “overt” versus “covert”. Overt attention is the act of directing sense organs towards a stimulus source. Covert attention is the act of mentally focusing on one of several possible sensory stimuli. Covert attention is thought to be a neural process that enhances the signal from a particular part of the sensory panorama.

There are studies that suggest the mechanisms of overt and covert attention may not be as separate as previously believed. Though humans and primates can look in one direction but attend in another, there may be an underlying neural circuitry that links shifts in covert attention to plans to shift gaze. For example, if individuals attend to the right hand corner field of view, movement of the eyes in that direction may have to be actively suppressed. The current view is that visual covert attention is a mechanism for quickly scanning the field of view for interesting locations. This shift in covert attention is linked to eye movement circuitry that sets up a slower saccade to that location.

1.3 History of the research of visual attention

1850s to 1900s: In James' time, the method more commonly used to study attention was introspection. However, as early as 1858, Franciscus Donders used mental chronometry to study attention and it was considered a major field of intellectual inquiry by such diverse authors as Sigmund Freud, Walter Benjamin, and Max Nordau. One major debate in this period was whether it was possible to attend to two things at once (split attention). Walter Benjamin described this experience as "reception in a state of distraction." This disagreement could only be resolved through experimentation.

1950s to present: In the 1950s, research psychologists renewed their interest in attention when the dominant epistemology shifted from positivism (i.e., behaviorism) to realism during what has come to be known as the "cognitive revolution" The cognitive revolution admitted unobservable cognitive processes like attention as legitimate objects of scientific study.

Colin Cherry and Donald Broadbent, among others, performed experiments on dichotic listening. In a typical experiment, subjects would use a set of headphones to listen to two streams of words in different ears and selectively attend to one stream. After the task, the experimenter would question the subjects about the content of the unattended stream. During this period, the major debate was between early-selection models and late-selection models. In the early selection models (first proposed by Donald Broadbent and Anne Treisman), attention shuts down or attenuates processing in the unattended ear before the mind can analyze its semantic content. In the late selection models (first proposed by J. Anthony Deutsch and Diana Deutsch), the content in both ears is analyzed semantically, but the words in the unattended ear cannot access consciousness. This debate has still not been resolved.

Anne Treisman developed the highly influential feature integration theory. According to this model, attention binds different features of an object (e.g., color and shape) into consciously experienced wholes. Although this model has received much criticism, it is still widely accepted or held up with modifications as in Jeremy Wolfe's Guided Search Theory.

In the 1960s, Robert Wurtz at the National Institutes of Health began recording electrical signals from the brains of macaques who were trained to perform attentional tasks. These experiments showed for the first time that there was a direct neural correlate of a mental process (namely, enhanced firing in the superior colliculus).

In the 1990s, psychologists began using PET and later fMRI to image the brain in attentive tasks. Because of the highly expensive equipment that was generally only available in hospitals, psychologists sought for cooperation with neurologists. Pioneers of brain imaging studies of selective attention are psychologist Michael I. Posner (then already renown for his seminal work on visual selective attention) and neurologist Marcus Raichle. Their results soon sparked interest from the entire neuroscience community in these psychological studies, which had until then focused on monkey brains. With the development of these technological innovations neuroscientists became interested in this type of research that combines sophisticated experimental paradigms from cognitive psychology with these new brain imaging techniques. Although the older technique of EEG had long been to study the brain activity underlying selective attention by cognitive psychophysiologists, the ability of the newer techniques to actually measure precisely localized activity inside the brain generated renewed interest by a wider community of researchers. The results of these experiments have shown a broad agreement with the psychological, psychophysiological and monkey literature.

1.4 Current researches

Attention remains a major area of investigation within education, psychology and neuroscience. Many of the major debates of James' time remain unresolved. For example, although most scientists accept that attention can be split, strong proof has remained elusive. And there is still no widely accepted definition of attention more concrete than that given in the James quote above. This lack of progress has led many observers to speculate that attention refers to many separate processes without a common mechanism.

Areas of active investigation involve determining the source of the signals that generate attention, the effects of these signals on the tuning properties of sensory neurons, and the relationship between attention and other cognitive processes like working memory. A relatively new body of research is investigating the phenomenon of traumatic brain injuries and their effects on attention. TBIs are a fairly common occurrence in a significant segment of the population and often result in diminished attention.

Concerning research of visual attention, the most prominent theories in cognitive psychology see attention as the set of processes enabling and guiding the selection of incoming perceptual information in order to limit the external stimuli processed by our bounded cognitive system and to avoid overloading it (Posner 1980[18]; Lavie and Tsal 1994[19], Chun and Wolfe 2001[20]). Attention can either be controlled voluntarily by the subject, or it can be captured by some external event. The former type of control mechanism is referred to as endogenous, or top-down, goal driven attention (Posner 1980; Yantis 1998[21]). The latter type of mechanism is referred to as exogenous, bottom-up, or stimulus-driven and it may have different degrees of power so that certain stimuli become basically impossible to ignore (e.g. sudden luminance changes), whilst others are more controlled by volition. Chun and Wolfe (2001) explain that the endogenous attention is voluntary, effortful, and has a slow (sustained) time course; exogenous attention draws attention automatically and has a rapid, transient time course. However, exogenous and endogenous mechanisms are not independent but interact constantly so that the endogenous mechanism in place (e.g. what one is looking for in a visual field) may determine whether one will automatically be able to ignore certain exogenous stimuli.

1.5 Spatial theories of visual attention

Spotlight theory: An important property of visual processing is the ability to allocate processing resources or attend to locations in the visual field that might contain important information. Considerable research has been conducted to determine the spatial limits of visual attention when subjects are required to attend to information at a specified position in the visual field. B. A. Eriksen and C. W. Eriksen (1974) [22] presented subjects with five simultaneous items in visual displays. The subjects were required to respond to the middle item of each display and to ignore the adjacent noise elements that were present. The response specified by the adjacent set of elements was either compatible or incompatible with the response to the central target. By varying the spatial separation of the noise elements relative to the central target, the size of focused attention could be measured. If the noise elements fell within the focus of attention, reaction time (RT) would be greater when they were incompatible with the response to the central target than when they were compatible. Using this paradigm, B. A. Eriksen and C. W. Eriksen (1974) found that the interfering effects of the incompatible noise elements decreased with greater spatial separations between the target and noise elements up to 1^0**.** In other studies containing similar paradigms, similar limits have also been found (C. W. Eriksen & Hoffman, 1973[23]; Hoffman & Nelson, 1981[24]; Posner, Nissen, & Ogden, 1978[25]). However, other studies have yielded evidence that the spatial limits of attention are greater than the 10 limit. LaBerge (1983) [26] presented subjects with displays containing letters that sometimes formed words. Some subjects were required to attend to single letters; other subjects were required to attend to entire words. The size of the focus of attention, as measured with a response target that varied in horizontal position, was larger for the subjects who were required to attend to words. LaBerge proposed that attention operated like a spotlight in the visual field. Items falling within the beam of this spotlight received processing priority over items not falling within the "beam" of attention.

Zoom lens theory: Since the advent of the initial spotlight theory (B. A. Eriksen and C. W. Eriksen, 1974), the ubiquitous 'beam of attention' has existed in several guises. One popular modification to the basic theory allows the previously fixed-width spotlight to vary in diameter according to the amount of attention one wishes to invest at any particular locus (e.g. Eriksen and Yeh, 1985[27]; Eriksen and Murphy, 1987[28]). This is often called the zoom lens theory of attention. Several other variants have been suggested in the previous, such as the 'theatre' of multiple spotlights (Sperling and Weichselgartner, 1995[29]), or the concerns over the seeming ability to split focal attention into two separate spotlights. The greatest problem for spotlight theories of attention has come from the 'object-based attention' hypothesis. This suggests that we do not attend to an area of space; instead we attend to objects. Since the initial suggestion of object-based attention, a growing number of studies have demonstrated perceptual grouping on the basis of factors other than proximity and have argued against attending to a contiguous area of space.

The zoom lens analogy is the most relevant to the driving studies, as the majority of researchers in this field refer to the narrowing of attention, implying that the field of view of attention contracts according to processing demands at the point of fixation (Miura, 1990[30], Williams, 1982, 1985, 1988[31], [32], [33]). Many researchers in related fields freely discuss the narrowing effects upon attention that occur under increased levels of demand or anxiety (e.g. Hammond, 2000[34]), even though recent evidence for an actual shrinkage of spatial visual attention is tenuous at the very least (e.g. Janelle et al., 1999[35]). The findings have produced an equal if not greater number of results pointing to a model of degradation that has previously been termed “general interference” (e.g. Crundall et al., 1999[36]). This is represented by a general degradation that occurs equally for all extra-foveal stimuli regardless of their eccentricity from the point of fixation. The alternative model of a shrinking functional field of view, often termed ‘tunnel vision’ in applied contexts, if it exists at all, seems only to be produced under particular and stringent conditions. Williams (1988) stated that participants needed to be placed under three conditions in order to induce tunnel vision—a highly demanding foveal task, which increases the amount of processing required at the point of fixation; instructions to focus primarily on the central task rather than a peripheral task (despite the peripheral performance being the measure of prime interest); and speed stress on the primary task.

Gradient theory: Another variant of this approach is that the allocation of processing priority might vary according to the position of the items within the focus of attention. According to this view, targets that fall within the central regions of the spotlight would receive the greatest priority for processing, whereas items that are located farther away from this central position, but still fall within the spotlight of attention, would receive less priority for perceptual processing. Thus, the allocation of attention can be viewed as a gradient of processing (LaBerge & Brown, 1989[37]; Andersen, 1990[38]; Andersen & Kramer, 1993[39]).

1.6 A three-dimensional space: Stereoscopic space and real space

Attention researches in real space: Research on the size of focused attention has involved the investigation of processing limitations when an item at a specific location is attended to in a two-dimensional (2-D) display. Few researches have been designed to investigate the size of focused attention within a three-dimensional (3-D) scene. It should be mentioned that, however, there have been three studies in which the movement of attention (shifting the focus of attention from one location to another location) in a 3-D scene was investigated. Downing and Pinker (1985) (see Figure 1-8) required subjects to attend to the central position within an array of lights in a 3-D scene. The lights were organized along different visual directions in two rows located at different distances from the subject. A cue presented at the central location indicated the visual direction in which a light might appear. Responses were slower for targets positioned farther away than for closer targets. In addition, the cost of attending to farther targets increased with increased retinal eccentricity. They proposed that the mental representation underlying visual attention was similar to the 2½-Dsketch proposed by Nishahara (1978), in which depth and visual angle were important in the underlying representation.

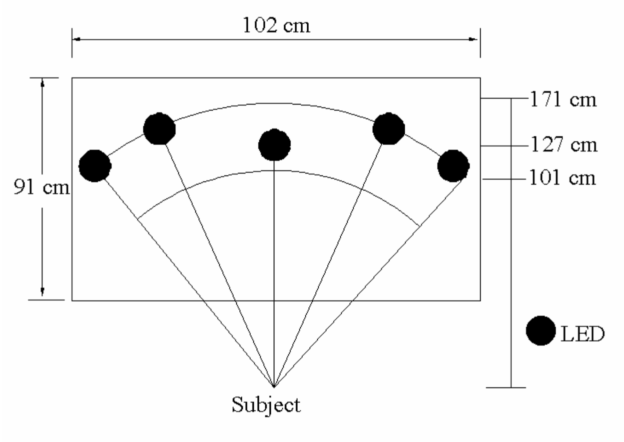


Figure 1-8 Collocation of cue and stimuli in the experiment of Downing & Pinker

Gawryszewski, Riggio, Rizzolatti, and Umiltâ (1987) [40] also investigated the movement of attention in depth. Subjects were presented with a central stimulus that cued the subject to a position along the same visual direction that was either closer or farther away than the central stimulus (see Figure 1-9). A response target was then presented at either of these two positions. On some of the trials, the central cue was valid, but on other trials, the cue was invalid. Mean RT were greater for invalid cues than for valid cues, suggesting that the subjects could not simultaneously attend to targets positioned at different distances.

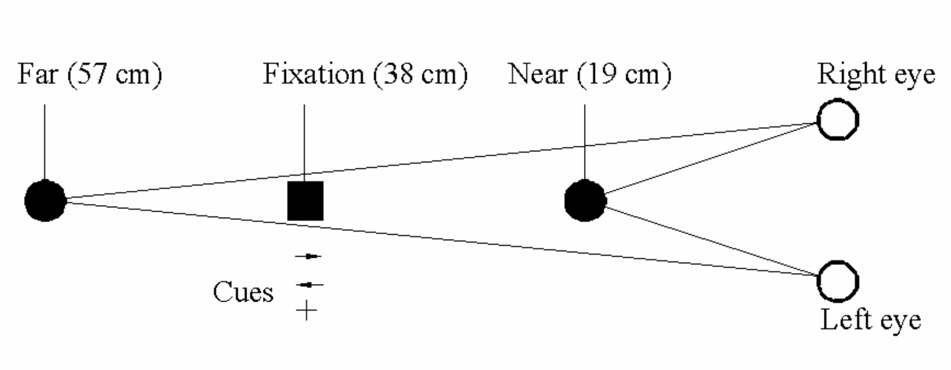


Figure 1-9 Collocation of cue and stimuli in the experiment of Gawryszewski et al.

Miura, Shinohara & Kanda (2002) [41], base on their previous research on eye movements and useful field of view in real driving, investigated the influence of visual aids (e.g., automobile navigation systems) on driving safety, and mentioned the rapid and efficient switching of attention between the forward environment and the inside display of a car was crucial for safety. The characteristic of shifts of attention in depth for moving and stationary observers was examined by the use of an improved tunnel simulator. In their experiment, subjects moved at apparent speeds of 40 km/h or 80 km/h or were stationary, digital LEDs cue and stimuli were used at fixation point and targets location, the subjects' task was judgment of the relative distance of targets (farther, nearer, or the same), in comparison with a fixation point (see Figure

1-10). Results demonstrated that reaction times for nearer targets were shorter than those for farther targets in all conditions.

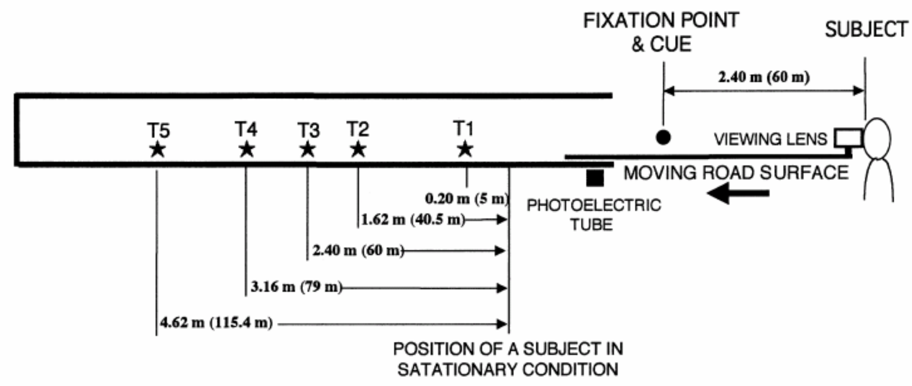


Figure 1-10 Collocation of cue and stimuli in the experiment of Miura et al.

Two experiments were conducted in order to examine top-down and bottom-up controls of attention in three-dimensional space when observers were moving forward by Kimura, Miura, Doi and Yamamoto (2002) [42] (see Figure 1-11). In their experiments, the cue about the location of a target by means of top-down information and three moving conditions were used, and bottom-up cue by brief change of luminance at target locations was presented in two moving conditions. Observers were required to judge whether the target presented nearer than fixation point or further than it. The results show that both top-down and bottom-up cue have the effect on reaction time, and that shift of attention were faster from far to near than the reverse. These findings suggest that (1) attention in 3-D might be operated with both top-down and bottom-up controls included the depth information, (2) the shift of attention in 3-D has an asymmetric characteristic in depth and it remarkably shown in observers were moving condition. Furthermore, it indicates that bottom-up and top-down controls do not operate independently, and top-down control might modulate bottom-up control.

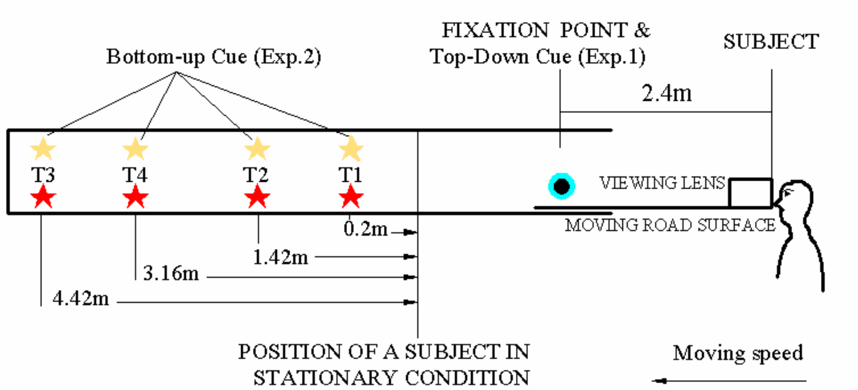


Figure 1-11 Top-down and bottom-up cue paradigm in the experiment of Kimura et al.

Attention researches in stereoscopic space: In another type of research involving the effects of depth variations on attention, Nakayama and Silverman (1986)[43] investigated the usefulness of depth information as a discriminating feature in a visual search task (see Figure 1-12). The target to be identified was embedded within a field of noise items in a stereoscopic display. If the target was located at a different depth plane than the noise items were, then the search for the target proceeded in parallel. This occurred for a variety of combinations of perceptual information used to define the noise items.

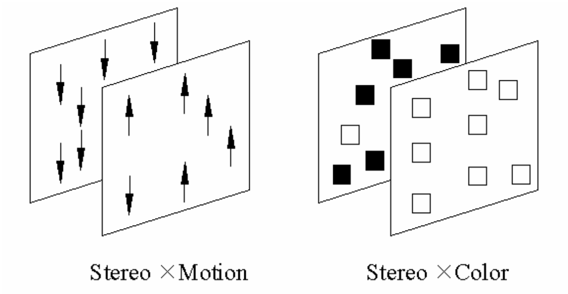


Figure 1-12 Collocation of stimuli in the experiment of Nakayama and Silverman

1.7 A few cases on visual attention research simulated traffic environment

Another research, using 39 MPEG hazard-perception clips randomly presented within four counterbalanced blocks by Crundall, Underwood and Chapman (2002)[44], explored the role of experience as a key factor in the potential narrowing of spatial attention, and the possibility of differences in the time course of attentional deployment (see Figure 1-13).

It was predicted that the amount of narrowing due to central processing demands would change as a function of driving experience, with more experienced drivers suffering less narrowing due to their mastery of central processing demands in road scenes. The data did not support the narrowing hypothesis, though they did support the alternative strategic difference between the driver groups in the time-course of attentional deployment. Learners seem to suffer attentional degradation in extra-foveal regions over a longer period of time whereas experienced drivers seem to invest peripheral attention at the hazard location in short but intense bursts.

Figure 1-13 A still from a hazard perception clip with the four target placeholders in the experiment of David Crundall et al.

Andersen & Ni (2005) [45] examined the limits of spatial attention during driving using a dual-task performance paradigm (see Figure 1-14); drivers were asked to follow a lead vehicle that varied in speed while also detecting a light change in an array located above the roadway. Their results showed reaction time increased and accuracy decreased as a function of the horizontal location of the light change and the distance, from the driver, of the light change. In addition, reaction time error in car following increased immediately following the light change. These results demonstrate that when drivers attend to a centrally located task, their ability to respond to other events varies as a function of horizontal visual angle and distance in the scene, and was a result consistent with previous useful field of view studies as well as studies examining the spatial limitations of visual attention (e.g., Eriksen & Yeh, 1985), however, they found lower accuracy and long reaction time for detecting light changes positioned at greater distances. As distance increased, the spatial separation between the centrally located lead vehicle and the changing light was decreased.

Figure 1-14 Attention measurement systems in front view of the driving scene
in the experiment of Andersen and Li

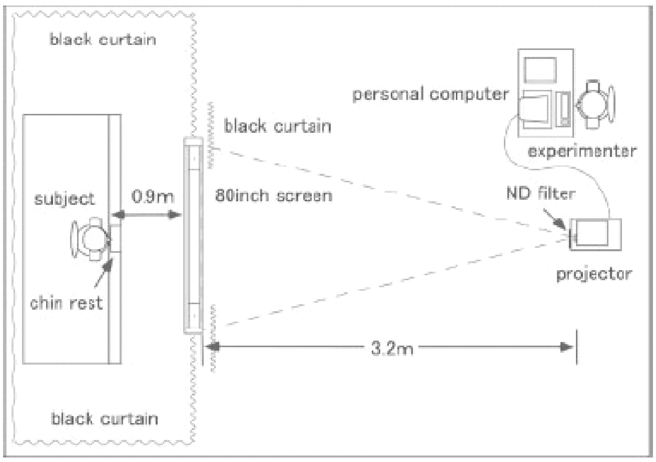


Figure 1-15 Attention search in differential background illuminance
in the experiment of Ochiai and Sato

Concerning the effect of peripheral luminance and color of targets on reaction time of drivers' visual attention in traffic environment, only a few literatures were reported, for example, Ochiai and Sato (2005) [46] (see Figure 1-15), their results showed that the efficiency in searching for orange targets decreases as the number of distractors under different background luminance levels and illuminance conditions increases, whereas that for red and yellow targets barely decreased, differences in target colors have greater influence on visual search than the luminance contrast between a target and a background.

1.8 Purpose and significance

Although the reaction time of visual attention shifting was measured in many of previous investigations, most previous studies have addressed to measure the reaction time in 2-D space, and characteristics of depth attention in 3-D space remained unclear. The purpose of present study is to reveal characteristics of visual attention of drivers in 3-D space under traffic environment. That is, whether there are also same characteristics of visual attention in 3-D space compared with 2-D space, in particular, the depth visual attention characteristic (e.g., asymmetry in depth). In addition, visual function including depth information of visual attention will be also reveal under different observing conditions and peripheral luminance environment.

In present study, we used a three-dimensional visual attention measurement system which can simulate speeds of car, brightness of traffic environment; color signals etc. (1) Three types of subjects will take part in experiments: young students, young students simulated low-visual and elderly peoples. (2) There are two observing conditions: static and dynamic conditions; (3) There are three cue locations: valid, invalid and neutral locations.

One of purpose of present study is that when peripheral environment illuminance will change, young subjects present the characteristics of attention in depth. The background illuminances are: bright (460-680 lx), twilight (95-135 lx) and dawn (6-8 lx) conditions, respectively. That is, whether background illuminance will influence depth attention. Furthermore, we will discuss whether the direction of attention switching has an asymmetry in real space. Second of purpose is that what are differences of attention of elderly subjects comparing with young subjects.

In addition, third of purpose is to research the importance of prior awareness of location (valid and invalid) and prior feature information (color, shape, orientation) for target.

Study of visual attention in 3-D space is a very important work in which cognitive information processing are clarified in our real life. In order to comprehend the relationship between our behaviors and visual attention in real world, it is necessary to reveal visual attentional principium, for example, attention control and attention shifting as well as allocation of attentional resource etc. Furthermore, which way will influence our visual cognition and judgment performance is also a very importance.

Chapter 2　Experimental Procedure

2.1 Introduction

Eye is like a camera (see Figure 2-1). The external object is seen like the camera takes the picture of any object. Light enters the eye through a small hole called the pupil and is focused on the retina, which is like a camera film. Eye also has a focusing lens, which focuses images from different distances on the retina. The colored ring of the eye, the iris, controls the amount of light entering the eye. It closes when light is bright and opens when light is dim. A tough white sheet called sclera covers the outside of the eye. Front of this sheet (sclera) is transparent in order to allow the light to enter the eye, the cornea. Ciliary muscles in ciliary body control the focusing of lens automatically. Choroid forms the vascular layer of the eye supplying nutrition to the eye structures. Image formed on the retina is transmitted to brain by optic nerve. The image is finally perceived by brain. A jelly like substance called vitreous humor fill the space between lens and retina. The lens, iris and cornea are nourished by clear fluid, aqueous humor, formed by the ciliary body and fill the space between lens and cornea. This space is known as anterior chamber. The fluid flows from ciliary body to the pupil and is absorbed through the channels in the angle of anterior chamber. The delicate balance of aqueous production and absorption controls pressure within the eye.

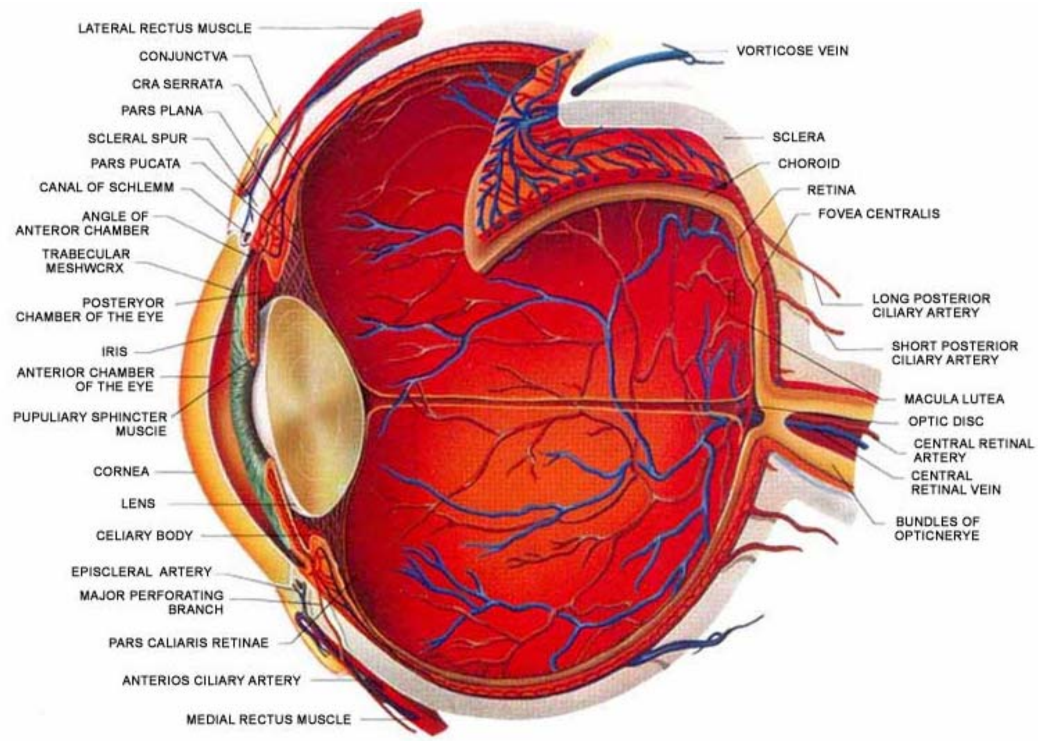


Figure 2-1 Structure of the eye (From structure and function of Garfield et al.)

2.1.1 Adjusting for light and focusing

The eye needs to be able to control the amount of light entering it. In dim conditions, more light is allowed to enter so that a clear image can be formed on the retina. In bright conditions less light is allowed to enter so that the retina is not damaged.

This adjustment is done by two sets of muscles in the iris: its circular muscles contract to close up the iris, making the pupil smaller - while its radial muscles contract to open up the iris, making the pupil larger. You can see how this reflex action works in the animation.

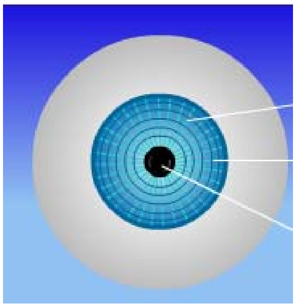


Figure 2-2 Iris reflex in bright conditions

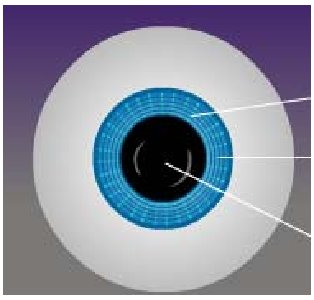


Figure 2-3 Iris reflex in dim conditions

2.1.2 Focusing

Light from an object is reflected in all directions. Some of it enters the front of the eye-the transparent cornea - and is refracted as it meets its curved surface. It then goes through the pupil, and enters the lens. At the lens it is refracted again - this time with fine adjustments to ensure the image focused onto the retina is sharp. From the retina the impulses are taken by the optic nerve to the brain for processing. (The image projected onto the retina is actually upside down, but the brain takes care of this so that we 'see' it the right way up.)

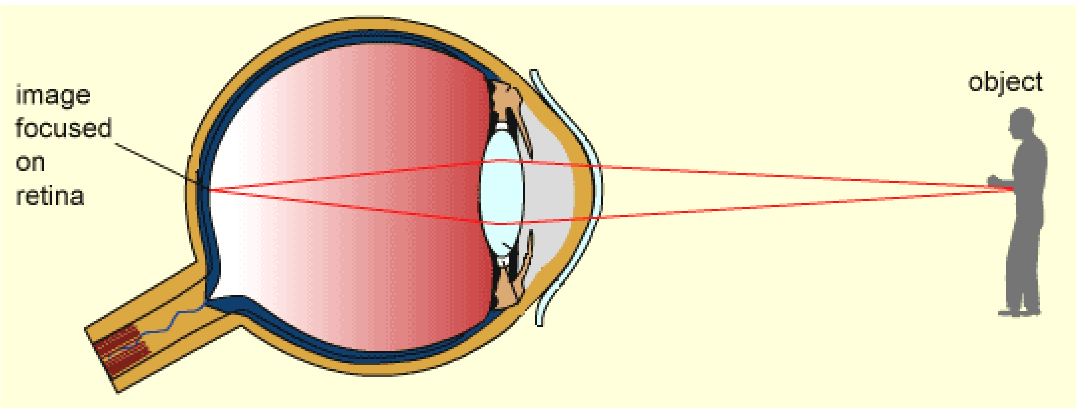


Figure 2-4 Focusing of the eye

When light travels to the eye from a distant object, the rays are almost parallel and need to be bent very little to be brought to a focus. So when viewing a distant object, the lens must be made thinner and less convex. This is done by:

- relaxing the ciliary muscles
- stretching the suspensory ligaments, and
- increasing the muscular tension on the lens.

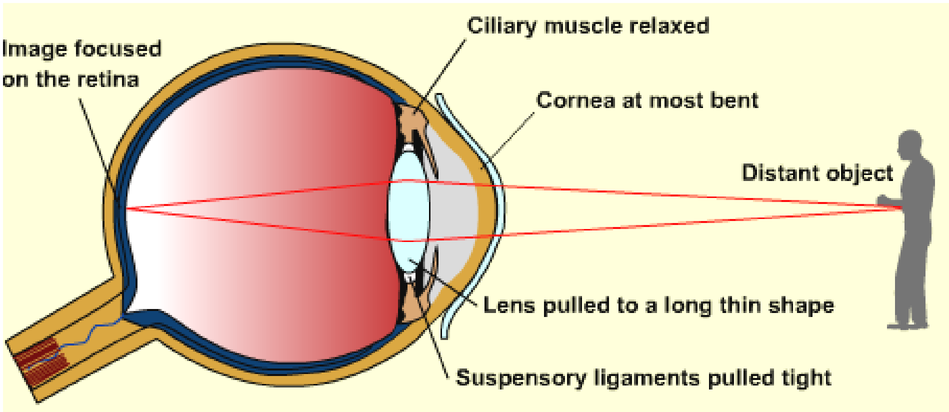


Figure 2-5 The ability of the lens at far place

When light travels from a near object the rays are going away from each other and need to bend a lot more to be brought to a focus. So when viewing a near object the lens needs to be made fatter and more convex. This is done by:

- contracting the ciliary muscles
- slackening the suspensory ligaments, and
- reducing the muscular tension on the lens.

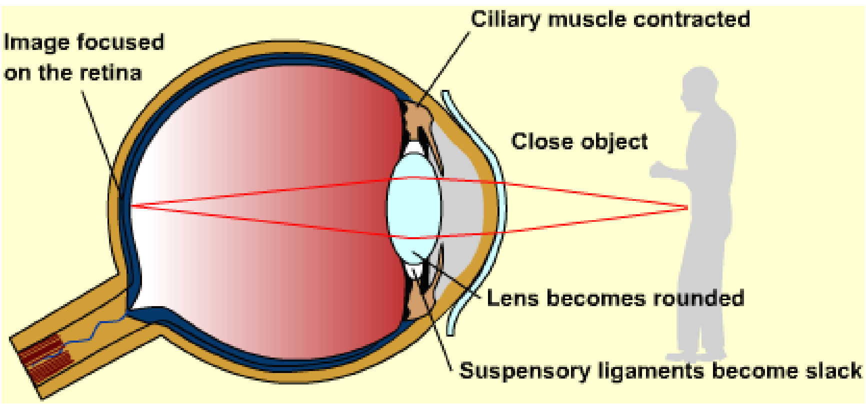


Figure 2-6 The ability of the lens at near place

2.1.3 Accommodation: The ability of the lens to change its shape to focus near and distant objects is called accommodation. The Table 2-1 shows how this is done.

Table 2-1 Reflex action course in near and far places

Object	Ciliary muscles	Suspensory ligaments	Muscle tension on lens	Lens shape
near	contract	slackened	low	fat
distant	relax	stretched	high	thin

2.2 Experimental procedure

The visual functions of the subjects in present study must be tested, including two-dimensional (2-D) and three-dimensional (3-D) visual functions. Only subjects with normal visual functions can be selected as the experimental participators in the Experiment 1 to Experiment 4. Figure 2-7 show the visual functions composition of human in 2-D and 3-D space.

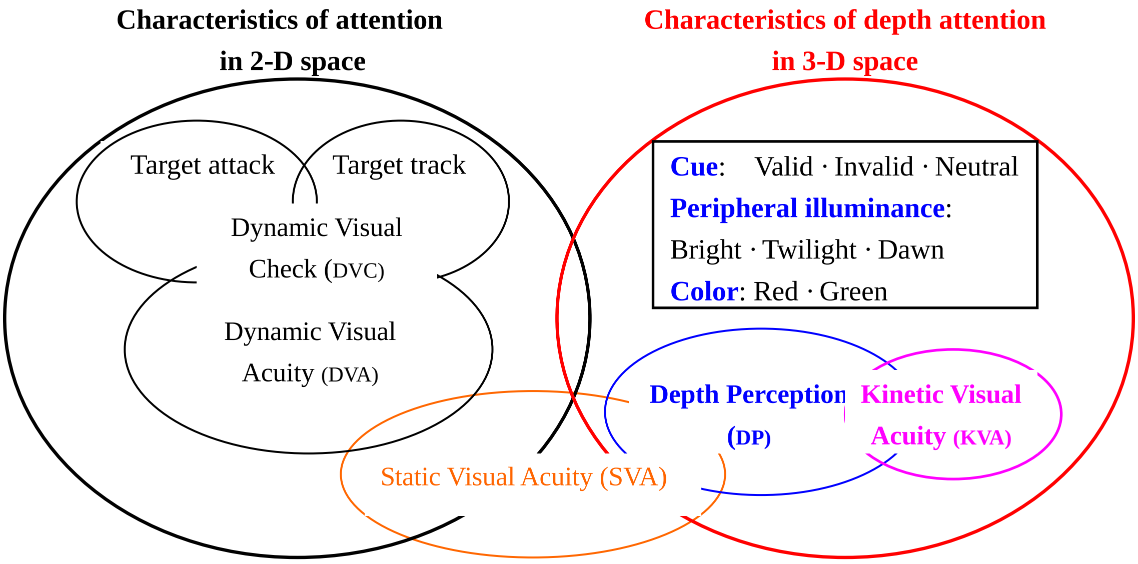


Figure 2-7 Visual functions composition of human attention

2.2.1 Test of visual functions of young subjects in 2-D space

The visual functions of the subjects include ambience adaptability and moving adjustability. Ambience adaptability (a_1) is the ratio of mesopic vision to photopic vision; it was tested using multifunctional sight inspection apparatus STN-04 (see Figure 2-8), mesopic vision and photopic vision of the subjects can be tested using it. Moving adjustability (a_2) is the ratio of kinetic visual acuity to static visual acuity; it was tested using dynamic visual measurement apparatus AS-4D (see Figure 2-9), and dynamic visual check system MMO-DVC-2011 (see Figure 2-10). Kinetic visual acuity and static visual acuity of the subjects can be tested. The sum of a_1 and a_2 is the visual ability of subjects.

$$a_1 = \text{mesopic vision / photopic vision} \tag{1}$$

$$a_2 = \text{kinetic visual acuity / static visual acuity} \tag{2}$$

$$a = a_1 + a_2 \tag{3}$$

Figure 2-8 Multifunctional sight inspection apparatus (STN-04)

Figure 2-9 Kinetic visual measurement apparatus (AS-4D)

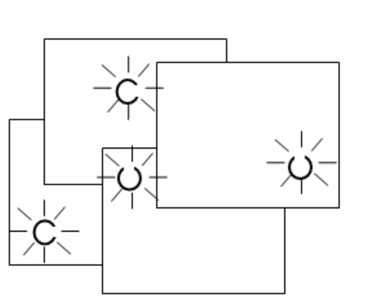


Figure 2-10(a) Target attack program

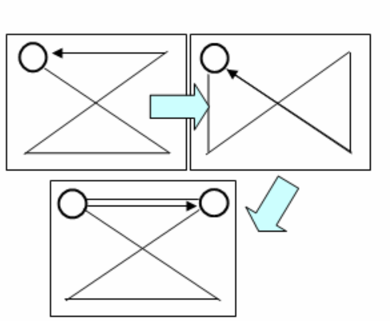


Figure 2-10(b) Target track program

Figure 2-10 (c) Scene of visual target attack and track testing MMO-DVC-2011

2.2.1.1 Test method

Testing of visual function of the subjects include dynamic discrimination (target attack and target track), ambience adaptability (mesopic vision and photopic vision) and moving adjustability (kinetic visual acuity and static visual acuity), in which the subjects will be divided low visual adaptability subjects from high visual adaptability subjects, that is, low visual adaptability group and high visual adaptability group.

(1) Subjects: 15 undergraduate and graduate students of Faculty of Engineering of Kagawa University, whose age vary from 19 to 22 years old.

(2) Apparatus: Using a multifunction sight inspection apparatus (STN-04: Institute of complex medical engineering), mesopic vision and photopic vision of subjects were tested. Kinetic visual acuity and static visual acuity of subjects were tested by the use of a dynamic visual measurement apparatus (see Figure 2-8 and Figure 2-9).

(3) Procedure: The prearrangement experiments consisted of three testing experiments. Subjects were provided with information on display or experimental screen about where targets would present, and reacted accordingly. The subject’s task was to judge the sign (shape) of stimulus displayed at the display or experimental screen and correctly press the corresponding button as quickly as possible.

2.2.1.2 Results of visual function test

Ambience adaptability and moving adjustability of young subjects were listed in Tables 2-1 and 2-2. Table 2-3 listed visual adaptability statistic values of subjects. In order to discuss the effect of visual function on reaction time in detail, the subjects were divided low visual adaptability subjects and high visual adaptability subjects, that is, low visual adaptability group and high visual adaptability group (see Table 2-4). Figure 2-11 suggested the distribution of visual function of young subjects. Testing results showed that visual performance of the subjects had greater individual difference, five subjects had high visual adaptability, and four subjects had lower visual adaptability, one was the lowest, and another was the highest. Dynamic discrimination of subjects in both target track program and target attack program experimental conditions were listed in Tables 2-5 and 2-6. It can be seen from Tables 2-5 and 2-6 that subjects had higher dynamic discrimination in two-dimensional space under the target attack and track programs conditions. Values of dynamic discrimination were all higher (>90 %).

Table 2-2 Moving adaptability test values of young subjects

Subjects	Moving adjustability test		
	Static visual acuity	Kinetic visual acuity	Moving adjustability
Subject1	0.8	0.1	0.125
Subject2	0.9	0.1	0.111
Subject3	1.4	0.8	0.571
Subject4	1.5	0.8	0.533
Subject5	1.2	0.2	0.167
Subject6	1.2	0.6	0.500
Subject7	1.2	0.6	0.500
Subject8	1.0	0.5	0.500
Subject9	0.8	0.4	0.500
Subject10	1.2	0.7	0.583
Subject11	0.8	0.3	0.375
Subject12	1.1	0.7	0.636
Subject13	1.2	0.8	0.667
Subject14	0.8	0.5	0.625
Subject15	1.3	1.0	0.769

Table 2-3 Ambience adaptability test values of young subjects

Subjects	Ambience adaptability test		
	Photopic vision	Mesopic vision	Ambience adaptability
Subject1	0.8	0.1	0.125
Subject2	0.7	0.4	0.571
Subject3	0.8	0.1	0.125
Subject4	1.2	0.3	0.250
Subject5	1.2	0.9	0.750
Subject6	1.2	0.7	0.583
Subject7	1.5	1.0	0.667
Subject8	1.0	0.7	0.700
Subject9	1.2	0.9	0.750
Subject10	0.9	0.7	0.778
Subject11	0.7	0.7	1.000
Subject12	0.9	0.7	0.778
Subject13	0.7	0.6	0.857
Subject14	0.7	0.7	1.000
Subject15	0.7	0.9	1.286

Table 2-4 Visual adaptability statistic values of young subjects

Subjects	Visual adaptability		
	Moving adjustability	Ambience adaptability	Visual adaptability
Subject1	0.125	0.125	0.250
Subject2	0.111	0.571	0.682
Subject3	0.571	0.125	0.696
Subject4	0.533	0.250	0.783
Subject5	0.167	0.750	0.917
Subject6	0.500	0.583	1.083
Subject7	0.500	0.667	1.167
Subject8	0.500	0.700	1.200
Subject9	0.500	0.750	1.250
Subject10	0.583	0.778	1.361
Subject11	0.375	1.000	1.375
Subject12	0.636	0.778	1.414
Subject13	0.667	0.857	1.524
Subject14	0.625	1.000	1.625
Subject15	0.769	1.286	2.055

Table 2-5 Visual performance of subjects of young subjects

	Low group				High group				
a_1	0.57	0.13	0.25	0.75	0.78	1.00	0.78	0.86	1.00
a_2	0.11	0.57	0.53	0.17	0.58	0.38	0.64	0.67	0.63
a	0.68	0.70	0.78	0.92	1.36	1.38	1.42	1.53	1.63

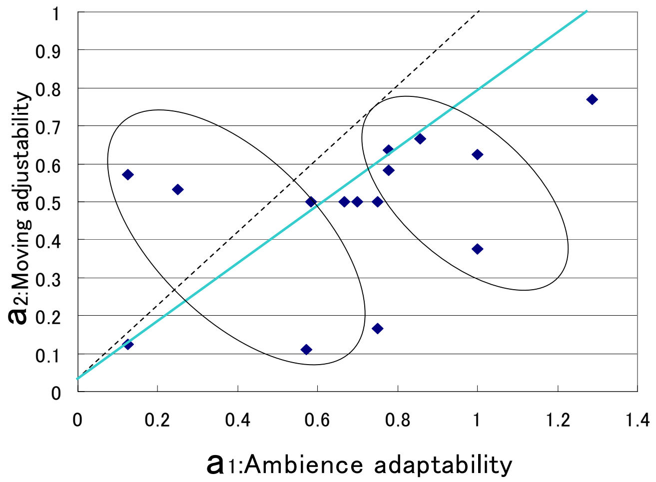


Figure 2-11 Distribution of visual performance of subjects

Table 2-6 Dynamic discrimination of subjects (target track item)

	Target track item				
	Right Response (%)	Delay tendency (times)	Oversight Tendency (times)	Error Tendency (times)	Dynamic discrimination (%)
Subject1	99	0	2	1	99
Subject2	96	42	4	1	98
Subject3	96	28	4	2	97
Subject4	100	0	0	0	100
Subject5	100	0	0	0	100
Subject6	98	0	2	1	98
Subject7	100	0	0	1	99
Subject8	100	0	0	2	98
Subject9	96	4	4	2	97
Subject10	100	0	0	1	99
Subject11	96	0	4	3	97
Subject12	92	0	8	3	96
Subject13	84	26	16	11	88
Subject14	96	0	4	1	98
Subject15	100	0	0	0	100

Table 2-7 Dynamic discrimination of subjects (target attack item)

	Target attack item				
	Right Response (%)	Delay tendency (times)	Oversight Tendency (times)	Error Tendency (times)	Dynamic discrimination (%)
Subject1	100	9	0	0	100
Subject2	98	0	4	0	99
Subject3	100	2	0	0	100
Subject4	96	16	4	0	99
Subject5	100	4	0	0	100
Subject6	93	10	7	1	97
Subject7	96	5	4	2	97
Subject8	100	11	0	3	98
Subject9	87	44	13	0	96
Subject10	98	0	2	2	98
Subject11	96	5	4	9	93
Subject12	91	10	9	2	96
Subject13	100	4	0	0	100
Subject14	100	7	0	4	97
Subject15	100	11	0	0	100

2.2.2 Test of visual functions of young subjects in 3-D space

Depth perception of subjects: Depth perception is currently measured by the “parallel” method. As an alternative to this, there are two new methods for measuring depth perception. One of them is the “control” method, in which subjects control the equipment for themselves. The other is the “momentary” method, in which subject are required to judge within a moment whether the center one of three target poles is to the rear of the poles on either side. In present experiment, we employed “control” method.

Testing of depth perception of the young subjects is conducted by means of depth perception apparatus. In order to conduct the depth attention experiments, subjects must have penetrating response to the fore-and-aft sticks presented in the front of subjects. Figure 2-12 (a) and (b) are overall of apparatus. Figure 2-12 (c) presented scene of depth vision testing. Figure 2-13 is the principium sketch of depth perception testing. Table 2-8 listed depth perception testing values of subjects.

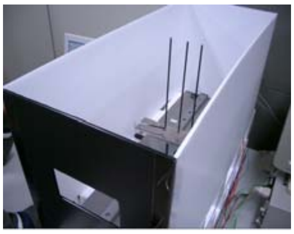


Figure 2-12(a) Overall of depth perception testing apparatus


Figure 2-12(b) Frontispiece of depth perception apparatus


Figure 2-12(c) Depth perception testing scene

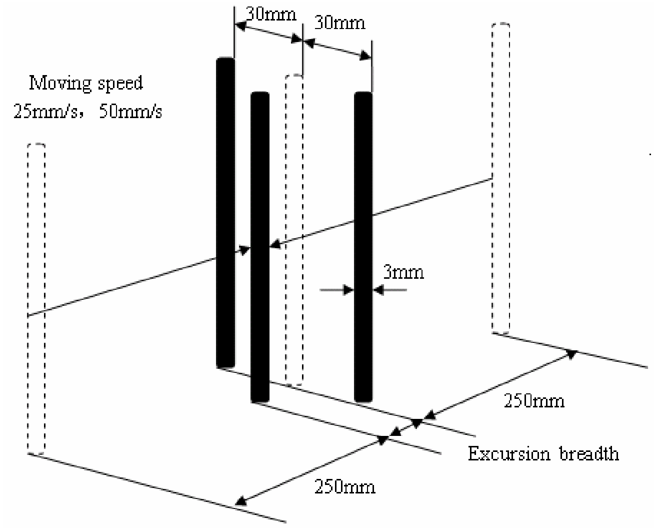


Figure 2-13 Principium sketch of depth perception test

Table 2-8 Depth perception test values of subjects

Subjects	Depth perception		
	Depth adjustability	Perception (from front to back)	Perception (from back to front)
Subject1	10.7	7.67	15.25
Subject2	17.0	13.67	20.33
Subject3	13.7	20.2	7.2
Subject4	10.17	8.6	6.5
Subject5	16.28	10.33	20.75
Subject6	12.45	12.0	8.4
Subject7	23.0	21.0	25.0
Subject8	20.0	9.6	33.0
Subject9	16.55	7.83	30.83
Subject10	13.4	10.5	17.75
Subject11	11.5	9.0	14.0
Subject12	14.0	8.75	14.8
Subject13	9.9	8.67	9.13
Subject14	6.08	6.83	5.33
Subject15	9.58	6.5	12.67

2.2.3 Test of visual functions of older subjects in 2-D space

2.2.3.1 Testing method

(1) Subjects: 17 old drivers form the Hayashi-cho of Takamatsu City. Their age vary from 59 to 68 years old, mean age 63.9 years old.

(2) Apparatus: The apparatus was the same as the experimental apparatus of young subjects.

(3) Procedure: The procedure was the same as the procedure of young subjects.

2.2.3.2 Results of testing

Moving adaptability testing values of older subjects were listed in Table 2-9. It can be seen that there are two wanting data in the experimental results, the kinetic visual acuity value was less than 90%.

Table 2-9 Moving adaptability test values of older subjects

Subjects	Static visual acuity	Kinetic visual acuity	Dynamic discrimination(%) (Target track item)	Dynamic discrimination(%) (Target attack item)
Subject1	0.7	0.4	98	94
Subject2	0.4	0.2	98	98
Subject3	0.6	0.5	95	100
Subject4	1.1	0.5	98	96
Subject5	0.9	0.5	98	99
Subject6	0.6	0.3	96	91
Subject7	0.4	0.4	93	90
Subject8	0.8	0.6	98	95
Subject9	1.0	0.4	93	98
Subject10	0.7	0.4	100	97
Subject11	0.5	0.3	95	88
Subject12	1.0	0.5	96	93
Subject13	0.5	0.2	93	99
Subject14	0.7	0.3	94	97
Subject15	0.7	0.2	97	96
Subject16	0.8	0.3	97	93
Subject17	0.7	0.1	92	60

2.3 Summary

The vision quality of drivers was appraised base on ambience adaptability and moving adjustability as well as depth perception. According to the results, the subjects are apart into two groups, that is, high visual adaptive ability and low visual adaptive abilities. The subjects with low visual adaptive ability will conducted the super-addition experiment in Chapter 3, the aims are to investigate that whether visual adaptability of the subjects with low visual adaptive ability can be improved through visual trainings. Compare with the visual ability of subjects between low and high visual adaptive ability groups, we can found that although the subjects were higher visual ability in 2-D space, and the individual differences was not obvious, there were obvious individual differences on the visual ability in 3-D space. In addition, although many previous researches suggested that impairments in vision, motor-reaction, and cognitive abilities were often associated with aging, even if age of subjects was not visible difference, their visual performance was obvious disparity. So, drivers with lower visual acuity in driving were in greater danger. The results showed that it was necessary to study visual attentional characteristics of drivers in real word.

The subjects with wanting visual ability will not take part in reaction time test experiments (Experiment 3 in Chapter 5).

Chapter 3 A Study on Characteristics of Attention in Depth of Young Subjects in Changing Supposed Environmental Illuminance

3.1 Introduction

An important property of visual processing is the ability to allocate processing resources or attend to locations in the visual field that might contain important information. Considerable research has been conducted to determine the spatial limits of visual attention when subjects are required to attend to information at a specified position in the visual field.

B. A. Eriksen and C. W. Eriksen (1974) presented subjects with five simultaneous items in visual displays. The subjects were required to respond to the middle item of each display and to ignore the adjacent noise elements that were present. The response specified by the adjacent set of elements was either compatible or incompatible with the response to the central target. By varying the spatial separation of the noise elements relative to the central target, the size of focused attention could be measured. If the noise elements fell within the focus of attention, reaction time (RT) would be greater when they were incompatible with the response to the central target than when they were compatible. Using this paradigm, B. A. Eriksen and C. W. Eriksen found that the interfering effects of the incompatible noise elements decreased with greater spatial separations between the target and noise elements up to 1^0. In other studies containing similar paradigms, similar limits have also been found (Posner, Nissen, & Ogden, 1978).

However, other studies have yielded evidence that the spatial limits of attention are greater than the 1^0 limit. LaBerge (1983) presented subjects with displays containing letters that sometimes formed words. Some subjects were required to attend to single letters, whereas other subjects were required to attend to entire words. The size of the focus of attention, as measured with a response target that varied in horizontal position, was larger for the subjects who were required to attend to words. LaBerge proposed that attention operated like a spotlight in the visual field. Items falling within the beam of this spotlight received processing priority over items not falling within the "beam" of attention.

In general, research on the size of focused attention has involved the investigation of processing limitations when an item at a specific location is attended to in a two-dimensional (2-D) display. Few researches have been designed to investigate the size of focused attention within a three-dimensional (3-D) scene. There have, however, been two studies in which the movement of attention (shifting the focus of attention from one location to another location) in a 3-D scene was investigated. They are studies of Downing and Pinker (1985)[47] and Gawryszewski, Riggio, Rizzolatti, and Umiltâ (1987).

Downing and Pinker required subjects to attend to the central position within an array of lights in a 3-D scene. The lights were organized along different visual directions in two rows located at different distances from the subject. A cue presented at the central location indicated the visual direction in which a light might appear. Responses were slower for targets positioned farther away than for closer targets. In addition, the cost of attending to farther targets increased with increased retinal eccentricity. They proposed that the mental representation underlying visual attention was similar to the 2½-D sketch proposed by Man & Nishahara, in which depth and visual angle were important in the underlying representation.

Gawryszewski, Riggio, Rizzolatti, and Umiltâ also investigated the movement of attention in depth. Subjects were presented with a central stimulus that cued the subject to a position along the same visual direction that was either closer or farther away than the central stimulus. A response target was then presented at either of these two positions. On some of the trials, the central cue was valid, but on other trials, the cue was invalid. Mean RTs were greater for invalid cues than for valid cues, suggesting that the subjects could not simultaneously attend to targets positioned at different distances.

In another type of research involving the effects of depth variations on attention, Nakayama and Silverman (1986) investigated the usefulness of depth information as a discriminating feature in a visual search task. The target to be identified was embedded within a field of noise items in a stereoscopic display. If the target was located at a different depth plane than the noise items were, then the search for the target proceeded in parallel. This occurred for a variety of combinations of perceptual information used to define the noise items. Although the three studies discussed above examined the role of depth information on attention switching (Downing & Pinker, 1985; Gawryszewski et al., 1987) and visual search (Nakayama & Silverman, 1986), they did not assess the size of focused attention in 3-D space.

Although the studies discussed above examined the role of depth information on attention switching (Downing & Pinker, 1985; Gawryszewski et al., 1987) and visual search (Nakayama & Silverman, 1986), they did not assess the size of focused attention in 3-D space. Andersen (1990), Andersen and Kramer (1993) examined the distribution of attention in 3-D space by means of random dot stereograms (RDS).

Subjects, in Andersen's experiments (1990), viewed random-dot stereogram displays in which they responded differentially to vertical and horizontal bars. Adjacent noise elements either were identical to the response target or specified the opposite response. The position of the noise elements was varied in depth according to binocular disparity. Interference by incompatible noise elements decreased with depth separation between the noise elements and response target. In addition, interference was greater for noise elements that were more distant from the observer than from the response target than it was for noise elements that were closer to the observer than to the response target. The implications of these results for a viewer-centered representation of focused attention in depth are discussed. Subjects, in Andersen and Kramer's experiments (1993), performed a response-compatibility task in which they were instructed to respond to a centrally located target and ignore flanking distractors. The irrelevant distractors were presented at combinations of seven different depths, three different horizontal separations, and three different vertical separations relative to the target. Depth was varied in a stereoscopic display viewed through polarized glasses. The results, the size of the response-compatibility effect decreased with increased separation in all three dimensions. Interestingly, the response-compatibility effect was larger for horizontal separations than for vertical separations and was larger for crossed disparities than for uncrossed disparities. The results suggest an elliptical focus of attention, with steeper gradients in the vertical dimensions than in the horizontal dimensions. In addition, the results suggest, along the vertical dimension, a steeper gradient for objects located beyond the focus of attention relative to that for objects located between the observer and the focus of attention.

In the other hand, as for "depth-blind", Ghirardelli and Folk (1996)[48] found in their study by cuing paradigm that the attentional effect did not change between in 3-D display and 2-D display; this was called "depth-blind", internal representation of attention without depth information.

Atchley, Kramer, Andersen and Theeuwes (1997)[49] also investigated "depth-aware" attentional focus. In their experiment 1, observers viewed stereoscopic displays in which one of four spatial locations was cued. Two of the locations were at a near-depth location and two were at a far-depth location, and a single target was presented along with three distractors. The results indicated a larger cost in reaction time for switching attention in x, y and depth than in x, y alone, supporting a "depth-aware" attentional spotlight. In their experiment 2, no distractors were present, similar to the displays used by Ghiradelli and Folk. In this experiment, no effect for switching attention in depth was found, indicating that the selectivity of attention in depth depends on the perceptual load imposed on observers by the tasks and displays.

Recently, considerable interest has been generated in investigations of the relationship between visual attention and traffic safety. Miura, Shinohara & Kanda (1994) investigated the influence of visual aids (e.g., automobile navigation systems) on driving safety, based on their previous research of eye movements and useful field of view in real driving. They mentioned that the rapid and efficient switching of attention between the forward environment and the inside display of a car was crucial for safety. The characteristic of shifts of attention in depth for moving and stationary observers was examined by the using an improved tunnel simulator. In their experiment, subjects moved at apparent speeds of 40 km/h or 80 km/h or were stationary, digital LEDs cue and stimuli were used at fixation point and targets location, the subjects' task was to judge the relative distance of targets (farther, nearer, or the same), in comparison with a fixed point. Results demonstrated that reaction times for nearer targets were shorter than those for farther targets in all conditions. Andersen & Ni (2005) examined the limits of spatial attention during driving using a dual-task performance paradigm. Drivers were asked to follow a lead vehicle that varied in speed while also detecting a light change in an array located above the roadway. Their results showed reaction time increased and accuracy decreased as a function of the horizontal location of the light change and the distance, from the driver, of the light change. In addition, reaction time error in the car following increased immediately following the light change. These results demonstrate that when drivers attend to a centrally located task, their ability to respond to other events varies as a function of horizontal visual angle and distance in the scene, and was a result consistent with previous useful field of view studies as well as studies examining the spatial limitations of visual attention (e.g., Eriksen & Yeh, 1985; Laberge, 1983), however, they found lower accuracy and a long reaction time for detecting light changes positioned at greater distances. As distance increased, the spatial separation between the centrally located lead vehicle and the changing light was decreased.

3.2 Method

3.2.1 Subjects

Fifteen students, at Faculty of Engineering, Kagawa University, served as participants, whose age vary from 21 to 25 years old, all subjects had normal vision and more than one year of driving experience by self-report.

3.2.2 Apparatus

The overall size and structure of the experimental apparatus (see Figure 3-1 and Figure 3-2) were 800 cm length, 110 cm wide and 165 cm high. Scale the model to be one twenty-five of actual size in the inner of this apparatus, it looks like a tunnel (see Figure 3-3) in which there were four targets, inner size of the apparatus were 720 cm depth, 30.5 cm wide and 15.5 cm high. The observer viewed the scene by an eyepiece (1/2 multiple), so the apparent scenery was 1/50 scale. The tunnel simulator had miniature of typical tunnel lights, sidewalls and road surface. The fixation point was a yellow digital light-emitting diode (LED) with a diameter of 5 mm and approximately 4.3 cd/ m^2 in brightness, and was located at high of 1.5 cm above the central line of sight of subject, presented at a distance of 120 cm from the subject. There were two targets separately in front and behind of the fixation point, 30 cm and 81cm (in front) as well as 158 cm and 231 cm (in behind) from observer. It is equated distance of 15 m, 40.5 m, 79 m and 115 m respectively in real space by means of eyepiece. Presentation of targets and fixation point was implemented using PC (Gateway [OS: Windows XP, CPU: Pentium III 1 GHz, RAM: 256MB SDRAM). The subject sat on the chair (see Figure 3-4) of a cart moving to-and-fro in tunnel alleyway. The stimuli were digital LED located in the front of sight line of the subject. When the observer was moved at a speed of 0.44 m/s, which, looking through an eyepiece could create the visual sensation of traveling at 80 km/h. Subject was provided with prior information in fixation point about where target would appear, and reacted accordingly, and then push the button (see Figure 3-5) as soon as possible. Figure 3-6 express detailed overall size of experimental apparatus. Figure 3-7 is Experimental apparatus control systems.

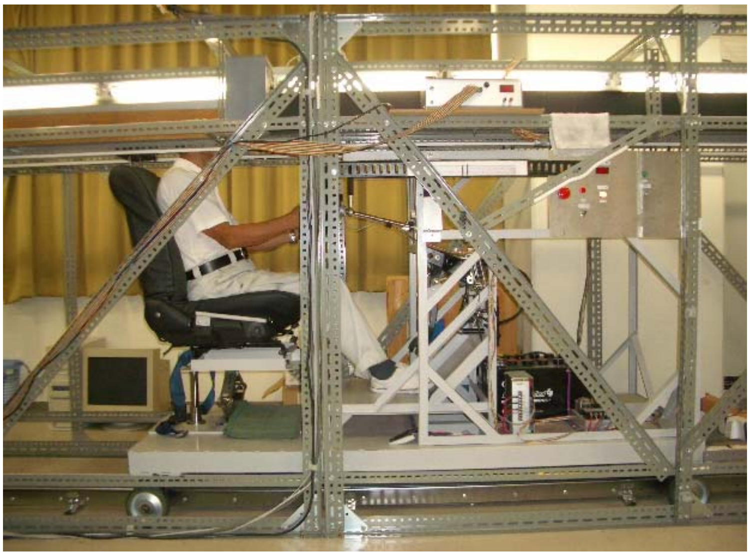


Figure 3-1 Overall of experimental apparatus

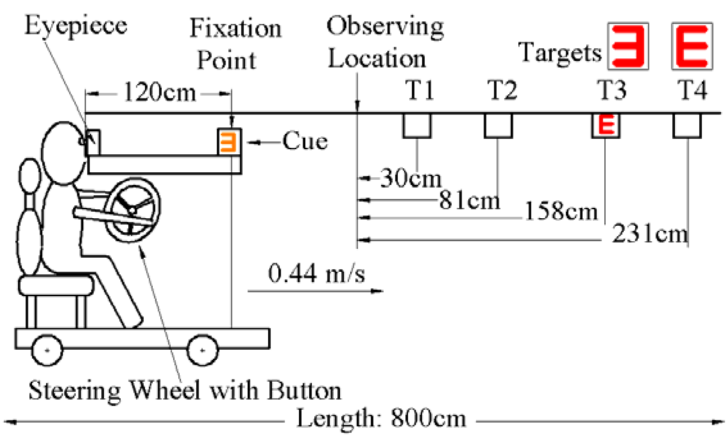


Figure 3-2 A three-dimensional attentional measurement systems

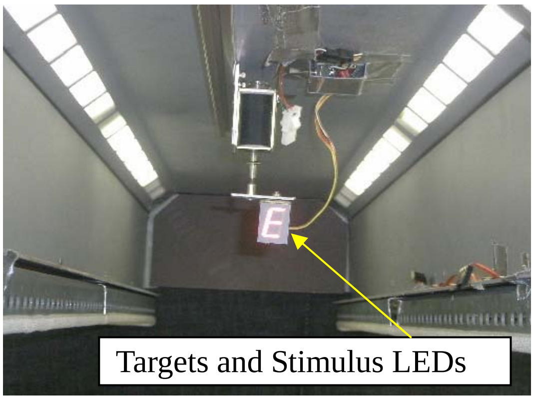


Figure 3-3(a) A tunnel scene under bright condition

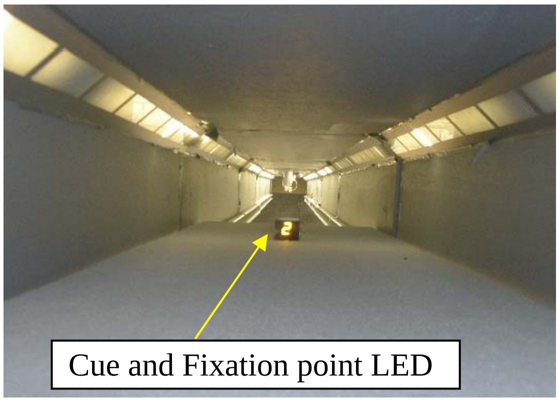


Figure 3-3(b) A tunnel scene under twilight condition

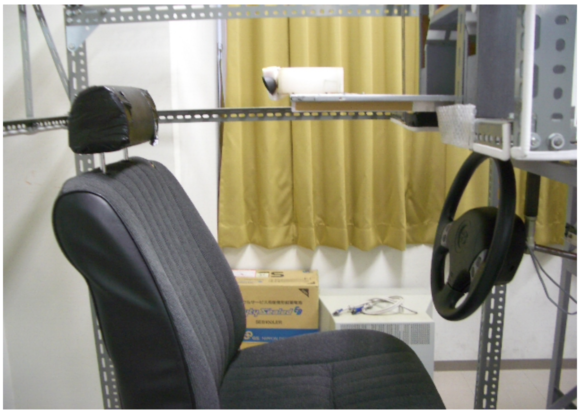


Figure 3-4 Chair of a cart moving to-and-fro

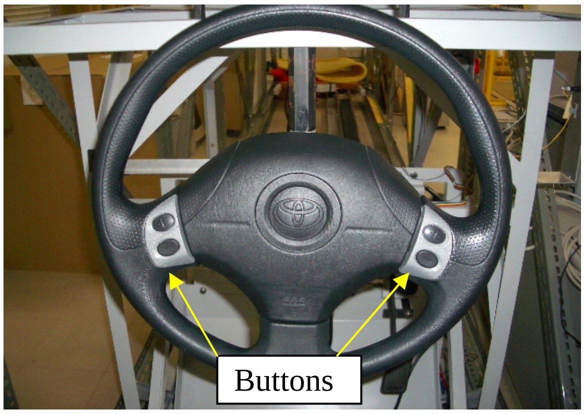


Figure 3-5 Steering wheel with buttons

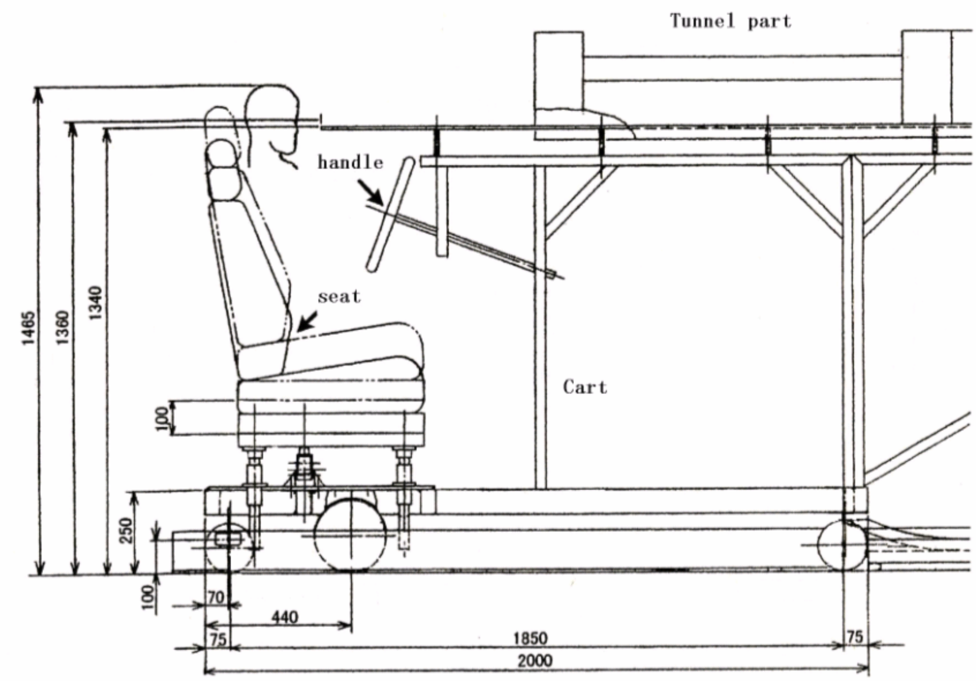


Figure 3-6 Size of experimental apparatus

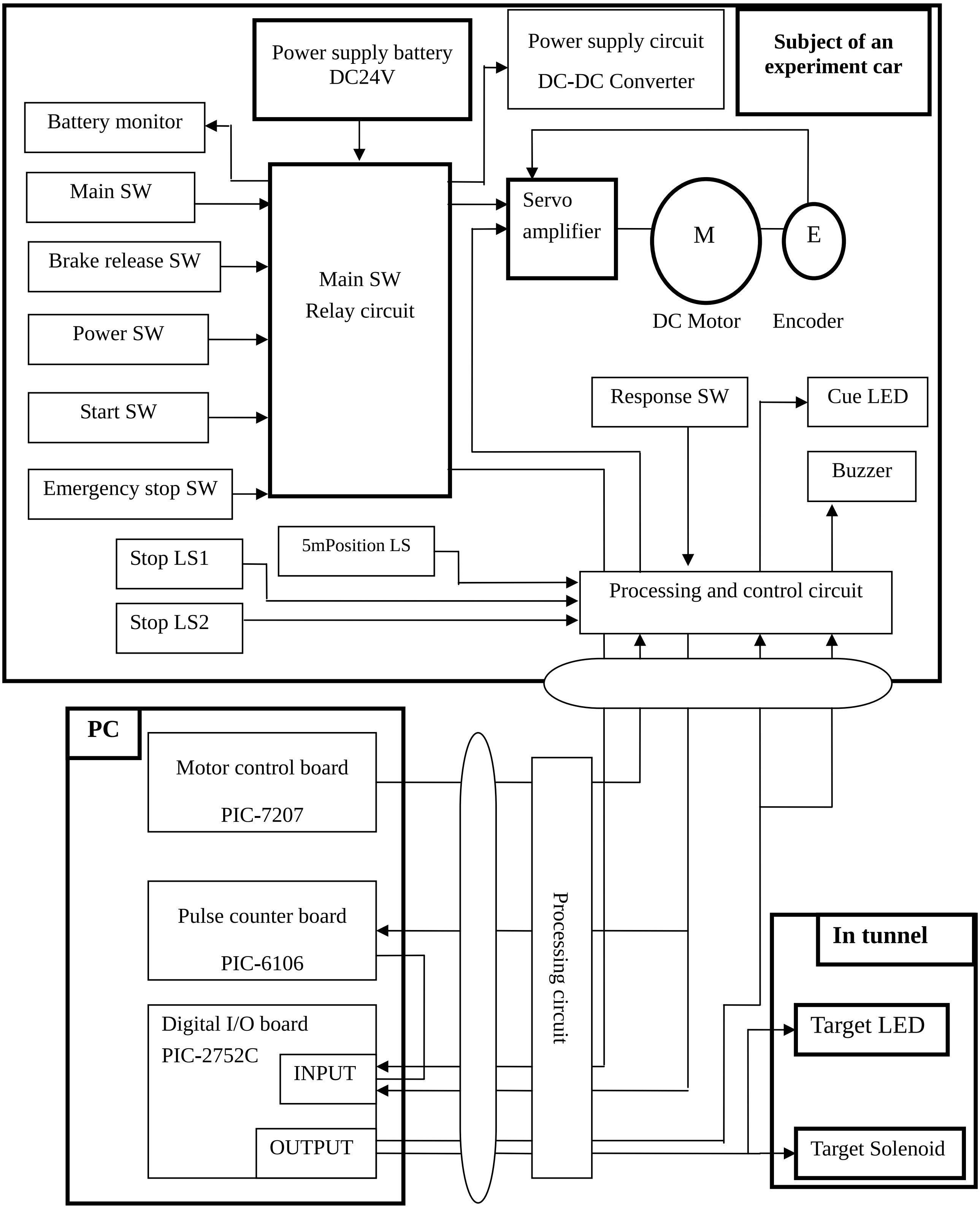


Figure 3-7 Experimental apparatus control systems

3.2.3 Cue and stimuli

The numbers of cue were “1”, “2”, “3”, “4” and “0”with yellow color, the shape of stimuli in target locations (T1, T2, T3 and T4) was “E” or “3” with red color digital LED. Size of the cue was 10×16mm. Size of the target was 10×16mm (T1), 12×18mm (T2), 20×27mm (T3) and 22×35mm (T4), respectively.

3.2.4 Experimental design

The observing condition was in moving condition (0. 44 m/s). Three within-observe variables were used: cue validity (valid: V, invalid: I, neutral: N). 65% of all trials were the valid, 15% were the invalid and 20% were the neutral. The entire experiment consisted of a unique session of 320 trials. Subjects have a short rest around 5min every 160 trials. The fixation point was presented after 1000ms from the beginning of each trial and the information of target location were presented in the fixation position by digital LED (1 to 4). And then, the targets were presented until subjects made response. In order to judge accurately targets which appeared timely, shape of targets were used in “E” or “3”. Concerning the invalid condition of cues, there were two condition, it was named as the invalid-same (I-s) when the target indicated in depth at approximately same region as the fixation point, for example, T2 of Figure 3-2 was shown when T1 was presented in the fixation point, similarly, T4 was shown when T3 was presented. On the other hand, it was named as Invalid-different (I-d) when the target indicated in depth at further opposite region as the fixation point, for example, T4 of Figure 3-2 was shown when T1 was presented in the fixation point. T3 was shown when T2 was presented. The distance of attention shifting between target and fixation were showed in Figures 3-8 and 3-9. Figure 3-10 showed the interface of control measurement systems.

3.2.5 Task and procedure

Task of the subject was to judge whether the target presented nearer than fixation point or further than it, then the subjects must make a quick response according to the information presented beforehand at the targets location: “E” or “3”, and then push the button as soon as possible. Subjects have to exercise before the formal experiment. The procedure and task in exercise are almost the same as the formal experiment. When subject can accomplish the task by achieving the criteria of accuracy, the exercises stop.

This experiment regarded peripheral illuminance 480-680 lx as a bright condition, and 95-135 lx as a twilight condition. According to results of experiment, analyze characteristic of depth attention of young subjects.

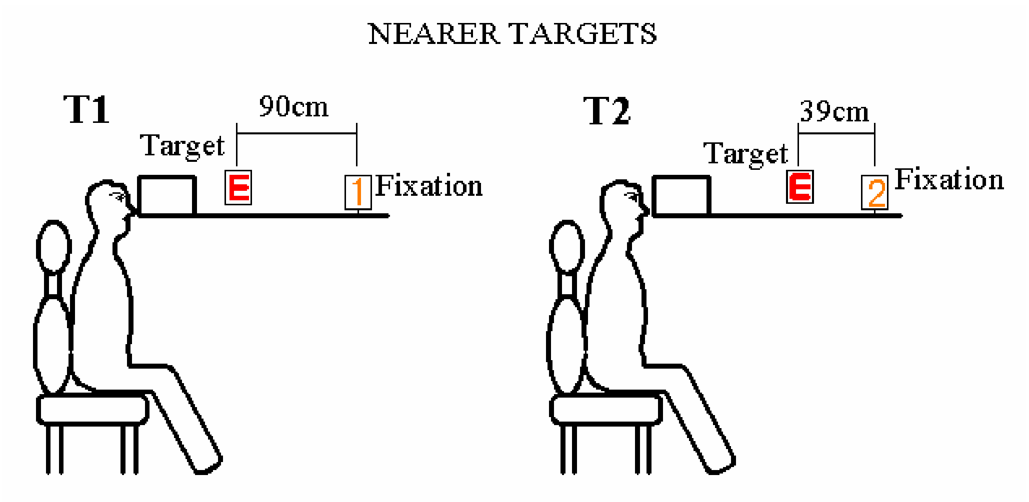


Figure 3-8 Distance between target and fixation (nearer targets)

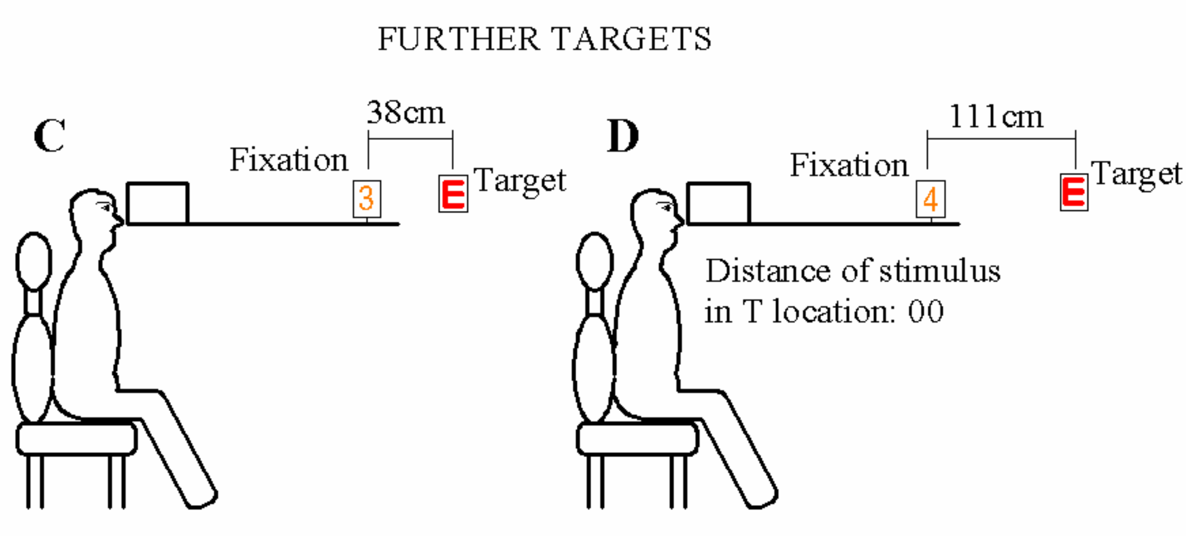


Figure 3-9 Distance between target and fixation (farther targets)

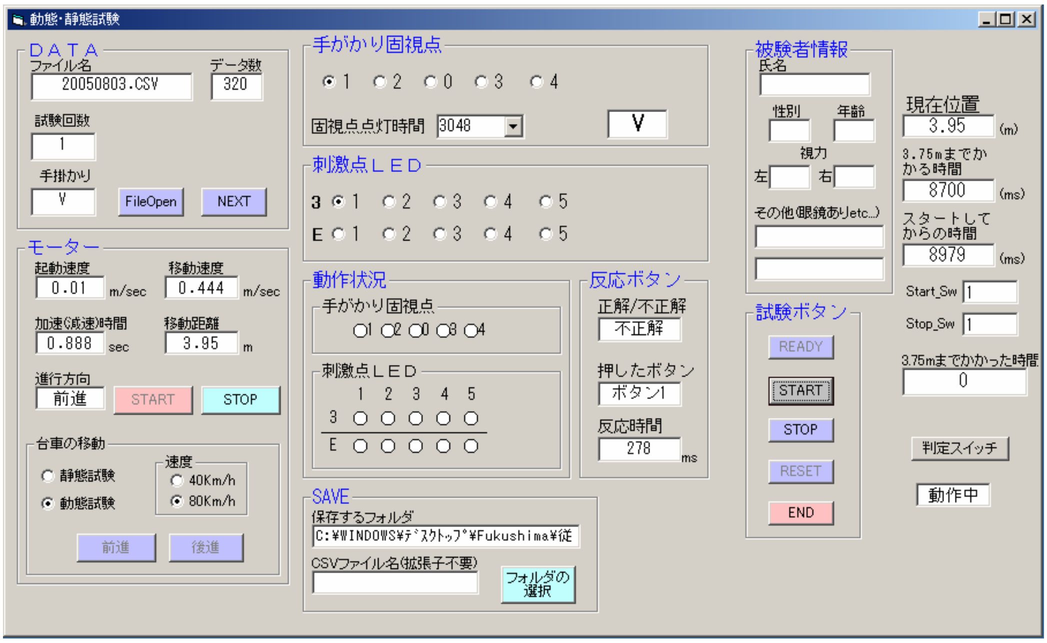


Figure 3-10 Interface of control systems

3.3 Results and discussion

The reaction time of subjects for correct responses under both bright and twilight conditions were listed in Tables 3-1 and 3-2.

Table 3-1 Mean RTs in bright condition (ms)

	Bright condition				
	Valid	Invalid	Neutral	From far to near	From near to far
Subject1	329	400	359	388	412
Subject2	501	512	529	492	528
Subject3	351	450	400	414	489
Subject4	429	572	487	584	612
Subject5	346	414	358	388	436
Subject6	418	579	466	547	615
Subject7	428	521	461	528	515
Subject8	361	442	389	407	480
Subject9	485	632	539	642	638
Subject10	386	421	393	405	440
Subject11	362	418	392	386	453
Subject12	349	429	379	408	451
Subject13	341	440	370	388	485
Subject14	363	495	413	491	499
Subject15	414	439	423	442	435
Average	391	478	424	461	499

Table 3-2 Mean RTs in twilight condition (ms)

	Twilight condition				
	Valid	Invalid	Neutral	From far to near	From near to far
Subject1	405	418	418	407	427
Subject2	492	565	557	531	603
Subject3	413	515	433	451	568
Subject4	375	564	412	520	609
Subject5	388	441	404	434	449
Subject6	347	379	359	363	395
Subject7	345	403	364	388	420
Subject8	407	603	499	573	631
Subject9	422	435	427	431	439
Subject10	352	475	382	430	526
Subject11	343	408	359	359	449
Subject12	398	535	433	507	565
Subject13	389	520	431	506	536
Subject14	431	467	436	462	472
Subject15	366	447	407	435	459
Average	392	479	421	453	503

The reaction time of subjects for correct responses under both bright and twilight conditions were shown in Tables 3-3 and 3-4.

Table 3-3 Mean RTs in invalid-same and invalid-different under bright condition (ms)

	Bright condition			
	From far to near		From near to far	
	Invalid-s	Invalid-d	Invalid-s	Invalid-d
Subject1	503	533	506	519
Subject2	522	486	521	532
Subject3	596	664	539	684
Subject4	460	421	437	461
Subject5	409	403	459	432
Subject6	395	381	404	486
Subject7	381	373	399	419
Subject8	509	567	562	651
Subject9	415	377	440	433
Subject10	394	425	458	509
Subject11	353	404	438	515
Subject12	522	535	655	588
Subject13	471	495	495	502
Subject14	446	441	432	438
Subject15	400	424	459	448
Average	452	462	480	508

Table 3-4 Mean RTs in invalid-same and invalid-different under twilight condition (ms)

	Twilight condition			
	From far to near		From near to far	
	Invalid-s	Invalid-d	Invalid-s	Invalid-d
Subject1	401	413	404	435
Subject2	548	523	590	598
Subject3	437	457	476	614
Subject4	514	529	644	580
Subject5	438	431	462	442
Subject6	373	361	410	387
Subject7	375	394	375	441
Subject8	583	652	581	656
Subject9	437	428	478	415
Subject10	407	442	461	559
Subject11	355	361	413	464
Subject12	568	520	581	555
Subject13	518	500	569	517
Subject14	450	469	461	478
Subject15	440	434	435	474
Average	456	461	489	508

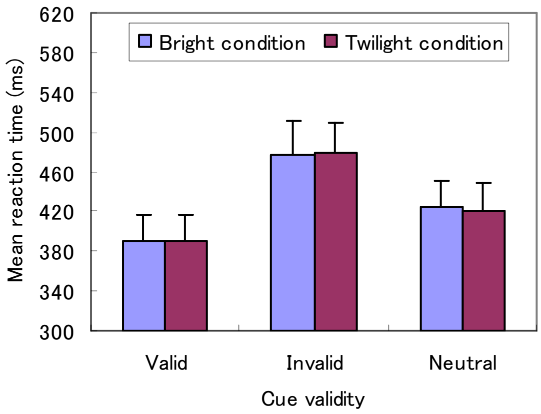


Figure 3-11 Mean reaction time in each condition

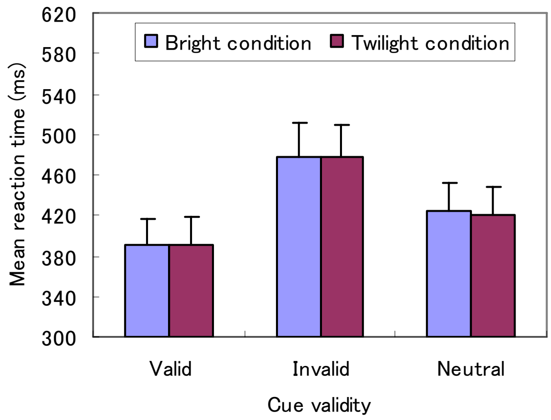
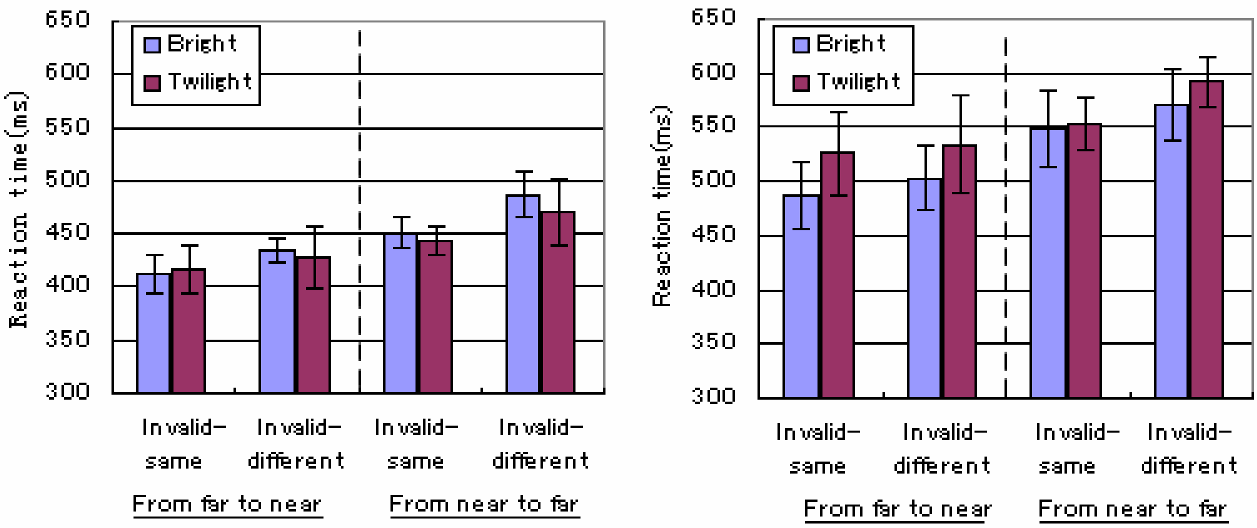


Figure 3-12 Mean reaction time in invalid conditions

There was a significant main effect of attention. RTs in the valid condition were shorter than those in the neutral condition, which were in turn shorter than those in the invalid condition (see Figure 3-11). Besides, Figure 3-12 showed the difference of RTs in I-s and I-d condition as well as the shifts of attention from far to near was faster than from near to far. The mean RTs was shorter from far to near than from near to far in both I-s and I-d condition, in the other hand, response was faster in I-s condition than in I-d condition. These results showed that there was an influence by the moved distance of attention switching, there was anisotropy in the shifts of the attention because RTs was delayed when the attention was moved from" from far to near "to "from near to far" in the I condition, that is, shifts of attention had an asymmetry in 3-D space, the results were consistent with previous reports (Miura, 1994, 2002; kimura, 2002).

Figure 3-13 (a) and (b) showed a clear the comparison of the mean RTs of the subjects with (a) high visual adaptability and (b) low visual adaptability group.



(a)High visual adaptability group (b) Low visual adaptability group

Figure 3-13 Mean reaction times of subjects in both bright and twilight conditions

Table 3-5 Mean RTs in both bright and twilight conditions

Luminance condition	High visual adaptability				Low visual adaptability			
	From far to near		From near to far		From far to near		From near to far	
	I-s	I-d	I-s	I-d	I-s	I-d	I-s	I-d
Bright (480-680 lx)	412.9	434.7	451.0	486.6	486.6	503.3	548.1	569.8
Twilight (95-135 lx)	417.0	427.6	443.4	470.5	526.2	534.1	553.2	591.9

It can be seen that the mean RTs of subjects with high visual adaptability was far less that with low visual adaptability in I-s and I-d condition as well as both from far to near and from near to far cases (see Table 3-5).

When peripheral environment illuminance was bright condition (480-680 lx), to high visual subjects, RTs were the longest in I-d of “near to far” cases, was the shortest in I-s of “far to near” cases. To high visual subjects, RTs margin was 94ms, the mean RTs margin between them above-mentioned was approximately 74ms. RTs were 48ms (in I-s cases) and 52ms (in I-d cases) more in “near to far” than “far to near”, corresponding. To low visual subjects, RTs were 61ms (in I-s cases) and 67ms (in I-d cases) more in “near to far” than “far to near”, corresponding.

When peripheral environment illuminance was twilight condition (95-135 lx), similarly, RTs were the longest in I-d of “near to far” cases, was the shortest in I-s of “far to near” cases. RTs of the subjects with high visual adaptability were faster in each Invalid cases of twilight (except I-s) than in bright. However, RTs of the subjects were slow in twilight than in bright condition under each case.

It may be remarked that the subjects with high visual adaptability will acquired more information if the contrast of the target and the background gone up by lowered the illuminance of the environment base on the vision theory.

The N condition was understood to be the normal driving condition. The differences between the I and the N conditions were considered costs (inhibiting reaction), while those between the N and the V conditions were considered benefits (promoting reaction). The costs and benefits result of the subjects with high visual adaptability was shown in Figure 3-14, and the result of the subjects with low visual adaptability was shown in Figure 3-15. Figure 3-14, compared with Figure 3-15, illustrated that the attention moved distance could produced a lager impact on the delay of reaction time in attention switching of “from near to far” than in attention switching of “from far to near”. In addition, it was shown that the attention moved distance could produce a larger impact on the delay of reaction time in the subjects with low visual adaptability than the subjects with high visual adaptability in Figure 3-15.

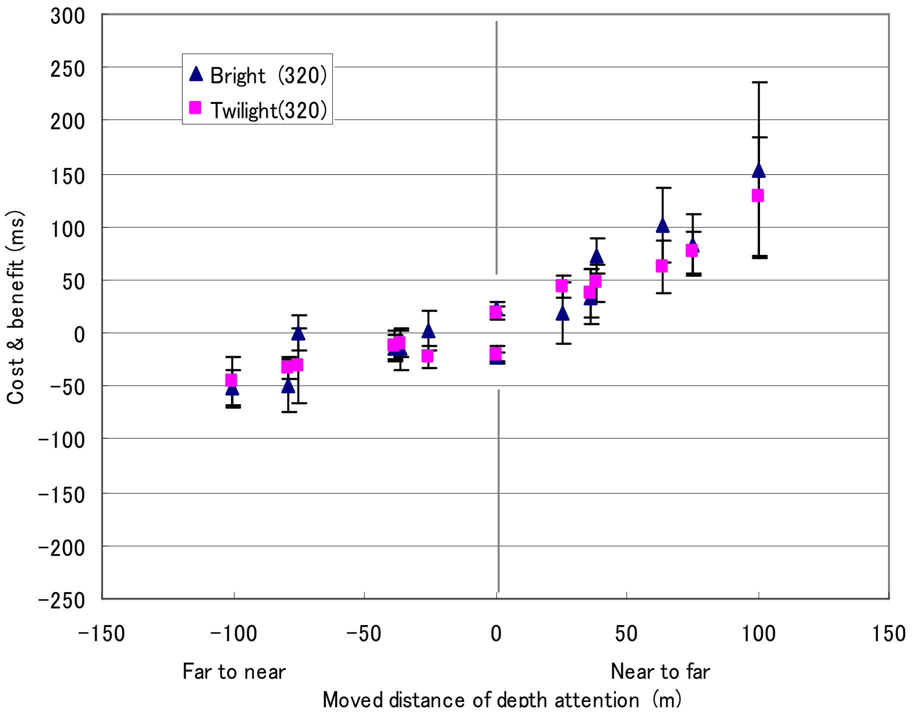


Figure 3-14 Cost & benefit of the moved distance (High visual adaptability group)

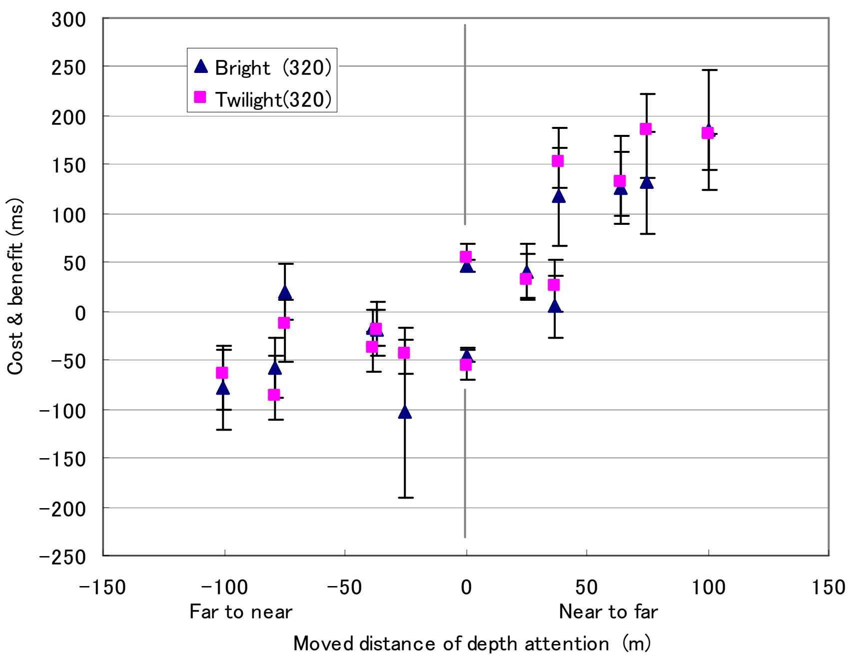


Figure 3-15 Cost & benefit of the moved distance (Low visual adaptability group)

The difference of low visual adaptability group between both two kinds of bright conditions when attention switching of “from far to near”. The difference of low visual adaptability group between both the condition of the bright condition and the twilight condition was obvious than high visual adaptability group. Moreover, the attention moved distance appears more remarkably between 38.5m and 75m. It follows from above-mentioned results that the quiescent vision and dynamic vision in bright condition fell with aging, and the visual adapt ability was also decreased with aging. So, it was necessary that the individual difference of the subjects in visual adaptive ability was affected by cue were investigated aftertime.

In conclusion, the mean RTs slowed more in the twilight condition than in the bright condition in both groups, and the mean RTs was faster more in “from far to near” cases than in “from near to far” cases in both groups. It appeared that the adjustment ability of ocular convergence fell by the background's darkening on twilight quiescent vision and dynamic vision; the quiescent vision would decrease more along with aging in bright condition and twilight condition, it was obvious low visual adaptability group than high group.

3.4 Superaddition experiment

3.4.1 Method

Although some drivers behaved an insufficiency of visual performance in driving, had forecast ability to the frontage, and could made an advance response. Training of visual attention could ameliorate responses to further and nearer events in traffic environment. The purpose of this experiment was to open out the relationship of the delay of reaction time and the distance of the attention moved distance. In this superaddition experiment, subjects were selected from observers with low visual adaptability in term of results in Table 3-5, changing forecast degree was executed.

3.4.1.1. Subjects

Two students with low visual adaptability (Mean age was 21.5 years old) as participants. Both cleared about experimental procedure.

3.4.1.2. Apparatus and stimuli

Experimental apparatus was the same as one of depth attention measurement experiment, rate of cue presented in fixation location was a valid cue 65% of the trial, a invalid cue 15% of the trial and a neutral cue 20% of the trial, but stimuli information presented in the target location and information of cue in the fixation point location was given to the subject in advance.

3.4.1.3. Procedure

Stimuli information in target location “T1” only was prompted with number “1” in valid condition, moreover, cue of fixation point used all number “1” in target point in invalid condition. There were two kinds of cases: from far to near cases and from near to far cases. When being from far to near cases, in invalid condition, cue of fixation point was presented “4”, on the other hand, when being from near to far cases, cue of fixation was presented “1”. Two kinds of cases were 120 times, respectively.

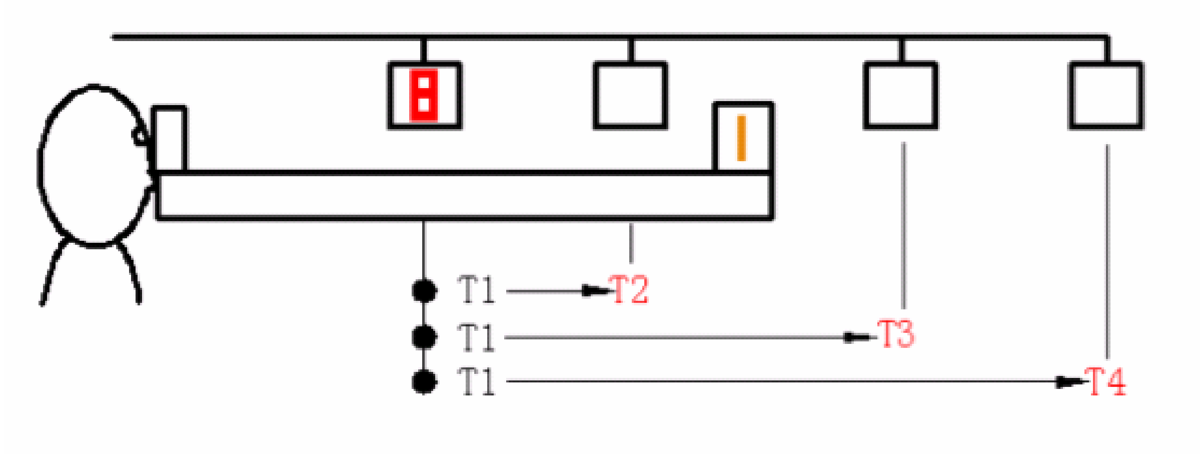


Figure 3-16 From near to far cases

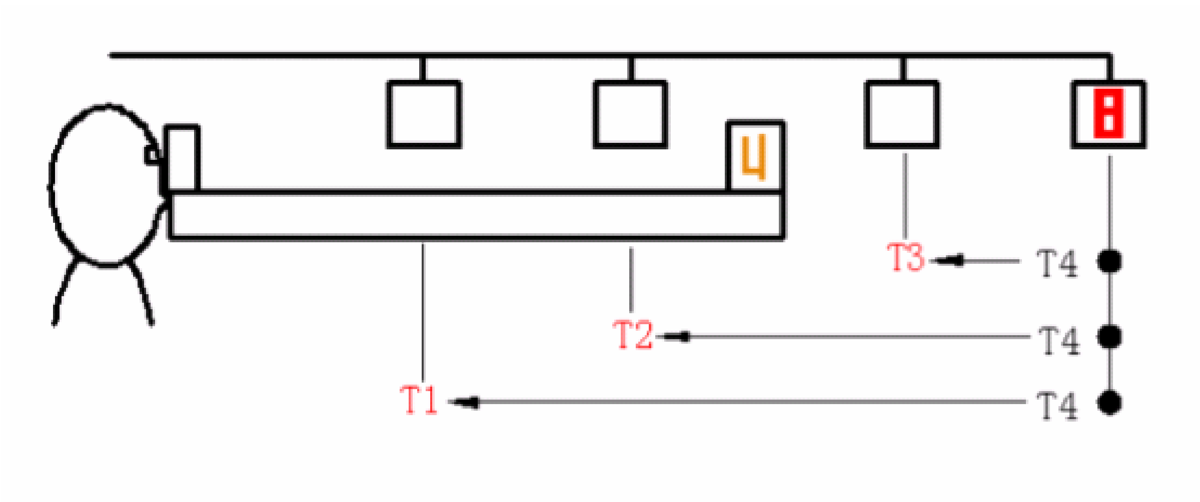


Figure 3-17 From far to near cases

Table 3-6 Cost & benefit values of two subjects with low visual adaptability

(Values with underline were data of 320 trials in depth attention measurement experiment)

	Attention shift direction (far to near)				Attention shift direction (near to far)			
Attention moved distance(m)	-100.5 (T4 to T1)	-79 (T4 to T2)	-25.5 (T4 to T3)	0 (V)	0 (V)	38.5 (T1 to T2)	75 (T1 to T3)	100.5 (T1 to T4)
Cost & benefit (ms) (in bright condition)	-77.8	-57.1	-103	-45.9	45.9	117.4	131.7	185.3
	-122.1	-95.3	-90.2	-68.7	25.8	120.5	169.6	235.5
Cost & benefit (ms) (in twilight condition)	-67.7	-56.9	-36.3	-128.4	56.9	125.3	189.3	196.5
	-63.7	-86.1	-43.3	-55.4	55.4	153.5	184.5	182.3

3.4.2. Results and discussion

Figure 3-18 was the experimental results by changing forecast degree. This figure contrasted data in depth attention measurement experiment with data in superaddition experiment. Broken line expressed results of 320 trials of two subjects with low visual adaptability in depth attention measurement experiment when attention shifted from far to near and from near to far; real line expressed results of 240 trials (from T1:120 trials; from T4: 120 trials, respectively) of two subjects in superaddition experiment. Cost & benefit values were listed in Table 3-6, and contrasted data of two subjects with low visual adaptability in depth attention measurement experiment. Comparing with data in Table 3-6, it can be seen that when the direction of attention switching was imparted beforehand, the shortening tendency of reaction time to benefit was shown, especially, the tendency was remarkable when the moved distance which attention was moved to "from far to near "and "from near to far" was large.

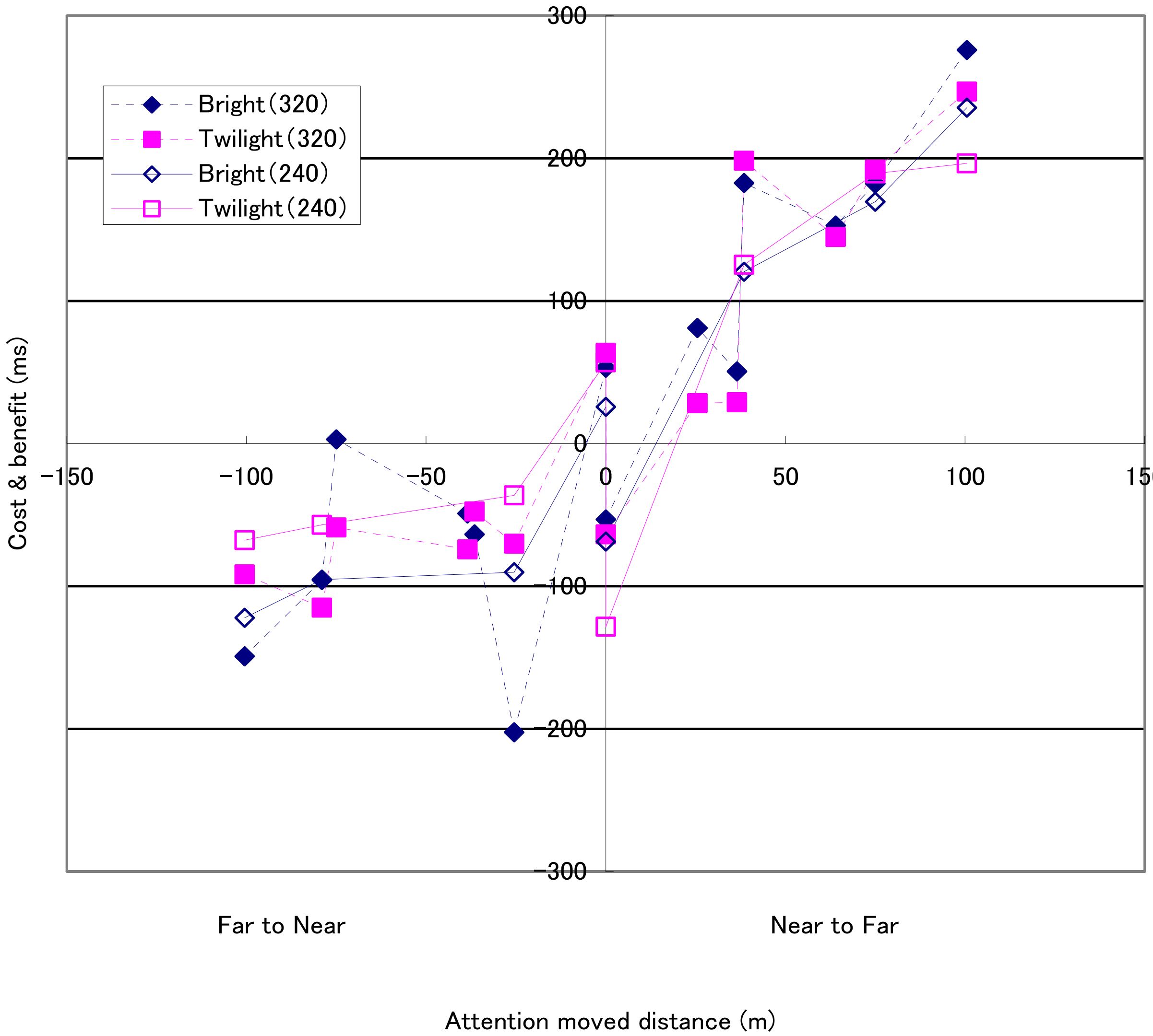


Figure 3-18 Cost & Benefit of response by forecast degree change (Low visual adaptability group)

This result suggested that the characteristic of attention in depth switching received not only the visual adaptive ability but the influence of the cue. As a result, it was possible that failing of the visual adaptive ability was a symptom that happens without fail for the elder drivers, and the characteristic of attention in depth switching decreases. However, it may be remarked that shortening the delay of the reaction may became possible by training with forecasting cue as information like this experiment.

3.5 Summary

The present investigation validated previously researched results on shifts of depth attention in three-dimensional space by means of depth visual attention measurement apparatus. Base on results of three experiments above-mentioned, about the characteristic of attention switching, the following conclusions can be made at this investigation:

Visual adaptability of subjects had a noticeable individual diversity, although static and dynamic acuity of drivers decreases greatly with age, some younger drivers had also poor visual performance, principal causation of diversity were eye movements and useful field of view.

Mean reaction time of subjects was slower for the I condition than for either the V or the N condition, and fastest for the V condition, indicating the effectiveness of a cue. Within the I condition, reaction time was slower for I-d than for I-s, indicating the impact of the distance of the shift in attention. Reaction time was also greater when attention shifted from near space to far space than when shifted from far space to near space, indicating that attention shifting was directionally dependent.

Reaction time was slower for twilight condition than for bright condition, in fact, there are a lot of accidents at twilight time, results demonstrated consistent with the fact. It was evident that the environment luminance could produce an impact on response lag in dangerous scene.

Reaction time was slower for subjects with low visual adaptability than for subjects with high visual adaptability. It follows that visual adaptive ability of drivers could produce different impact on response lag.

The tendency was shown to shorten the reaction time delay to the subjects with low visual adaptability by training which the direction of the attention switching was imparted.

Although three experiments above-mentioned were conducted, and exposed a few characteristic of depth attention in three-dimensional space, much attention characteristic in 3-D space keep unclear, for example, as described above, reaction time was affected by cue, if the reminded time of cue change as well as color of stimulus is different, whether reaction time will change. Visual perception will be examines according to the characteristic of ocular convergence and people's the depth visual function for the future. In addition, it will be examined that a darker illuminance environment such as nighttimes or foggy day produces an impact on the attention switching characteristic in depth in the future. Moreover, it will be investigated the bright of stimulus influence to characteristic of the attention, and it will be investigated to change the color of target, and develops traffic safety education system in driving for the aged drivers base on studies above in future.

Chapter 4 A Study on Characteristics of Attention in Depth of Subjects Simulated Low-vision in Changing Supposed Environment Illuminance

4.1. Introduction

We have revealed some characteristics of attention of subjects with low visual ability in chapter 3 (experiment 1) through testing visual function of subjects, and suggest that vision adaptability of low vision drivers can be improved by vision adaptability training. According to physiology theory, the main causes of vision deterioration were retinal degeneration. One of the most noticeable impacts of vision on driving was the need for increased lighting due to the changes in the variable lens and the pupil. Indeed, visual adaptability of many younger drivers falls because of their retinal degeneration. Low vision drivers are effectually blind, making them unable to use the visual information necessary to make the quick and safe decisions necessary for driving. During the day, glare results from the large amounts of natural light entering through the windows of the vehicle. Window tints and sunglasses may help to control glare, but will further limit the amount of light that enters the eye, in other words, vision of drivers will be lower if drivers wear color glasses in driving even if they have higher visual acuity, and probability bring traffic accidents will increase.

The important reasons bringing traffic accidents was poor visual attention of drivers. Static acuity - the ability for the eyes to focus on a stationary object - is what's measured for drivers' tests. Dynamic acuity, the ability for the eyes to stay focused on moving objects, decreases greatly with age, and it's not tested in drivers' vision tests. Even if an older driver might have perfect static vision, that person's dynamic vision is probably much worse than that of a younger driver. There are also other memory and perception aspects of vision that vision tests do not take into account. The important reasons bringing traffic accidents was poor visual attention of drivers. Static acuity - the ability for the eyes to focus on a stationary object - is what's measured for drivers' tests. Dynamic acuity, the ability for the eyes to stay focused on moving objects, decreases greatly with age, and it's not tested in drivers' vision tests. Even if an older driver might have perfect static vision, that person's dynamic vision is probably much worse than that of a younger driver. There are also other memory and perception aspects of vision that vision tests do not take into account.

Dark field would influence depth attention of drivers, and would certainly cause hazards while driving. Well then, which peripheral scenery would influence visual attention of drivers who are in the dark field? How to influenced depth attention? What about reaction time of drivers to objects presented while driving in the dark field? Previous literature on poor vision of elderly drivers reported that the elderly have large vision problems in low light environments. The elderly have neural losses, and the major decline is due to changes in the eye's optics. First, the lens becomes yellow, making discrimination of else colors more difficult. More importantly, less light entering the eye reaches the photoreceptors. One problem is that the lens and other optical media become opaque. Further, the pupil shrinks, allowing less light to enter the eye. Although many investigators have studied the effects of periphery environment luminance on visual judgment of drivers while driving, and have also studied reaction time of drivers with low vision to frontage objects in driving condition. But, most investigators were carried out by the use of virtual reality environment or driving simulation system or in 2-D space. Subjects have not real motion feel when experiments were made to exam reaction time. It is little investigators on the characteristic of depth attention of drivers who are in the dark field.

However, characteristic of depth attention of drivers who are in the dark field remained unclear. We focused in this study on measured reaction time of depth attention shifting of subjects simulating low-vision, and analyzed the effects of attention moved distance on reaction time. The present investigation aimed to reveal characteristics of depth attention shifting of low-vision drivers during driving. Near and far stimuli were used by means of a three-dimensional attention measurement apparatus that simulated traffic environment. A special test eyepiece, there was a yellow plastic film in front of eyepiece, have been fabricated, it can simulate low-vision scene. We measured reaction time of subjects while attention shifted in three kinds of imitational peripheral environment illuminance (bright, twilight and dawn conditions). Subjects were required to judge whether the target presented nearer than fixation point or further than it. The results showed that the peripheral environment illuminance had evident influence on the reaction time of subjects, reaction time was slow in dawn and twilight condition than in bright condition, distribution of attention in depth had the advantage in nearer space than farther space, that is, and the shifts of attention in 3-D space had an anisotropy characteristic in depth. These findings suggested that (1) attention in 3-D space might be operated with both precue paradigm and stimulus controls included the depth information, (2) an anisotropy characteristic of attention shifting in 3-D space depend on the attention moved distance, and it showed remarkably in dawn condition than in bright and twilight condition. The results were beneficial to development of intelligent driving support systems.

4.2 Method

In the experiments spatial cost-benefit cue paradigm was used: valid cue, invalid cue and neutral cue. The stimuli were presented at four different depth locations in the front of sight line of the subject, the cue was presented at a central fixation locations, using the eyepiece as an index of depth, transmissivity of eyepiece was 86% (testing by MIKI Optics Inst. Japan), the experimental apparatus was a traffic environment simulator in driving. Traffic environment illuminance change was simulated (the three illuminance conditions: bright (480-680 lx), twilight (95-135 lx) and dawn condition (5-8 lx) by the use of two rows daylight lamp which were settled at the outer flank of corridor. The two moving forward conditions were used: static condition and moving (0.44 m/s) condition. In this study, the experiments were conducted in a three-dimensional attention measurement system.

After bright condition experiment finished, changed illuminance of experimental environment in tunnel by adjusted illuminance of two rows daylight lamp, dawn condition experiment will conducted, and next twilight condition experiment.

4.2.1 Subjects

Fourteen students, mean age was 24.9 years old, at Faculty of Engineering of Kagawa University, participated in the experiments as paid volunteers. All subjects had normal or corrected-to-normal visual acuity and normal depth perception.

4.2.2 Apparatus

The apparatus used was the same as apparatus (3.2.2) in chapter 3 with the exception of eyepiece. The structures of eyepiece were showed in Figures 4-1(a), 4-1 (b) and 4-1(c).

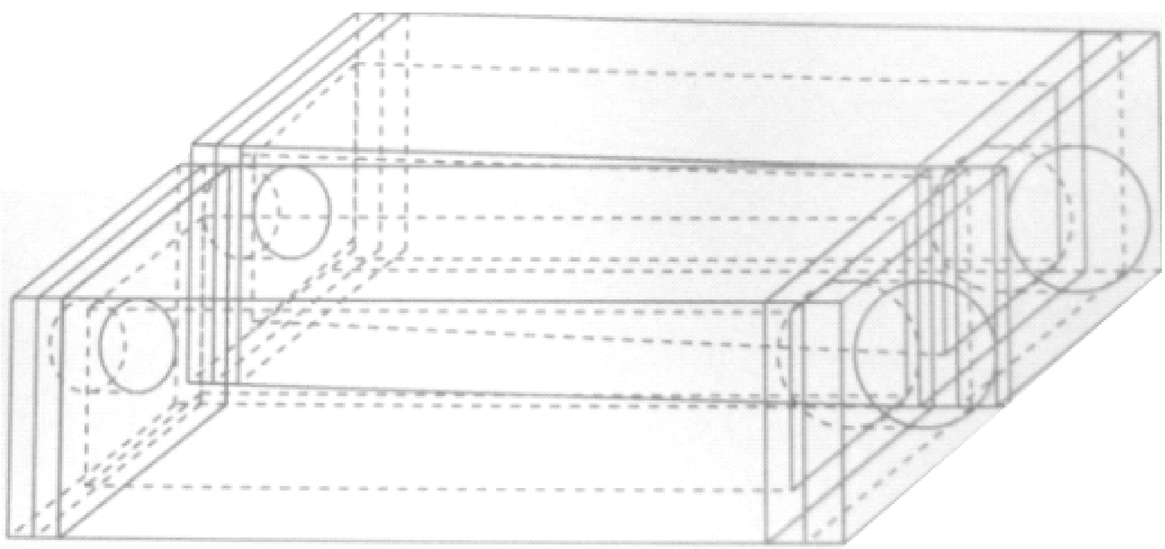


Figure 4-1(a) Inner structure of eyepiece (the overall)

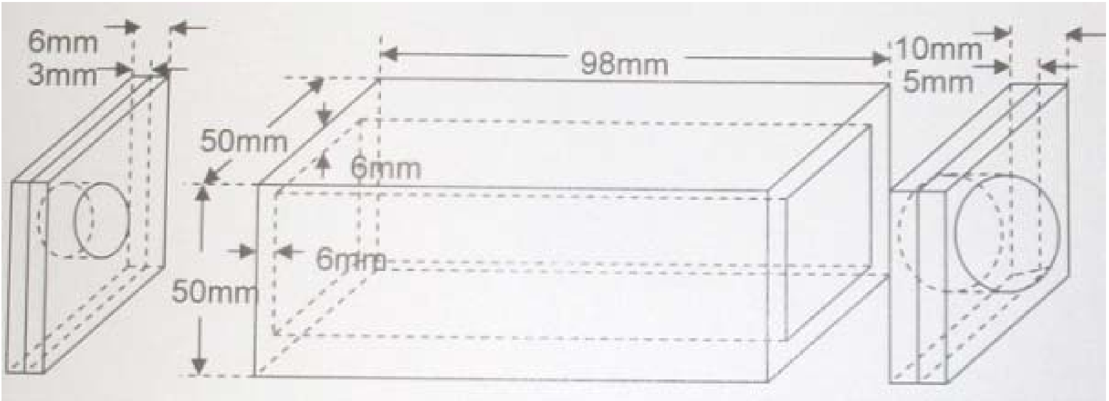


Figure 4-1(b) Inner structure of eyepiece (size)

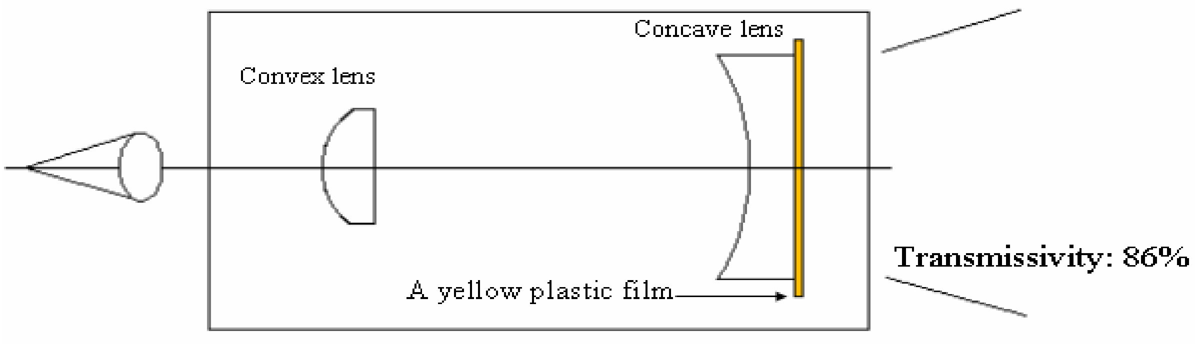


Figure 4-1(c) Inner structure of eyepiece with the yellow plastic film

Figure 4-2 (a) Bright condition (480-680 lx)

Figure 4-2 (b) Dawn condition (5-8 lx)

Figure 4-2 (c) Twilight condition (95-135 lx)

The three traffic environment illuminance conditions were simulated (see Figures 4-2 (a), Figures 4-2 (b) and Figures 4-2 (c)).

4.2.3 Cue and stimuli

Cue and stimuli was the same as cue and stimuli (3.2.3) in chapter 3.

4.2.4 Experimental design

In the experiments, two observing conditions were used: static condition and moving condition (0. 44 m/s). Three kinds of peripheral environment illuminance were designed: bright condition (480-680 lx), twilight condition (95-135 lx) and dawn condition (5-8 lx), respectively. Using cost-benefit cuing paradigm to measure reaction time of subjects, in this paradigm, when attention was previously attended to the region in depth (near location or far location), there were three cases that indicated the position that a target would appear. In the first case, the stimulus appeared in the same region where the precue indicated (Valid). In the second case, the stimulus appeared in the opposite region where the precue indicated (Invalid). In the finally case, no information was given (Neutral). There were two Invalid conditions, it was named as Invalid-same (I-s) when the stimulus indicated in depth at approximately same region as the fixation point, it was named as Invalid-different (I-d) when the stimulus indicated in depth at further opposite region as the fixation point.

4．2.5 Task and procedure

The task and procedure were the same as task and procedure (3.2.5) in Chapter 3.

4.3 Results and discussion

4.3.1 Results in dynamic observing condition

Mean reaction time and standard deviation of subjects in dynamic observing condition were listed in Table 4-1 and Table 4-2. Figure 4-3 showed reaction time and standard deviation in three kinds of cue cases (Valid, Neutral and Invalid) under different peripheral illuminance. It can be seen that mean reaction time was slower in Invalid cases. The mean values of that reaction time were 453 ms, 444ms and 462 ms, respectively, and reaction time in dawn condition was slowest than those in twilight and bright condition. In daylight condition, the mean values of that reaction time were 407 ms for Valid trials, 453 ms for Invalid trials and 421 ms for Neutral trials. A two-way analysis of variance showed that the main effect of cue validity was significant [$F(2, 99) = 5.61$, $MSe = 12372$, $p < .005$], but in twilight and dawn conditions, the main effect of cue validity was not significant ($p < .2$ and $p < .36$). Moreover, Figure 4-3 showed also that the difference of reaction time was not evidence in both Valid and Neutral cases under bright and twilight condition (407ms vs. 421ms and 410ms vs. 423ms, respectively), but difference was evidence under dawn condition (431ms vs. 447ms). In both I-s and I-d cases, the results were also shown that mean reaction time was slower in I-d than in I-s condition. Figure 4-4 showed reaction time in different switch direction of depth attention. The results showed that there was anisotropy in the shifts of the attention. Mean reaction time was slow from near location to far location than from far location to near location (469ms vs. 431ms, 468ms vs. 423ms and 478ms vs. 442ms, respectively). The effect of peripheral illuminance on shift direction of depth attention did not reach significance [$F(2,33) = 0.35$, $p > .01$].

Table 4-1 Mean RTs with different cue cases (Dynamic condition)

Cue cases	Reaction time and standard deviation (ms)				
	Valid	Neutral	Invalid	I-s	I-d
Bright condition (480-680 lx)	407±18	427±16	483±25	485±23	481±27
Twilight condition (95-135 lx)	410±20	443±24	494±26	447±27	471±28
Dawn condition (5-8 lx)	431±25	457±29	498±24	455±31	479±33

Table 4-2 Mean RTs with different switch direction (Dynamic condition)

	Reaction time and standard deviation (ms)	
Switch direction of attention	From near to far	From far to near
Bright condition (480-680 lx)	518±28	469±24
Twilight condition (95-135 lx)	533±34	483±25
Dawn condition (5-8 lx)	578±24	542±23

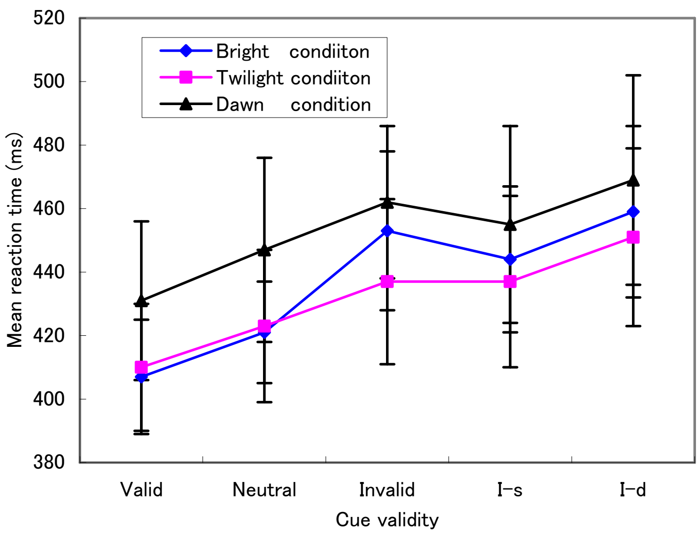


Figure 4-3 Mean reaction times and standard deviations (Dynamic condition)

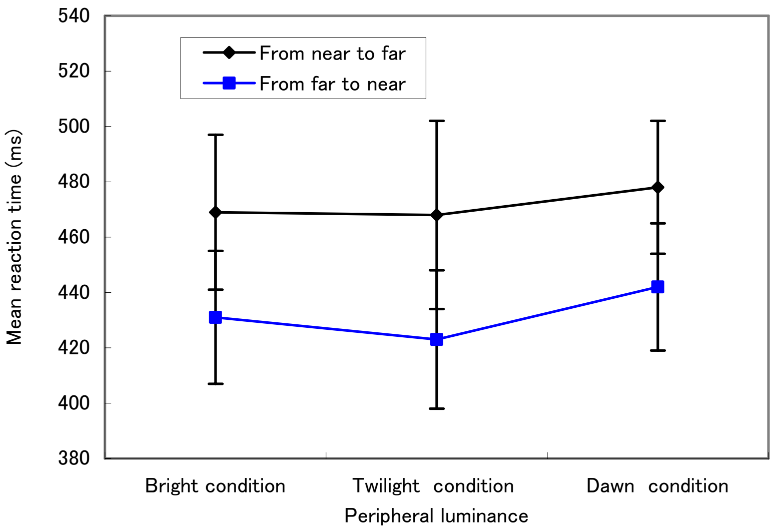


Figure 4-4 Mean reaction time and standard deviation in different switch direction of attention (Dynamic condition)

4.3.2 Results in static observing condition

Mean reaction time and standard deviation of subjects in static observing condition were listed in Table 4-3 and Table 4-4, and were plain described in Figure 4-5 and Figure 4-6. It can be seen that mean reaction time was also slower in Invalid cases. Similarly, reaction time in dawn condition was also slowest than those in twilight and bright condition. But, in Invalid condition, reaction time was an approximation in both twilight and dawn condition (482ms vs. 479ms). Figure 4-7 showed reaction time in different switch direction of depth attention. Similarly, mean reaction time was slow from near to far space than from far to near space. But, reaction time was slower in twilight than those in bright condition (479ms vs.456ms and 447ms vs.441ms, respectively).

Experimental results mentioned-above showed that the characteristics of shifts of depth attention had comparability in both dynamic and static condition. Reaction time was different when cue (Valid, Invalid and Neutral) was different in both dynamic and static condition. It showed that attention shifting was controlled by the cue, that is, reaction time under Invalid and Neutral condition was longer than that under Valid condition. In fact, vision information while driving was random in traffic environment, so Neutral condition was understood to be the normal driving condition. The differences between Invalid and Neutral condition were considered cost (inhibiting reaction), while those between Neutral and Valid conditions were considered benefit (promoting reaction) (M. Posner, M. J. Nissen & W. C. Ogden, 1978). Figure 4-8 indicated the benefit and cost values in both dynamic and static conditions. Furthermore, reaction time of subjects was affected by peripheral environment illuminance, and it was evidence in dawn condition. When cue was in Neutral condition, reaction time had no evidence difference in both daylight and twilight condition, it showed that the illuminance of both bright and twilight condition had a little effect on vision attention of drivers with low vision. Otherwise, when attention switch direction was different, shifts of attention from far to near space was faster than the reverse, that is, the shifts of attention in 3-D space had an anisotropy characteristic in depth. Why asymmetry switch of attention was shown? Previous results (T. Kimura, T. Miura, S. Doi & Y. Yamamoto, 2004) indicated two potential reasons, that is, the "switching speed" of attention might be a cause when attention should shift from certain location to another, as well as not "switching speed", but "switching itself" might be related to anisotropy characteristic of attention shift.

In order to illuminate the asymmetric of shifts of attention, relationship of benefit (or cost) and moved distance of attention shifting was analyzed. Moved distance was 100.5m, 75m, 64m, 38.5m, 36.5m and 25.5m when switch direction of attention was from "T1 to T4", "T1 to T3" "T2 to T4", "T1 to T2", "T2 to T3" and "T3 to T4"(similarly, as reverse). Figure 6 showed allocation of benefits &costs when switching direction was "from far to near" and "from near to far" condition. It can be seen from Figure 4-8 that benefits values were smaller than costs values when we compared "from near to far" with "from far to near" condition, and the attention moved distance appeared more remarkably between 38.5m and 100.5m.

Table 4-3 Mean RTs with different cue cases (Static condition)

Cue cases	Reaction time and standard deviation (ms)				
	Valid	Neutral	Invalid	I-s	I-d
Bright condition (480-680 lx)	427±20	438±16	474±20	475±17	473±24
Twilight condition (95-135 lx)	435±22	446±10	486±28	482±23	483±37
Dawn condition (5-8 lx)	451±21	457±19	485±36	479±26	489±43

Table 4-4 Mean RTs with different switch direction (Static condition)

	Reaction time and standard deviation (ms)	
Switch direction of attention	From near to far	From far to near
Bright condition	456±15	441±11
Twilight condition	479±18	447±9
Dawn condition	474±19	462±12

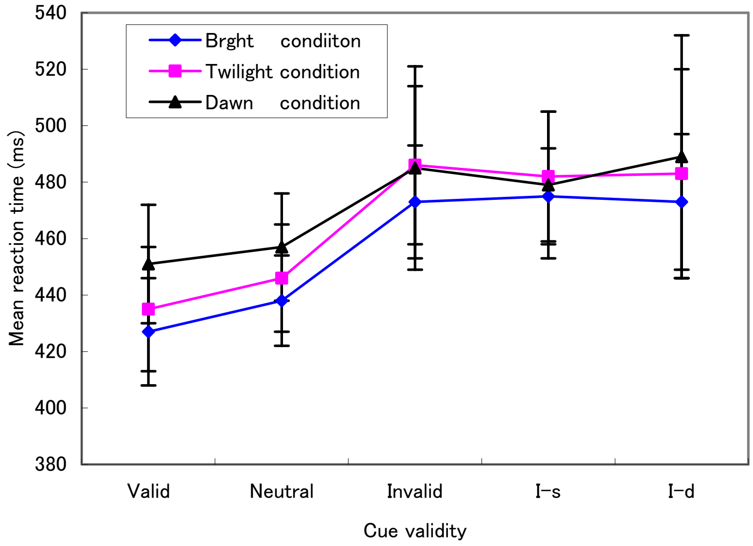


Figure 4-5 Mean reaction times and standard deviations (Static condition)

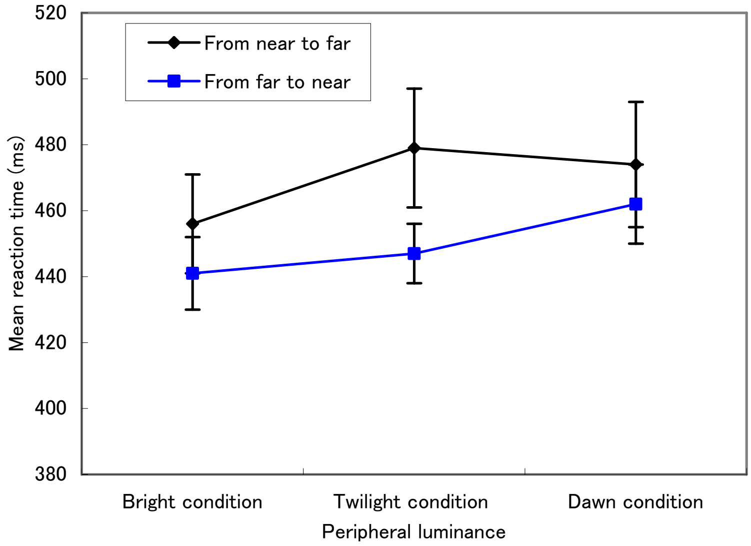


Figure 4-6 Mean reaction times and standard deviations in different switch direction of attention (Static condition)

Table 4-5 Benefits &costs values in three luminance conditions

	Dynamic condition		Static condition	
	Benefit (ms)	Cost (ms)	Benefit (ms)	Cost (ms)
Bright condition	14	32	11	36
Twilight condition	13	21	11	20
Dawn condition	16	15	7	15

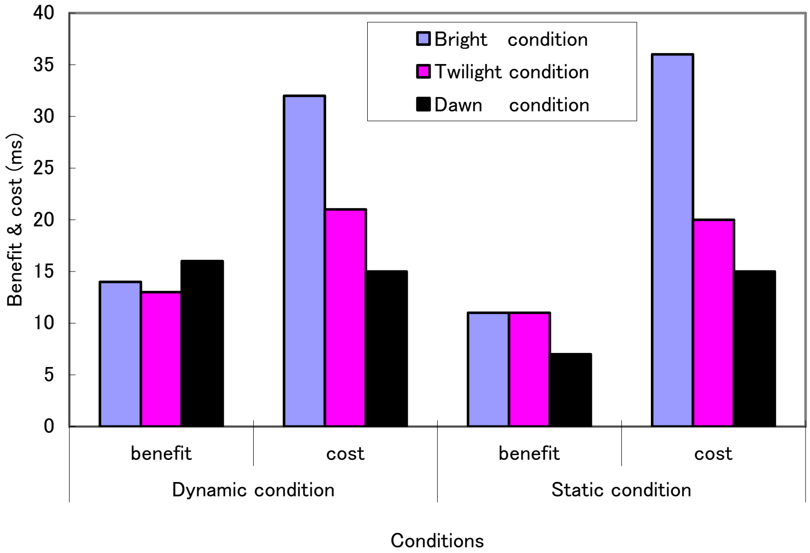


Figure 4-7 Benefits &costs in three illuminance conditions

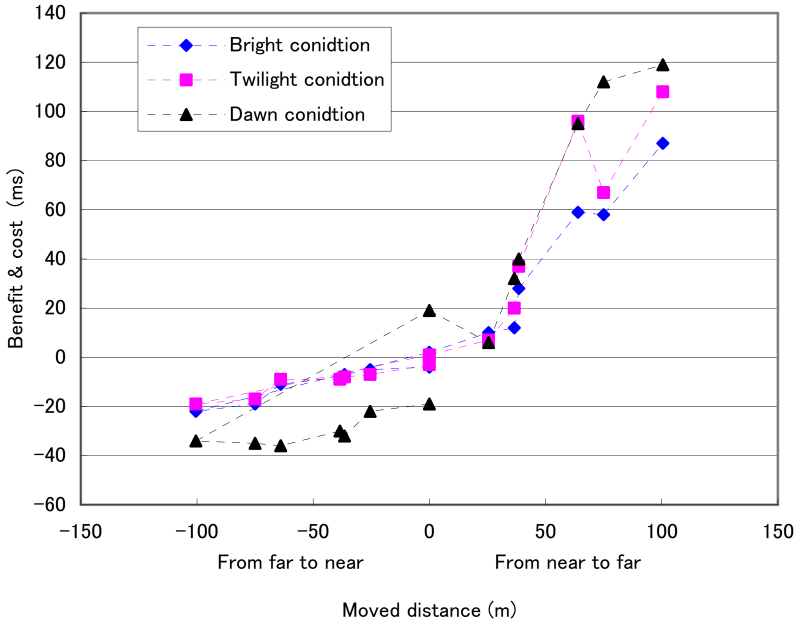


Figure 4-8 Value of benefits & costs in both “from far to near” and “from near to far” conditions

4.4 Summary

The present investigation measured reaction time of the subjects simulated low vision while attention shifted in three kinds of imitational peripheral environment illuminance. The results obtained in this paper showed that the reaction time of depth attention shifting was controlled by cue and target presented in front of drivers with low vision in driving. The investigation validated previously researched results on shifts of depth attention in 3-D space. Base on experimental results above-mentioned, about the characteristic of attention shifting of drivers, the following conclusions can be made:

The peripheral environment illuminance had evident influence on the reaction time of drivers, reaction time was slow in dawn and twilight condition than in bright condition, allocation of attention in depth had the advantage in nearer space than farther space, and namely, the shifts of attention in 3-D space had an anisotropy characteristic in depth. The anisotropy characteristics depend on the attention moved distance.

In addition, although a few characteristic of depth attention were exposed, much attention characteristic in 3-D space keep unclear, for example, if the reminded time of cue change as well as color of stimuli were different, whether reaction time will change. Reaction time of drivers with low-vision will be measured when color configuration of cue and stimulus change as well as cueing time of cue in the fixation point change in the future.

Chapter 5 A Study on Characteristics of Attention in Depth of Older Subjects in Supposed Bright Condition

5.1 Introduction

There is a great deal of evidence that older drivers rank far lower than other drivers for incidents of dangerous aggressive driving behavior, but they tend to make more driving errors than other drivers in congested areas and where quick comprehension of signs is required. In vision, most aspects of vision typically deteriorate with age. Static acuity- the ability for the eyes to focus on a stationary object - is what's measured for drivers' tests. Dynamic acuity, the ability for the eyes to stay focused on moving objects, decreases greatly with age, and it's not tested in drivers' vision tests. Even if an older driver might have perfect 20/20 static vision, that person's dynamic vision is probably much worse than that of a younger driver with 20/20 vision. There are also other memory and perception aspects of vision that vision tests do not take into account. Older drivers are also much more susceptible to glare, such that is encountered when exiting tunnels or seeing oncoming headlights, and they also have reduced contrast sensitivity, which can make low light conditions problematic even if their vision is sharp. In reaction time, though it can vary greatly depending on the person, and there seems to be some conflicting information, reaction time is estimated by some researchers at 0.2 to 0.3 second slower for drivers 65 and older, with an accompanying drop in motor skills that can further exaggerate the delay.

Many authors have stated that older drivers are less safe, basing their conclusion on statistical analyses that found older drivers to have more accidents per mile driven. However, recent research (e .g, Hakamies-Blomqvist, Raitanen, & O'Neill, 2002) has shown that these studies failed to control an important variable - actual mileage driven. Older and younger drivers who drove the same number of miles had about the same accident rates. The new finding illustrates important points both about the effects of age on driving and on interpreting epidemiological studies. The original studies simply averaged over miles driven and did not consider actual driving habits. Older people drive less in general but, more importantly, also make many fewer long trips (between cities, etc) which builds up total mileage. Accidents on interstates are spectacular but relatively low per mile because traffic is lighter, attentional demands lower and quick reaction less often is required. Older drivers are more likely to drive in shorter trips within more congested urban areas where accident overall accident rates are higher and where demands on perception, attention and decision-making are great.

In resent years, it is rapidly progressing aging society in Japan. It is estimated that the total amount of elderly persons 2025 in Japan will be 33 millions. It will be also increasing the population of elderly drivers. In 1996, it is counted that about 5.25millions of people of 65 years older had drivers license in Japan. If it is holding this status, in 2025, it would be estimated that the total amount of driving license holders in Japan would be 18 millions of people of 65 years older. Many aspects of visual perception, including spatial and temporal contrast sensitivity, color perception, symmetry perception, binocular vision, and motion discrimination, decline with age (Faubert, 2002[51]; Sekuler & Sekuler, 2000[52]; Spear, 1993[53]; Yu, Wang, Li, Zhou, & Leventhal, 2006[54]). Some of the effects of age may be attributed to changes in the optical quality of the eye (Nguyen-Tri, Overbury, & Faubert, 2003[55]; Shahidi & Yang, 2004[56]; Weale, 1992[57]; Winn, Whitaker, Elliott, & Phillips, 1994[58]), but optical factors alone cannot account for all of the changes in vision that occur in old age (Ball & Sekuler, 1986[59]; Bennett, Sekuler, & Ozin, 1999[60]; Herbert, Overbury, Singh, & Faubert, 2002[61]; Sekuler, Bennett, & Mamelak, 2000[62]; Sekuler & Ball, 1986[63]). Therefore, impaired visual performance in elderly human observers must be due, at least in part, to changes in the characteristics of visual neurons. Recent psychophysical evidence suggests that, at least in some conditions, motion perception is impaired in older human observers in a manner that is consistent with the physiological findings (Bennett, Sekuler, & Sekuler, 2007[64]). In addition, Habak and Faubert [65] (2000) found that age-related changes in grating detection thresholds were larger for second-order than first-order patterns, a result that is consistent with reports that the effects of aging are greater in extrastriate cortical visual areas (Yu, Wang, Y., Li, X., Zhou, Y., & Leventhal, A. G., 2006[66]).

In this study, it is focused visual capability that it is generally problems and characteristics of situations in Japan for ordinary elderly drivers. So, it is carried out to determine what was needed to secure their safety, and what visual attentional characteristic of older drivers is. Our concerns are the followings: (1) How does attention of older drivers operate in peripheral environment bright illuminance conditions (480-680 lx)? (2) Whether there is anisotropy of attention for older drivers? For these purposes, we conducted this experiment used typical cuing paradigm, Posner' cuing paradigm. In the experiment, three kinds of cue validity (valid, invalid and neutral) were used, peripheral illuminance (bright condition: 480-680 lx) and two observing conditions (static and dynamic conditions) were designed.

5.2 Method

5.2.1 Subjects

The subjects were 15 older drivers form the Hayashi-cho of Takamatsu City at Kagawa. Their age vary from 59 to 68 years old, mean age 63.9 years older. All subjects had normal or corrected-to-normal vision and were naive as to the purpose of the study. All subjects were tested for stereoscopic vision using the Randot Etest and were required to have disparity sensitivity of 20 sec of arc. All subjects had more than ten years of driving experience according to their driving licenses.

5.2.2 Apparatus

The apparatus was the same as the apparatus (3.2.2) in chapter 3.

5.2.3 Cue and stimuli

The numbers of cue were “**1**”, “**2**”, “**3**”, “**4**” and “**0**”with yellow color, the shape of stimuli in target locations (T1, T2, T3 and T4) was “**E**” or “**3**” with red color digital LED. Size of the cue was 10×16mm. Size of the target was 10×16mm (T1), 12×18mm (T2), 20×27mm (T3) and 22×35mm (T4), respectively.

5.2.4 Experimental design

The entire experiment consisted of the total number of 320 times as each subject. Subject was provided with information in advance about where targets would present at fixation location, and reacted accordingly. The stimulus information presented random was a valid (V) cue (cue and target were in the same spatial location) 65% of the time, an invalid (I) cue (cue and target were in different spatial location) 15% of the time and a neutral (N) cue (equivalent to no cue) 20% of the time. The fixation point, lighting 1000ms after initiation of the test, provided the subject with a cue to the location of the target in the form of numeric LEDs (1 to 4, as well as 0) that remained on through the lighting of the target display and the subject’s reaction. The subject’s task was to judge the shape (E or 3) of stimulus displayed at the target and correctly press the corresponding button as quickly as possible. On the I condition, although absolute target depth varied, cases where the perspective relative to the focal point was unchanged (e.g., in the diagram, T2T1 [T2 given as a cue but T1 lit] and, similarly, T3T4) were coded as invalid-same (I-s). On the other hand, cases where both the absolute positions of cue and target and their relationship to the fixation point changed were coded as invalid-different (I-d) (e.g., T1T4 and T3T2). Furthermore, imitated peripheral environment luminance, the light level in the experimental apparatus was set 480 to 680 lx as the bright condition. In the interest of arranging test conditions, the N condition was understood to be the normal driving condition. The differences between N and V conditions were considered benefits (promoting reaction) while those between I and N conditions were considered costs (inhibiting reaction). In addition, experimental data of beyond 1000ms within 100ms would be not accepted because response of the subject to the targets was too fast or too slow, and the data beyond mean RTs ±2SD was a reject.

5.2.5 Task and procedure

The task and procedure were the same as task and procedure (3.2.5) in Chapter 3.

5.3 Results and discussion

Mean reaction times of subjects for three cue validity were listed in Table 5-1.

It can be seen that Mean RT was shortest in the valid than that in the invalid and the neutral. Mean RT was longest in the invalid. The result of experiment suggested that the reaction time was affected by the cue validity. This pattern of results suggested hierarchical processing of visual information. In other words, valid location cues were sufficient for fast accurate detection response. In contrast, subjects had no sufficient times to response for stimuli in the invalid.

In addition, the reaction time of older subjects was evident longer compared with the results (see Table 3-1) of younger subjects. It can be seen from Figures 5-1 and 5-2 that the mean reaction time of older subjects was 199 ms longer than younger subjects.

Table 5-1 Mean RTs in three cue validity (ms)

	Valid	Invalid	Neutral
Subject1	585	582	590
Subject2	672	664	669
Subject3	669	691	689
Subject4	655	681	716
Subject5	499	626	525
Subject6	657	787	670
Subject7	538	648	601
Subject8	614	611	617
Subject9	567	821	693
Subject10	685	619	609
Subject11	617	614	634
Subject12	659	660	645
Subject13	646	637	622
Subject14	511	684	588
Subject15	542	649	609
Average	608	665	632

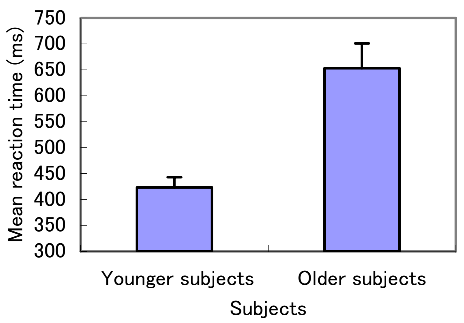


Figure 5-1 Mean RTs of the younger and older subjects

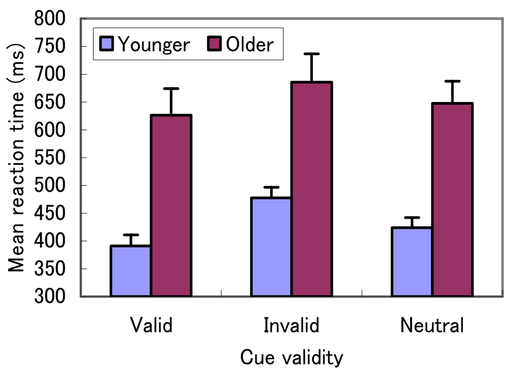


Figure 5-2 Mean RTs of the younger and older subjects in three cue validity

Mean reaction times of subjects for both I-same and I-different were listed in Table 5-2.

It can be seen that Mean RT was shorter in the I-same than that in the I-different. The result of experiment suggested that the reaction time was affected by the spatial location of cue validity. This pattern of results suggested spatial distributions of visual information. In other words, distributions of visual attention were more in the nearer space than in the further space.

Table 5-2 Mean RTs in I-same and I-different validity (ms)

	I-same	I-different
Subject1	564	602
Subject2	639	689
Subject3	666	719
Subject4	624	705
Subject5	605	637
Subject6	755	818
Subject7	633	655
Subject8	611	611
Subject9	688	811
Subject10	600	622
Subject11	614	615
Subject12	673	653
Subject13	648	631
Subject14	643	721
Subject15	584	727
Average	636	681

Figure 5-3 showed mean reaction times of older and younger subjects in both the I-same and I-different. It can be seen that the mean reaction time of older subjects was 45.31 ms shorter in the I-same than in the I-different, and mean reaction time of older subjects was 21.14 ms longer than that of younger subjects.

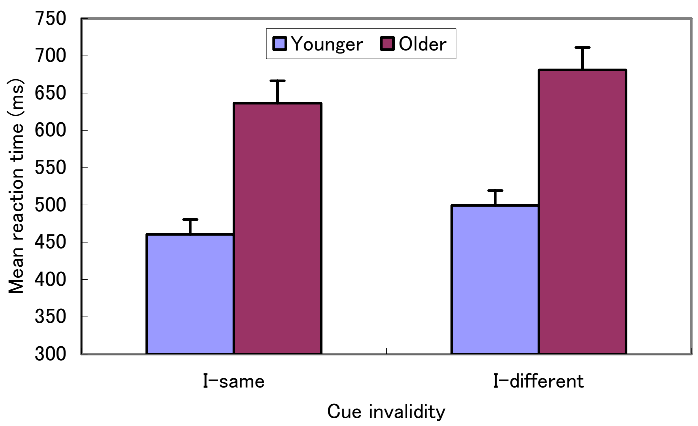


Figure 5-3 Mean RTs of the older and younger subjects in both the I-same and I-different

Table 5-3 showed mean reaction times from far space to near space and from near space to far space. The dada suggested difference in different switch direction of attention. Reaction time was shorter from far to near than from near to far.

Table 5-3 Mean RTs in different switch direction of attention (ms)

	Far to near	Near to far
Subject1	680	731
Subject2	661	668
Subject3	675	644
Subject4	656	616
Subject5	650	715
Subject6	586	663
Subject7	1214	1514
Subject8	416	428
Subject9	634	629
Subject10	842	1047
Subject11	604	698
Subject12	729	940
Subject13	603	704
Subject14	661	670
Subject15	570	652
Average	679	755

Figure 5-4 showed that mean reaction time was 76.94 ms shorter from far to near than from near to far. The results indicated further that the reaction time was affected by the spatial location of cue validity. This pattern of results suggested spatial distributions of visual information. This pattern of results suggested asymmetry of shifts of visual attention. This characteristic of attention shifting was due to attentional cost or benefit. Costs and benefits of attention shifting were listed in Table 5-4.

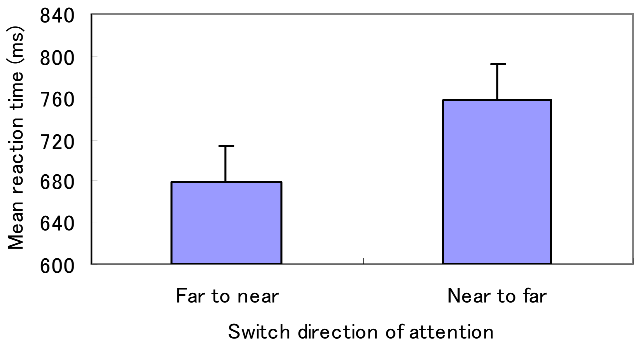


Figure 5-4 Mean RTs of the older subjects in different switch direction

Table 5-4 Costs and benefits of attention

	Cost	Benefit
Subject1	4.6	-7.7
Subject2	-2.7	-4.5
Subject3	20.5	2.2
Subject4	61.2	-35
Subject5	26.8	100.9
Subject6	13.7	116
Subject7	62.6	47.1
Subject8	3.2	-6
Subject9	126.5	127.8
Subject10	-76.7	10
Subject11	16.8	-19.8
Subject12	-13.9	14
Subject13	-24	14.2
Subject14	77.1	95.9
Subject15	67.2	40
Average	24.2	33

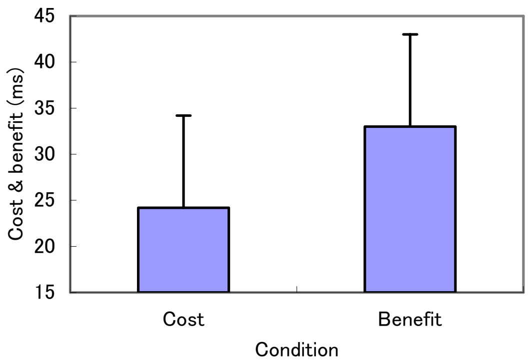


Figure 5-5 Cost & benefit of attention for the older subjects

5.4. Summary

In present study, we examined the reaction time of older subjects in three-dimensional space, three cue validity are used, that is, valid, invalid and neutral conditions. The experimental results suggested that the reaction times of older subjects are shortest in the valid than that in the invalid and neutral, are longest in the invalid. This result showed that the reaction time of older subjects is affected by the cue validity, and the reaction time, compared with the reaction time of younger subjects, is evident longer, approximately 200 ms longer. In addition, there also is an asymmetry characteristic of attention shifting for older subjects. That is, the reaction time is shorter when the attention switches from further space to nearer space. This pattern of result also suggested same characteristics as younger subjects. The data of experiment also suggested that response delay for the target detection is from the cost of attention shifting. Costs are greater when the attention switches from near space to far space; in contrast, benefits are greater from far space to near space. These results are consistent with the results of younger subjects, and also consistent with results from other studies (Andersen, 1990; Tipper, Lortie & Baylis 1992; Andersen & Kramer, 1993; Miura, Shinohara & Kanda, 2002; Kimura & Miura, 2004).

Chapter 6 A Study on Characteristics of Attention in Depth in Changing Cue Duration and Targets Color in Supposed Traffic Environment

6.1 Introduction

There is a great deal of evidence that prior information concerning the spatial location of a subsequent target facilitates the selection of that target for further visual processing (Eriksen and Hoffman 1973; Jonides 1981; Posner 1980; Posner et al. 1978). It is now also clear that prior feature information (color, shape, orientation) can also facilitate target processing (Duncan 1981[67]; Humphreys 1981[68]). However, over the last couple of decades there has been considerable debate over the relative importance of spatial versus feature-based visual attention. Thus many researchers argue that stimulus selection via spatial location is primary (Johnston and Pashler 1990[69]; Schneider 1995[70]; Tsal and Lavie 1988[71], 1993[72]), whereas others argue that location is just one selection attribute among many, including object features such as colour, shape and orientation (Bundesen 1990[73]; Duncan 1981; Humphreys 1981; Laarni 1999[74]; Laarni et al. 1996[75]).

Numerous experiments from several different experimental paradigms including discrimination, search, motor tasks and event-related potential (ERP) studies, have demonstrated that selection by location is faster, and/or occurs earlier than selection by object features. Location discriminations can be performed approximately 150–250 ms faster than color discriminations (Tanaka and Shimojo 1996[76]). Target orientation can be identified earlier if targets are cued by location rather than color (Laarni et al. 1996). The first observable signs of corrections on movement kinematics following perturbations of target color or location are evident 80 ms earlier for location than for color perturbations (Pisella et al. 1998[77]). ERP indices of visual attention are also consistent with faster and earlier processing of location cues. Location effects are visible in ERP waveforms as early as 80–100 ms after stimulus onset, and generally occur between 50 and 100 ms earlier than color or shape effects. In addition, the effects of feature cues are greater at attended than at unattended locations, and are virtually absent at unattended locations, suggesting that attention to features is dependent on prior attention to locations (Anllo-Vento and Hillyard 1996[78]; Eimer 1995[79]; Hillyard and Münte 1984[80]; Luck et al. 1993[81]).

There is also evidence suggesting that selection by location is an essential, primary stage of attentional orienting. For example, although target location can be known in the absence of feature (color or orientation) information, the reverse is not true (Brouwer and van der Heijden

1996[82]). Similarly, selection by feature information appears to be mediated by prior selection by location: identification of target location is more accurate than identification of target color or shape even when targets are cued by color or shape and not location (Laarni and Häkkinen 1994[83]). Feature conjunction search is thought to be mediated by location, with targets being identified via the locations containing specified feature conjunctions (Isenberg et al. 1990[84]; Nissen 1985[85]; Treisman 1988[86]; Treisman and Sato 1990[87]). There is also evidence that selecting by location is preferred even when target location is completely taskirrelevant (Cave and Pashler 1995[88]; Tsal and Lavie 1988, 1993).

Electrophysiological, anatomical and behavioral experiments have led to the proposal of two separate visual pathways for feature and location processing, respectively. According to this proposal, a ventral stream of projections from striate cortex to inferotemporal cortex is responsible for feature processing and a dorsal stream from striate cortex to posterior parietal cortex is responsible for spatial processing (Goodale and Milner 1992[89]; Ungerleider and Mishkin 1982[90]). Processing of location information via the dorsal pathway, and feature information via the ventral pathway, would provide a neurophysiological basis for faster and earlier location processing because the fast conducting neurons of the dorsal pathway would be expected to result in faster processing than the approximately equal numbers of slow and fast conducting neurons which make up the ventral pathway (Maunsell et al. 1990[91]; Nowak and Bullier 1997[92]; Rossetti 1998[93]).

The above evidence for a special, primary role for selection by location in visual processing seems fairly strong. However, there is evidence that color cues can be as effective or even more effective than location cues under certain conditions. For example, Laarni et al. (1996) observed equally accurate levels of performance following location or color cues provided optimal cue lead times (CLTs) were used for location and color cues (short and long CLTs, respectively). Laarni (1999) found color cueing effects as large as location cueing effects (both approximately 100 ms) when target and distractor were less easily discriminable (i.e. had the same global shape). Humphreys (1981) found that color information was processed faster than location information when locations were not easily discriminable (less than 1 degree apart). Hillyard and Münte (1984) found that the hierarchical dependence of selection by color on prior selection by location disappeared if attended and unattended locations were adjacent. Finally, van der Heijden et al. (1996) [94] found that subjects initially cued to select a target letter by color preferred to select additional letters by color rather than shifting to selection by location (as found by Tsal and Lavie 1993), unless performing with free vision and under poor viewing conditions.

Three recent experiments compared location and color cueing effects using designs which allowed partial investigation of the combined effects of color and location cues (Laarni et al.

1996; Lambert and Corban 1992[95]; Tsal and Lavie 1993). The results of these experiments indicated a strong overall advantage for location cueing, but also suggested that the effects of location and color cues can combine to produce greater facilitation when both types of cue are valid. This possibility has implications for the 'location special' view because it suggests that although feature cues generally have a smaller impact on performance, they can contribute to improved target identification even in the presence of valid location cues. This contrasts with a possible strong interpretation of the 'location special' view that feature information is redundant in the presence of valid location information. However, in the three experiments described above, only indirect evidence for additive effects of location and color is provided. For example, in Laarni et al.'s (1996) experiment, the effects of a location cue, in the form of an abrupt luminance increment, were compared with those of a feature cue, a color spot cue and a symbolic color cue. In Tsal and Lavie's (1993) experiment, location and color effects were the result of expectancies based on cue-target location and/or color concordance, rather than precues. However, direct comparisons seem again inappropriate because of the greater task relevance of color, which provided the 'go/no-go' signals. In fact, subjects were instructed to report a letter in a given location or of a given shape depending on color cueing. A further complication is that the discrimination tasks used in these three experiments may have increased the likelihood that color cues would be used even when location cues were valid, because color information was necessary to identify the target. Thus although there is evidence that the visual system uses location cues in tasks involving detection, discrimination, single feature and conjunction search, the same cannot be said for feature cues. In fact, all of the experiments comparing location and color cues outlined above used discrimination or search tasks in which color was necessary for target identification. To our knowledge no one has compared location and cueing effects using a detection task. This may be important since there is evidence that various tasks (detection, location discrimination, moving eyes or arms to target location) are subserved by different mechanisms than feature-based tasks (color, size, luminance and vernier discrimination; Tanaka and Shimojo 1996).

The present experiments were designed to investigate location and duration cueing effects as well as location and color cueing effects, using a 3-D attention measurement system. First experiment was designed to investigate the effect of location and duration cueing on reaction time of the subjects by changing cue attend duration; second experiment was designed to investigate the effect of the effect of three factors (location, duration and color cueing) on reaction time of the subjects by changing cue attend duration and color of cue and stimulus. Subjects were asked to respond to the color of stimuli at target locations which were highlighted in either red or green. Based on the results of Laarni et al. (1996), Lambert and Corban (1992) and Tsal and Lavie (1993), it was hypothesised that location validity effects would be larger than color validity effects. It was also hypothesised that there would be an interaction between location and color validity effects, such that the fastest responses would follow cues which were valid with respect to both location and color, while the slowest responses would follow cues which were invalid with respect to both location and color.

6.2 Experiment of effect of cue duration on reaction time (Duration experiment)

6.2.1 Method

6.2.1.1 Subjects

Ten students, with mean age 22.7 years old, served as participants. They were recruited from Doi lab of Faculty of Engineering, Kagawa University, were told to the purposes of the experiment. All subjects had normal vision.

6.2.1.2 Apparatus

The apparatus was the same as the apparatus (3.2.2) in chapter 3. Figure 6-1 showed measurement system of experimental apparatus.

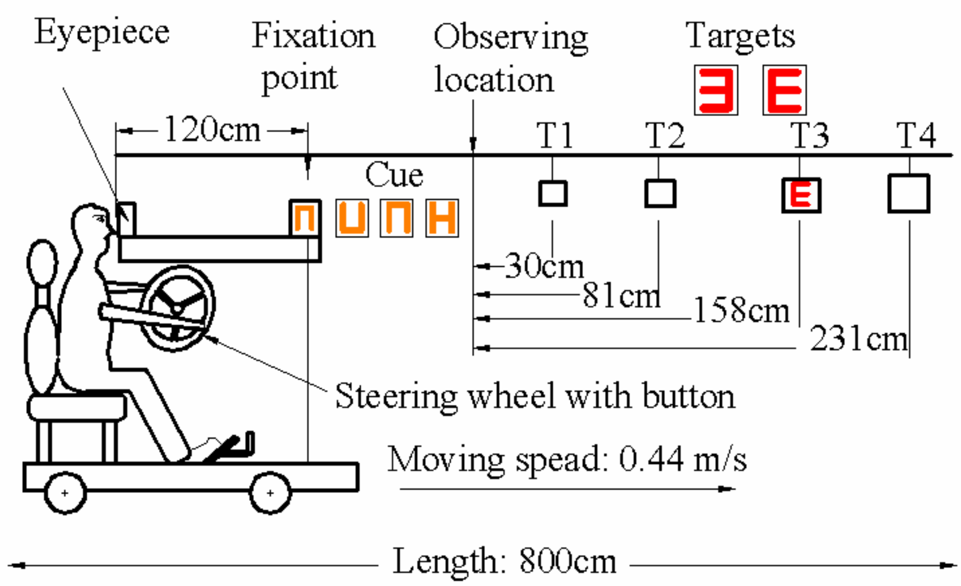


Figure 6-1 A three dimensional attention measurement system (cue duration experiment)

6.2.1.3 Cue and stimuli

The shape of cue was “**U**”, “∩”or “**H**” with yellow color, the shape of stimuli in target locations (T1, T2, T3 and T4) was “**E**” or “**3**” with red color digital LED. Figure 6-2 showed distributed conditions of cue and stimuli.

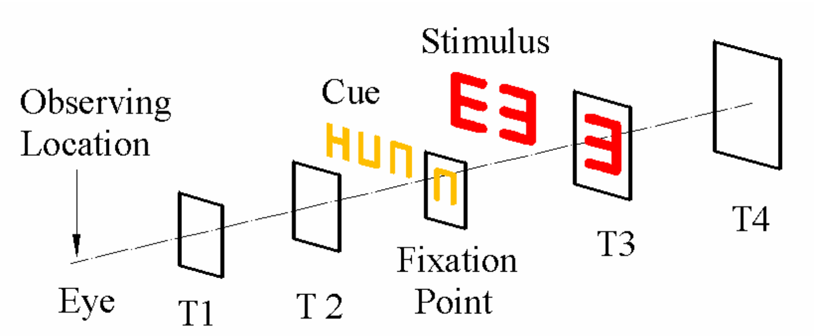


Figure 6-2 Distributed conditions of cue and stimuli. Stimulus will appear at T1 or T2 location when cue is "U", and will appear at T3 or T4 location when cue is "∩"; Stimulus will appear at any one of target location when cue is "H". T=Target.

6.2.1.4 Experimental design

In the experiment, stimulus will be presented in nearer location (T1 or T2) when cue was "U", and presented in further location (T3 or T4) when cue was "∩". The "H" expressed no cue. Two cue duration conditions were used: 600 ms and 1000 ms. The experimental illuminance simulated peripheral environment inside tunnel was 480-680 lx. Using cuing paradigm to measure reaction time of subjects, the cue information was a valid cue (V) 65% of the trials, an invalid (I) cue 15% of the trials and a neutral (N) cue (equivalent to no cue) 20% of the trials. There were two invalid conditions, it was named as invalid-same (I-s) when the stimulus indicated in depth at approximately same region as the fixation point, on the other hand, it was named as invalid-different (I-d) when the stimulus indicated in depth at further opposite region as the fixation point. All presentation of cue and stimulus were random.

6.2.1.5 Task and procedure

Each experiment consisted of 320 trials for each subject. After 1000ms from the beginning of each trial, a sound of buzzer was given. Following the buzzer, the fixation point containing the information of target position was shown. The subject must make a quick response according to the information ("E" or "3") presented at the target location. Subjects had to exercise before the formal experiment. The procedure and task in exercise were almost the same as the formal experiment. When subject accomplished the task by achieving the criteria of accuracy, the exercises stopped. Experimental time of each subject was about two hours.

6.2.2 Results and discussion for duration experiment

After experiment ended, the correct responses were analyzed and reaction times of less than 100 ms or more than 1000 ms were discarded, because the former was considered an anticipatory response without judgment and the latter that a target appeared when subject was distracted.

6.2.2.1 Cue location validity and duration effects

Reaction times of subjects in 600 and 1000 ms cue duration under static observing condition were listed in Table 6-1 and Table 6-2. Figure 6-3 showed reaction time in three kinds of cue cases (Valid, Neutral and Invalid) in both 600 and 1000 ms duration under static condition. It can be seen that mean reaction time was slower in the Invalid cases in both duration. The mean values of that reaction time were 374 ms, 371 ms and 389 ms in 600 ms duration; the mean values of that reaction time were 372 ms, 373ms and 390 ms in 1000 ms duration. It can be seen that mean RT was longer in the invalid in both durations. RT was shorter in the neutral in 600 ms duration, but RT was shorter in the valid in 1000 ms duration. It may suggest that the duration had an influence on cue validity.

Table 6-1 RTs of subjects in 600 ms duration (Static condition)

	Valid	Neutral	Invalid
Subject1	338	334	347
Subject2	361	360	371
Subject3	418	414	460
Subject4	357	349	423
Subject5	384	377	380
Subject6	390	380	391
Subject7	400	407	424
Subject8	341	360	349
Subject9	416	393	399
Subject10	336	334	347
Average	374	371	389

Table 6-2 RTs of subjects in 1000 ms duration (Static condition)

	Valid	Neutral	Invalid
Subject1	336	343	339
Subject2	365	355	369
Subject3	415	406	435
Subject4	347	353	457
Subject5	376	365	372
Subject6	399	387	386
Subject7	403	413	445
Subject8	338	354	359
Subject9	403	410	397
Subject10	336	343	339
Average	372	373	390

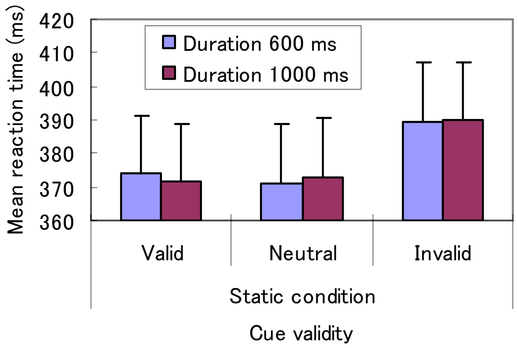


Figure 6-3 Mean RTs in both 600 and 1000 ms durations (Static condition)

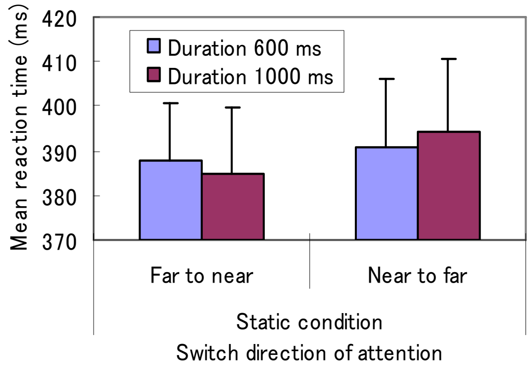


Figure 6-4 Mean RTs in different switch direction of attention (Static condition)

Table 6-3 RTs of subjects in 600 ms duration in different switch direction of attention (Static condition)

	From far to near	From near to far
Subject1	352	342
Subject2	384	357
Subject3	457	463
Subject4	409	441
Subject5	371	392
Subject6	382	400
Subject7	436	411
Subject8	350	347
Subject9	385	415
Subject10	352	342
Average	388	391

Table 6-4 RTs of subjects in 1000 ms duration in different switch direction of attention (Static condition)

	From far to near	From near to far
Subject1	337	341
Subject2	373	364
Subject3	432	438
Subject4	423	485
Subject5	377	368
Subject6	386	385
Subject7	445	445
Subject8	347	373
Subject9	392	403
Subject10	337	342
Average	385	394

Reaction times of subjects in 600 and 1000 ms cue duration under different switch direction of attention under static observing condition were listed in Table 6-3 and Table 6-4. Figure 6-4 showed mean RT in different switch direction of attention in static condition. It can be seen that mean RT was shorter from far to near than that from near to far. It suggested that the shifting of attention has asymmetry characteristic, and was obvious in 1000 ms duration than in 600 ms duration (600ms: 388 vs. 391ms; 1000ms: 385 vs. 394 ms).

Reaction times of subjects in 600 and 1000 ms cue duration under dynamic observing condition were listed in Table 6-5 and Table 6-6. Figure 6-3 showed reaction time in three kinds of cue cases (Valid, Neutral and Invalid) in both 600 and 1000 ms duration under static condition. It can be seen that mean reaction time was slower in the Invalid cases in both duration. The mean values of that reaction time were 373 ms, 376 ms and 392 ms in 600 ms duration; the mean values of that reaction time were 379 ms, 381 ms and 405 ms in 1000 ms duration. It can be seen that mean RT was longest in the invalid in both durations; RT was shortest in the neutral in 600 ms duration. It may suggest that the duration had an influence on cue validity, and was more evidence in 1000 ms duration.

Reaction times of subjects in 600 and 1000 ms cue duration under different switch direction of attention under dynamic observing condition were listed in Table 6-7 and Table 6-8. Figure 6-4 showed mean RT in different switch direction of attention in dynamic condition. It can be seen that mean RT was shorter from far to near than that from near to far. It suggested that the shifting of attention has also asymmetry characteristic, and was more evidence in 1000 ms duration than in 600 ms duration (600ms: 386 vs. 397; 1000ms: 394 vs. 416).

Table 6-5 RTs of subjects in 600 ms duration (Dynamic condition)

	Valid	Neutral	Invalid
Subject1	339	333	326
Subject2	395	399	433
Subject3	401	396	433
Subject4	346	337	436
Subject5	440	462	428
Subject6	340	356	355
Subject7	356	367	355
Subject8	329	335	343
Subject9	389	388	398
Subject10	371	389	412
Average	373	376	392

Table 6-6 RTs of subjects in 1000 ms duration (Dynamic condition)

	Valid	Neutral	Invalid
Subject1	352	340	370
Subject2	404	399	428
Subject3	401	401	455
Subject4	354	357	435
Subject5	450	454	452
Subject6	367	371	370
Subject7	369	370	383
Subject8	327	322	340
Subject9	390	393	404
Subject10	376	401	411
Average	379	381	405

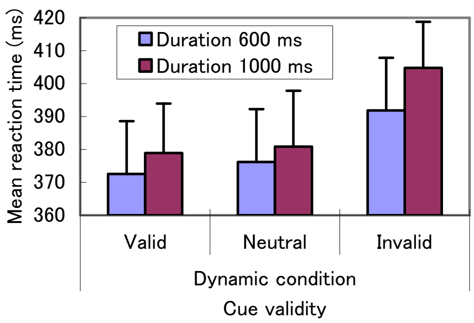


Figure 6-5 Mean RTs in both 600 and 1000 ms durations (Dynamic condition)

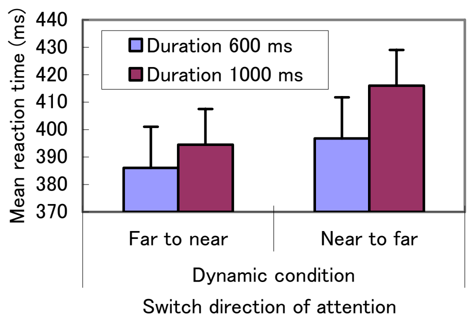


Figure 6-6 Mean RTs in different switch direction of attention (Dynamic condition)

Table 6-7 RTs of subjects in 600 ms duration in different switch direction of attention (Dynamic condition)

	From far to near	From near to far
Subject1	316	335
Subject2	432	435
Subject3	443	425
Subject4	431	441
Subject5	424	432
Subject6	355	354
Subject7	333	372
Subject8	339	347
Subject9	374	417
Subject10	413	411
Average	386	397

Table 6-8 RTs of subjects in 1000 ms duration in different switch direction of attention (Dynamic condition)

	From far to near	From near to far
Subject1	376	363
Subject2	414	442
Subject3	439	467
Subject4	394	489
Subject5	455	449
Subject6	373	367
Subject7	373	394
Subject8	327	353
Subject9	395	412
Subject10	398	423
Average	394	416

Because an attention characteristic of subjects in dynamic condition is real condition in actual traffic environment, so we will analyzed the attention characteristics of subjects in dynamic condition. A two-way (cue validity × cue duration) analysis of variance (ANOVA) indicated that the main effect of cue validity was significant [$F(2,81)= 7.85$, $p<.005$], the main effect of cue duration was not significant [$F(1,81)=1.71$, $p>.1$]. The interaction of cue validity and duration was not significant [$F(2,81)=1.31$, $p>.1$].

Scheffe's test for the 600 ms duration condition showed a significant difference between the valid and invalid conditions ($p< 0.05$), and between the neutral and invalid conditions ($p< 0.05$), and no significant difference between the valid and neutral conditions. Scheffe's test for the 1000 ms duration condition showed also a significant difference between the valid and invalid conditions ($p< 0.05$), and between the neutral and invalid conditions ($p< 0.05$), and no significant difference between the valid and neutral conditions.

According to these results, the 1000 ms cue duration condition, as compared with the 600 ms condition, resulted in benefit with the correct response. Thus, the effect of cue validity under both 600 and 1000 ms duration conditions was confirmed, as cue duration increased, mean RT decreased. The effect should be noticed.

6.2.2.2 Characteristics of switching of attention in depth

When an invalid cue is given, subjects have to switch attention in the opposite direction in depth immediately after the appearance of a target. If the content of the cue is "far locations", observers have to switch attention from "far locations" to "near locations", and if it is "near locations", they have to switch attention from "near locations" to "far locations".

The invalid cues are noteworthy in order to examine switching of attention in both 600 and

1000 ms duration conditions. As shown in Figures 6-6, mean RT for attention switching from far locations to near locations was shorter than for attention switching from near locations to far locations.

According to these results, mean RT of subjects was affected by switch direction of attention, the response to nearer targets was faster than to further targets, asymmetry of switching of attention in depth was found in two duration conditions. This suggests that attention resources may be distributed more densely in a near area relative to a fixation point. This suggests also an asymmetrical shape of the three-dimensional useful field of view. These results are consistent with results from other studies (Andersen, 1990; Tipper, Lortie & Baylis 1992; Andersen & Kramer, 1993; Miura, Shinohara & Kanda, 2002; Kimura & Miura, 2004).

6.3 Experiment of effect of color on reaction time (Color experiment)

6.3.1 Method

6.3.1.1 Subjects

Subjects in this experiment were as the same as the duration experiment; all subjects had normal or corrected-to-normal vision, and more than one years of driving experience.

6.3.1.2 Apparatus

The apparatus was the same as the apparatus (3.2.2) in chapter 3, but colors of cue and stimuli were different in static and dynamic conditions.

6.3.1.3 Cue and stimuli

Color combination of cue and stimuli were used. There were two colors of cue and stimuli: red and green. We designed four color combination conditions:

(1) Cue was red, and stimulus was red; (2) Cue was green, and stimulus was green;

(3) Cue was red, and stimulus was green; (4) Cue was green, and stimulus was red.

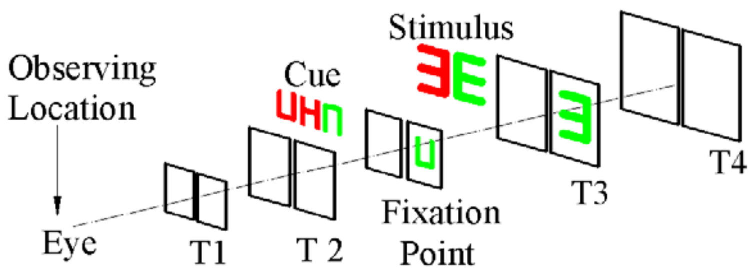


Figure 6-7 Collocation of LED & Color combinations of cue and stimuli. Stimulus will appear at T1 or T2 location when cue is “U”, and will appear at T3 or T4 location when cue is “∩”; Stimulus will appear at any one of target location when cue is “H”. T=Target.

6.3.1.4 Experimental design

The shape and duration of cue were the same as the duration experiment with the exception of color of cue and stimuli. In this experiment, two LEDs were set in each target location side by side (see Figure 6-7), left LED was red; right was green. Experiment for two cue duration was also 320 trials, respectively.

6.3.1.5 Task and Procedure

The task and procedure of this experiment were the same as duration experiment except for the presentation of color configuration of cue and stimulus.

6.3.2 Results and discussion

6.3.2.1 Color of cue and target is consistent under static observing condition (600 ms duration):

Reaction times of subjects as color consistent under static observing condition were listed in Table 6-9 and Table 6-10. Figure 6-8 showed reaction time in three kinds of cue cases (Valid, Neutral and Invalid) when being the consistent color under static condition. It can be seen that mean reaction time was slower when color of cue and target was consistent green. The mean values of that reaction time were 398 ms, 400 ms and 410 ms when being red consistent; the mean values of that reaction time were 400 ms, 403 ms and 412 ms when being green consistent. It can be seen that mean RT was longest in the invalid; RT was shortest in the valid. It may suggest that the cue validity had an influence on reaction time.

Reaction times of subjects as color consistent under different switch direction of attention under static observing condition were listed in Table 6-11 and Table 6-12. Figure 6-9 showed mean RT in different switch direction of attention in static condition. It can be seen that mean RT was shorter from far to near than that from near to far. It suggested that the shifting of attention has also asymmetry characteristic, and was more evidence when being green consistent than that when being red consistent (red consistent: 404 vs. 416 ms; green consistent: 394 vs. 427 ms).

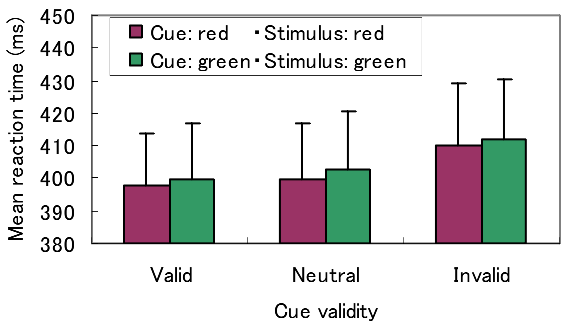


Figure 6-8 Mean RTs in three cue validity under static condition (color consistent)

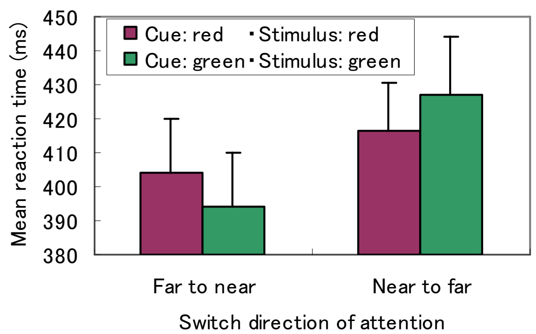


Figure 6-9 Mean RTs in different switch direction of attention under static condition (color consistent)

Table 6-9 RTs of subjects in 600 ms duration (Static condition)
Color consistent（Cue: red・Stimulus: red）

	Valid	Neutral	Invalid
Subject1	362	353	362
Subject2	420	419	460
Subject3	403	413	408
Subject4	379	367	354
Subject5	356	359	356
Subject6	357	367	446
Subject7	403	396	402
Subject8	434	449	448
Subject9	442	459	464
Subject10	424	415	403
Average	398	400	410

Table 6-10 RTs of subjects in 600 ms duration (Static condition)
Color consistent（Cue: green・Stimulus: green）

	Valid	Neutral	Invalid
Subject1	359	359	368
Subject2	416	420	439
Subject3	420	415	409
Subject4	368	370	361
Subject5	352	344	349
Subject6	357	374	441
Subject7	395	409	402
Subject8	441	449	448
Subject9	461	461	453
Subject10	428	426	453
Average	400	403	412

Table 6-11 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: red・Stimulus: red）(Static condition)

	From far to near	From near to far
Subject1	360	363
Subject2	445	475
Subject3	407	408
Subject4	347	362
Subject5	375	338
Subject6	381	418
Subject7	400	495
Subject8	404	399
Subject9	454	442
Subject10	464	463
Average	404	416

Table 6-12 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: green・Stimulus: green）(Static condition)

	From far to near	From near to far
Subject1	354	378
Subject2	424	451
Subject3	395	422
Subject4	350	348
Subject5	376	490
Subject6	393	412
Subject7	436	460
Subject8	352	369
Subject9	444	464
Subject10	419	477
Average	394	427

6.3.2.2 Color of cue and target is inconsistent under static observing condition (600 ms duration):

Reaction times of subjects as color inconsistent under static observing condition were listed in Table 6-13 and Table 6-14. Figure 6-10 showed reaction time in three kinds of cue cases (Valid, Neutral and Invalid) when being the inconsistent color under static condition. It can be seen that mean reaction time was longer when color combines were red cue and green target in the invalid, but was shorter in the valid and neutral. The mean values of reaction time were 399 ms, 399 ms and 412 ms when being red cue; the mean values of that reaction time were 399 ms, 395 ms and 414 ms when being green cue. It can be seen that mean RT was longest in the invalid; RT was shortest in the neutral. It may suggest that the cue validity had also an influence on reaction time when color combine was inconsistent.

Reaction times of subjects as color inconsistent under different switch direction of attention under static observing condition were listed in Table 6-15 and Table 6-16. Figure 6-11 showed mean RT in different switch direction of attention in static condition. It can be seen that mean RT was shorter from far to near than that from near to far. It suggested that the shifting of attention has also asymmetry characteristic, and was more evidence when being green cue than that when being red cue.

Table 6-13 RTs of subjects in 600 ms duration (Static condition)
Color inconsistent（Cue: red・Stimulus: green）

	Valid	Neutral	Invalid
Subject1	364	352	366
Subject2	408	419	447
Subject3	413	410	403
Subject4	373	368	362
Subject5	353	353	351
Subject6	351	371	478
Subject7	405	407	399
Subject8	443	436	446
Subject9	449	453	441
Subject10	434	424	422
Average	399	400	412

Table 6-14 RTs of subjects in 600 ms duration (Static condition)
Color inconsistent（Cue: green・Stimulus: red）

	Valid	Neutral	Invalid
Subject1	363	353	354
Subject2	414	419	442
Subject3	428	412	421
Subject4	369	367	375
Subject5	359	342	350
Subject6	349	362	460
Subject7	404	396	409
Subject8	429	445	445
Subject9	444	447	453
Subject10	427	408	432
Average	399	395	414

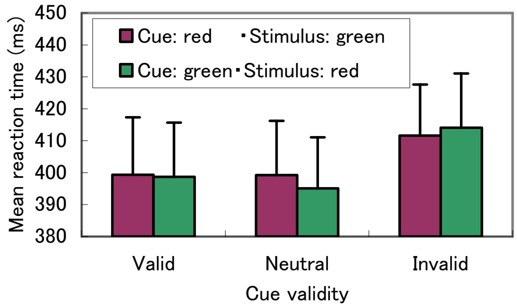


Figure 6-10 Mean RTs in three cue validity under static condition (color inconsistent)

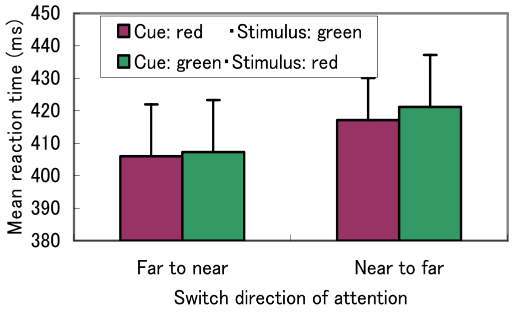


Figure 6-11 Mean RTs in different switch direction of attention under static condition (color inconsistent)

Table 6-15 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: red・Stimulus: green）(Static condition)

	From far to near	From near to far
Subject1	368	364
Subject2	433	461
Subject3	407	399
Subject4	361	363
Subject5	354	348
Subject6	463	493
Subject7	396	402
Subject8	433	459
Subject9	428	454
Subject10	417	427
Average	406	417

Table 6-16 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: green・Stimulus: red）(Static condition)

	From far to near	From near to far
Subject1	358	350
Subject2	419	469
Subject3	417	425
Subject4	370	380
Subject5	350	351
Subject6	436	486
Subject7	399	419
Subject8	423	465
Subject9	472	432
Subject10	428	436
Average	407	421

6.3.2.3 Color of cue and target is consistent under dynamic observing condition (600 ms duration):

Reaction times of subjects as color consistent under dynamic observing condition were listed in Table 6-17 and Table 6-18. Figure 6-12 showed reaction time in three kinds of cue cases (Valid, Neutral and Invalid) when being the consistent color under dynamic condition. It can be seen that mean reaction time was slower when color of cue and target was consistent green. The mean values of that reaction time were 386 ms, 384 ms and 401 ms when being red consistent; the mean values of that reaction time were 394 ms, 392 ms and 407 ms when being green consistent. It can be seen that mean RT was longest in the invalid; RT was shortest in the neutral. It may suggest that the cue validity had an influence on reaction time.

Reaction times of subjects as color consistent under different switch direction of attention under static observing condition were listed in Table 6-19 and Table 6-20. Figure 6-13 showed mean RT in different switch direction of attention in static condition. It can be seen that mean RT was shorter from far to near than that from near to far. It suggested that the shifting of attention has also asymmetry characteristic, and was more evidence when being green consistent than that when being red consistent (red consistent: 394 vs. 408 ms; green consistent: 395 vs. 420 ms).

Table 6-17 RTs of subjects in 600 ms duration (Dynamic condition)
Color consistent（Cue: red・Stimulus: red）

	Valid	Neutral	Invalid
Subject1	358	356	351
Subject2	413	404	427
Subject3	457	424	458
Subject4	375	377	383
Subject5	341	340	335
Subject6	370	383	494
Subject7	384	392	389
Subject8	385	373	377
Subject9	400	400	423
Subject10	380	387	378
Average	386	384	401

Table 6-18 RTs of subjects in 600 ms duration (Dynamic condition)
Color consistent（Cue: green・Stimulus: green）

	Valid	Neutral	Invalid
Subject1	366	358	346
Subject2	417	412	424
Subject3	451	438	485
Subject4	385	378	399
Subject5	345	345	345
Subject6	372	377	453
Subject7	406	398	405
Subject8	393	402	399
Subject9	412	394	416
Subject10	393	416	398
Average	394	392	407

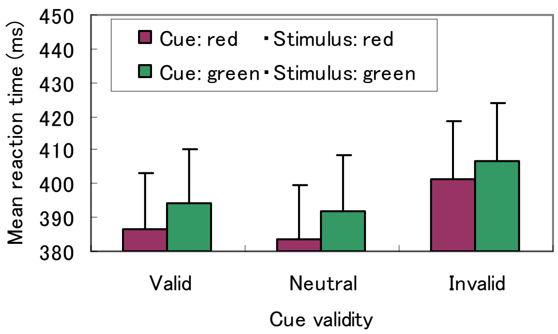


Figure 6-12 Mean RTs in three cue validity under static condition (color consistent)

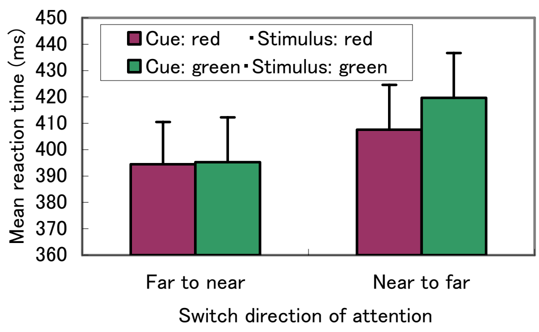


Figure 6-13 Mean RTs in different switch direction of attention under static condition (color consistent)

Table 6-19 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: red・Stimulus: red）(Dynamic condition)

	Far to near	Near to far
Subject1	352	350
Subject2	406	455
Subject3	455	462
Subject4	371	397
Subject5	339	331
Subject6	451	525
Subject7	412	367
Subject8	359	394
Subject9	413	432
Subject10	388	364
Average	394	408

Table 6-20 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: green・Stimulus: green）(Dynamic condition)

	Far to near	Near to far
Subject1	345	347
Subject2	427	420
Subject3	495	476
Subject4	393	405
Subject5	347	344
Subject6	403	508
Subject7	387	423
Subject8	402	397
Subject9	393	438
Subject10	361	439
Average	395	420

6.3.2.4 Color of cue and target is inconsistent under dynamic observing condition (600 ms duration):

Reaction times of subjects as color inconsistent under dynamic observing condition were listed in Table 6-22 and Table 6-23. Figure 6-14 showed reaction time in three kinds of cue cases (Valid, Neutral and Invalid) when being the inconsistent color under dynamic condition. It can be seen that mean reaction time was longer when color combines were red cue and green target than that when color combines were green cue and red target, and RT was longest in the invalid, was shorter in the valid and neutral. The mean values of reaction time were 391 ms, 389 ms and 409 ms when being red cue; the mean values of that reaction time were 388 ms, 386 ms and 403 ms when being green cue. It can be seen that mean RT was longest in the invalid; RT was shortest in the neutral. It may suggest that the cue validity had also an influence on reaction time when color combine was inconsistent.

Reaction times of subjects as color inconsistent under different switch direction of attention under dynamic observing condition were listed in Table 6-23 and Table 6-24. Figure 6-15 showed mean RT in different switch direction of attention in dynamic condition. It can be seen that mean RT was shorter from far to near than that from near to far. It suggested that the shifting of attention has also asymmetry characteristic, and was more evidence when being green cue than that when being red cue.

Table 6-21 RTs of subjects in 600 ms duration (Dynamic condition)
Color inconsistent（Cue: red・Stimulus: green）

	Valid	Neutral	Invalid
Subject1	370	363	352
Subject2	403	405	425
Subject3	444	430	461
Subject4	382	394	370
Subject5	346	342	343
Subject6	379	392	517
Subject7	404	394	389
Subject8	390	378	402
Subject9	409	401	431
Subject10	387	392	397
Average	391	389	409

Table 6-22 RTs of subjects in 600 ms duration (Dynamic condition)
Color inconsistent（Cue: green・Stimulus: red）

	Valid	Neutral	Invalid
Subject1	363	370	359
Subject2	410	405	433
Subject3	441	444	478
Subject4	384	376	386
Subject5	341	347	345
Subject6	368	378	424
Subject7	404	384	419
Subject8	390	387	384
Subject9	394	400	416
Subject10	389	375	385
Average	388	387	403

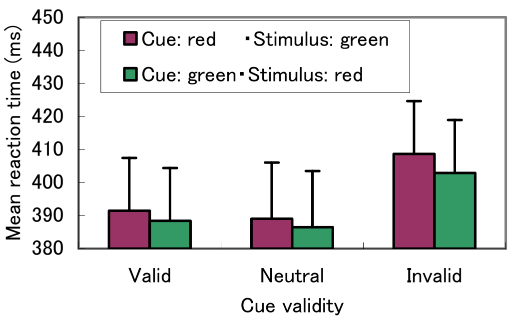


Figure 6-14 Mean RTs in three cue validity under static condition (color inconsistent)

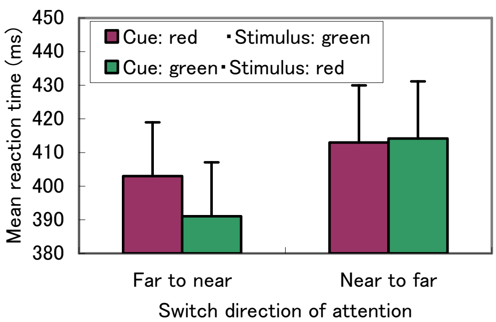


Figure 6-15 Mean RTs in different switch direction of attention under static condition(color inconsistent)

Table 6-23 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: red・Stimulus: green）(Dynamic condition)

	From far to near	From near to far
Subject1	371	336
Subject2	418	432
Subject3	462	459
Subject4	359	380
Subject5	335	349
Subject6	499	530
Subject7	402	376
Subject8	390	414
Subject9	433	429
Subject10	360	425
Average	403	413

Table 6-24 RTs of subjects in 600 ms duration in different switch direction of attention
Color consistent（Cue: green・Stimulus: red）(Dynamic condition)

	From far to near	From near to far
Subject1	348	368
Subject2	404	461
Subject3	473	483
Subject4	367	402
Subject5	334	353
Subject6	415	434
Subject7	415	423
Subject8	366	403
Subject9	422	410
Subject10	366	404
Average	391	414

By analysis above-mentioned, it can be seen that color combine of cue and target in 600 ms duration had same influence on response of subjects either static condition or dynamic condition, that is, RT was longest in the invalid than that in the valid and neutral; and there were an asymmetry characteristic of attention, that is, RT was shorter from far to near than that from near to far.

In traffic environment, attentional characteristic of drivers is mainly dynamic characteristic, so, in order to reveal the effect of cue duration and color combine on reaction time, it will be conduct the compare analyses of RT in both 600 and 1000 ms duration and, the effect of cue location validity and color combine on the RT of subjects in the following in detail.

Table 6-25 Mean RTs in valid and invalid location in both 600 and 1000 ms duration

	600 ms duration		1000 ms duration	
	Location valid	Location invalid	Location valid	Location invalid
Cue: red; Target: red (color valid 1)	386	401	374	389
Cue: green; Target: green (color valid 2)	394	407	378	402
Cue: red; Target: green(color invalid 1)	391	408	377	395
Cue: green; Target: red (color invalid 2)	388	403	376	388
Average	390	405	377	393

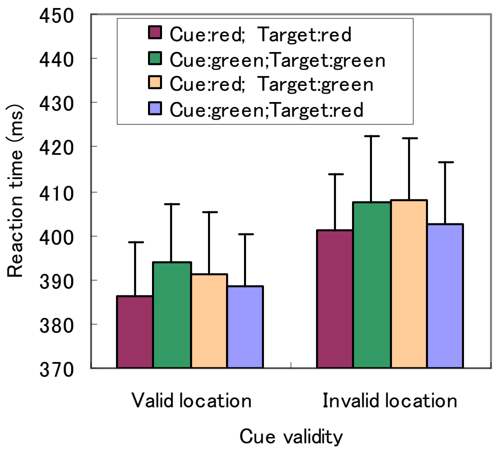


Figure 6-16 Effect of color and location validity on reaction time (600ms cue duration)

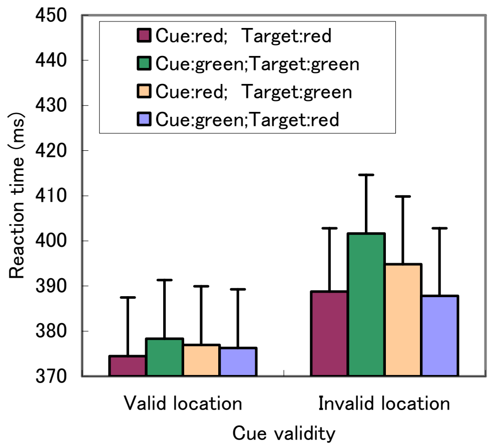


Figure 6-17 Effect of color and location validity on reaction time (1000ms cue duration)

6.3.2.5 Interaction effect of cue location validity and color combine on reaction time in both 600 ms and 1000 ms duration:

Mean RT in valid and invalid location in both 600 and 1000 ms duration was tabulated in Table 6-25. It was discovered as a "location valid" when precue and stimulus presented were in the same spatial region; "location invalid" was when precue and stimulus presented were in different spatial region. Similarly, it was named as a "color valid" when color of precue was consistent with color presented of stimulus, or else was "color invalid".

A three-way (cue validity × cue duration × color validity) analysis of variance (ANOVA) indicated that the main effect of cue validity was significant [$F(2, 243)=15.26$, $p<.001$], main effect of cue duration was also significant [$F(1, 243)=27.18$, $p<.001$]. The main effect of color validity was not significant [$F(3, 243)=13.12$, $P>0.1$], however, there was a significant interaction between the effects of cue validity and color validity [$F(3, 243)=11.2$, $P<0.01$], indicating that the effect of color validity differed depending on the validity of location cues. Thus, although there was no effect of color validity when location cues were valid, there was a significant effect of color validity when location cues were invalid ($P<0.05$).

The interaction between the cue validity and the duration [$F(1, 243)=1.04$, $p>.1$], and between the cue duration and the color validity [$F(3, 243)=1.02$, $p>.1$] was not significant. The three-way interaction of cue validity, cue duration, and color validity was not significant [$F(3, 243)=1.06$, $p>.1$].

Simple effects analysis of cue validity at each color configuration condition indicated that cue validity produced a significant effect in the color validity 2 [$F(2,243)=1.81$, $p<.005$], color invalidity 1 [$F(2,243)=7.85$, $p<.005$] and color invalidity 2 [$F(2,243)=2.91$, $p<.005$] conditions. The main effect of cue validity in the color invalidity 1 was not significant [$F(2,243)=2.56$, $p<.005$]. In addition, simple effects analysis of cue duration at each color configuration condition indicated that cue duration produced a significant effect in the color validity 1 [$F(2,243)=4.84$, $p<.005$], color validity 2 [$F(2,243)=4.17$, $p<.005$], color invalidity 1 [$F(2,243)=3.77$, $p<.005$] and color invalidity 2 [$F(2,243)=3.65$, $p<.005$] conditions. Furthermore, simple effects analysis of cue validity at each cue duration condition indicated that cue validity produced a significant effect in the 600 ms [$F(2,243)=3.15$, $p<.005$] and 1000 ms [$F(2,243)=5.12$, $p<.005$] duration conditions.

As shown in Figures 6-16 and 6-17, mean RT was longer for the cue invalid than for the cue valid in both 600 and 1000 ms duration conditions (in 600 ms duration condition: 405 vs. 390 ms, respectively; in 1000 ms duration condition: 393 vs. 377 ms, respectively). Furthermore, mean RT for color valid 1 and 2 in the valid in both 600 and 1000 ms duration conditions was shortest and longest, respectively. It might be a cause that visual attention was sensitive to red color, and sensitivities deficiency to green color of stimulus. In addition, mean RT for color valid 1 and invalid 1 in the invalid in 600 duration condition was shortest and longest, respectively; mean RT for color invalid 2 and valid 2 in the invalid in 1000 duration condition was shortest and longest, respectively.

In the 600 ms duration condition, Scheffe's test for the color valid 1 and 2 showed a significant difference between the valid and invalid conditions ($p< 0.05$), and also showed a significant difference for the color invalid 1 and 2 between the valid and invalid conditions ($p< 0.05$). However, there was nonsignificant difference among four color configurations (valid 1, valid 2, invalid 1 and invalid 2).

In the 1000 ms duration condition, Scheffe's test for the color valid 1and 2 showed a significant difference between the valid and invalid conditions ($p< 0.05$), and also showed a significant difference for the color invalid 1 and 2 between the valid and invalid conditions (p<

0.05). However, although there was nonsignificant difference among four color configuration patterns in the valid, there was a significant difference among four configuration patterns in the invalid, particularly between color valid 2 and color invalid 2.

According to these results, mean RT of subjects was affected by the cue validity and duration, color validity effects were significant only when location cues were invalid (indicated by a significant interaction between location and color validity effects).

6.4 Summary

In the present investigation, we designed two experiments in order to examine attentional processing of location and color cues during driving, and measured reaction time of attention shifting. Participants were required to judge whether the stimulus appeared nearer than the fixed point or further in the cue duration and cue type (location vs. color cues). The results in two experiments show that the valid effects are smaller than the invalid effects, that is, reaction time was shorter in the valid than that in the invalid. These results provided support for the hypothesis in which detection task are facilitated when the position of the target is known, and these results are consistent with results from early experiments (Eriksen and Hoffman 1973; Jonides 1981; Posner 1980; Posner et al. 1978). In addition, according to the results from duration experiments, asymmetry of switching of attention in depth was found, that is, reaction time was longer from nearer space to further space than the reverse. This suggests that attention resources may be distributed more densely in a near area relative to a fixed point; the results are consistent with results from other studies (Andersen, 1990; Tipper, Lortie & Baylis 1992; Andersen & Kramer, 1993; Miura, Shinohara & Kanda, 2002; Kimura & Miura, 2004) although attention was affected by cue duration.

The results in duration experiment show that reaction time is affected by cue duration, reaction time is longer in 600ms duration condition than that in 1000ms duration condition, that is, as cue duration increase, reaction time decrease. The results in color experiments show that there was a main effect of location validity, but color validity effects were significant only when location cues were invalid, and we obtained significant differences between the color valid 1, valid 2, invalid 1 and invalid 2 in the cue invalid in 1000 ms duration condition. Thus, color cues are as effective under the invalid condition.

The results in color experiment supported the hypothesis that location validity effects would be larger than color validity effects. However, results provided only partial support for the second hypothesis; although the slower RTs occurred on trials in which both location and color information was invalid, the faster RTs occurred on trials with valid location cues irrespective of the validity of color cues. This pattern of results suggests hierarchical processing of visual information. In other words, valid location cues are sufficient for fast accurate detection responses, so under these circumstances additional color information is redundant. Color information only becomes useful if location cues are invalid, when it facilitates detection of targets appearing at unexpected locations. This interpretation is consistent with the results of experiments showing that color cues have greater effects on responses when location information is unhelpful (Hillyard and Münte 1984; Laarni 1999). It is also consistent with a strong interpretation of the location special view (that feature information is redundant in the presence of valid location information), and with the view that selection by location is not only faster, but also an essential and primary stage of visual attention. However, it is also possible to explain the above pattern of results purely in terms of faster processing of location as opposed to color (feature) information, without arguing for the primacy of selection by location. According to this interpretation, color information is redundant when location cues are valid only because location cues are processed faster than color cues, which means that a response is made before color cues can be processed sufficiently to facilitate performance. In contrast, when location cues are invalid, attention must be shifted to a new location in order to locate the target, resulting in a delay before a response can be made. The extra processing time available because of this delay may be sufficient for subjects to use color cues to help locate the target. Although the results of the present experiment clearly demonstrated much larger location validity effects than color validity effects, it is possible that this was at least partly due to greater difficulty in identifying targets which were the same color as the preceding cue, particularly when location cues were valid. Thus the absence of color validity effects when location cues were valid may have occurred because subjects had greater difficulty detecting targets which were the same color and in the same location as the cue.

It is not possible to distinguish between these two interpretations on the basis of the results of the location by color validity analysis reported above. However, the two interpretations make different predictions concerning the pattern of location and color validity effects as a function of cue duration. The first interpretation predicts that color validity effects should never be significant when location cues are valid, but may be significant when location cues are invalid, regardless of duration. In contrast, the second interpretation predicts that there should be no color validity effects at short duration (600 ms), irrespective of location validity, but there should be color validity effects associated with the invalid location cues at longer duration (1000 ms). The pattern of location and color validity effects as a function of duration observed in the present investigation tends to support the second interpretation. At the shorter duration (600 ms) there was no evidence of color validity effects associated with either valid or invalid location cues, suggesting that there was insufficient time for subjects to use color cues. At the longer duration (1000 ms) there was a larger color validity effect when location cues were invalid, and a small color effect in association with valid location cues. The emergence of a color validity effect in association with valid location cues at duration of 1000 ms suggests that the apparent redundancy of color cues in association with valid location cues is the result of faster processing of location cues. Thus when duration is short, and location cues are valid, color cues are redundant in the sense that there is insufficient time to use them for target detection. In contrast, when duration is long, there is a gating effect on the processing of location information: although location cues can be processed much more quickly than color cues, the target does not appear until sufficient time for some processing of color cues has elapsed. As a result, small color validity effects can be observed even when location cues are valid. In conclusion, we demonstrate the integration of location and color information in detection task using a precueing paradigm, apart from supporting the notion that selection by location is faster and have a greater facilitatory effect than selection by color; the results of the present investigation provide the first direct evidence of color validity effects using a detection task. In order to reveal more characteristics of focused attention in the 3-D space, future research is needed, in which the orientation feature information (vertical and horizontal separations) can be varied between the cue and the target.

Chapter 7　General Discussion

In present thesis, we discussed the characteristics of depth attention of three kinds of subjects: young, low-vision subjects and older subjects. The patterns of attentional characteristics are spatial shifting in three-dimensional space using a prior cuing paradigm. Although the cuing paradigm used in present thesis has some difference compared with Posner' cuing paradigm, essential mechanism is same with the former. That is, Benefits express the faster reaction time in the valid condition than in the neutral condition (attentional 'benefits'), and costs express the slower reaction time in the invalid condition than in the neutral condition (attentional 'costs'). Attentional benefits or costs interpret these importances as a consequence of characteristic of attention shifting. Moreover, subjects were not allowed to move their eyes, insure subject's sight on the center of cue. Three within-observe variables were used: cue validity (valid, invalid and neutral cues). These experimental conditions all are being in the three-dimensional space for obtaining significant data. Based on the above-mentioned experimental conditions, we have discussed two issues: effect of peripheral illuminance on the attention and, effect of color and location on attention. Before general discussed, we review the experimental results and research methods of previous researches.

(1) The experimental results of Posner (1980) examined the dynamics of visual attention, found that it is possible to pay attention to a certain spatial location, independently of the direction of gaze, and showed faster reaction time in the valid condition than in the neutral condition (attentional 'benefits'), and slower reaction time in the invalid condition than in the neutral condition (attentional 'costs'). Because subjects were not allowed to move their eyes, he interpreted these differences as a consequence of a correct / incorrect orienting of attention. Posner also showed that peripheral non-symbolic cues (e.g. flashing a light below a given spatial location) elicited an automatic (involuntary) orienting of attention, whereas centrally located symbolic cues (e.g. an arrowhead pointing to a given spatial location) elicited a controlled (voluntary) orienting of attention. These results are mainly based on experiments that were conducted within a two-dimensional visual world.

(2) The experimental results of Downing and Pinker (1985) showed that attentional benefits and costs for attentional shifts in both the frontal plane and depth. Also, they found that, in depth, attentional costs were greater when subjects were invalidly cued to a near location then when they were invalidly cued to a far location; the direction of switching attention has asymmetry in real space situation. That is, the cost when attention should shift from far to near is smaller than

the cost when attention should shift from near to far (37 ms and 48 ms, respectively). The targets design of Downing and Pinker was that a light was shown at one of eight possible locations; the lights were arranged in two different depth planes with the subjects' fixation directed between them.

(3) The experimental results of Gawryszewski et al. (1987) showed that that shift of attention from near to far is faster than the reverse condition (225 ms and 252 ms, respectively), and found greater costs for shifting attention from near to far locations than for shifting attention from far to near locations. Experimental targets were arranged in two different depth locations (far and near) before and after fixation point.

(4) The experimental results of Miura et al. (2002) showed that attention operates more efficiently at nearer locations than at farther locations relative to a fixation point; the effect of expectancy is confirmed in depth, this effect is more remarkable in three-dimensional space than in two-dimensional space; attention operates in unexpected events more efficiently in moving situations than in stationary situations; attention shifts more efficiently from far locations to near locations than the reverse, especially in moving situations; these results suggest that the attention resource is more densely distributed in the near area in moving situations than in stationary situations. Shift of attention in their experiments was examined in depth by the use of an improved tunnel simulator.

(5) The experimental results of Andersen and Kramer (1993) showed that the size of the interference effect was directly related to the distance in depth between targets and distractors. That is greater costs were observed for near than for far distractors. Because the computer generated stereograms were perceived as being at a greater distance than in the previous study (140 cm vs. 21 cm), and subjects might have mapped them on to distant, extrapersonal space, Andersen and Kramer argued that this factor was responsible for the inversion of the attentional asymmetry. Results suggested that attention in a three-dimensional visual world seems to have a gradient form because the interference of noise was attenuated where it grow away from the target. Shift of attention in their experiments was examined by means of random dot stereograms (RDS) in "virtual world".

Based on the above-mentioned review, we would discuss our experimental results in following.

7.1 Discussion of the results for young subjects' reaction times

Three related issues in Chapter 3 were investigated within the context of focused attention in depth by means of a three-dimensional attention measurement apparatus in real three-dimensional space. Spatial cuing paradigm (Posner, et al., 1978; Posner et al., 1980) was used. Although Posner' experiments were conducted in a two-dimensional visual space, offered a significant experimental cueing paradigm for vision researches in three-dimensional space, so there were three experimental conditions in our experiments: a valid condition (cue and target were in the same spatial location), an invalid condition (cue and target were in different spatial locations), and a neutral condition (all target locations were cued). Experimental central cue directed shifts of attention between two nearer locations after fixation point and two farter locations before fixation point. The first issue concerned whether visual contexts of young subjects that produce depth information by four LEDs before and after fixation point influence the shifting of spatial attention in perceived three-dimensional space. The difference between reaction times was obtained among three cue validity conditions (valid, invalid and neutral). Our results showed that responses to targets at cued locations were faster than those at uncued locations; this cue validity effect was not influenced by the visual context, irrespective of whether the cued and uncued locations were perceived at the same or different depths. The experimental results also showed longer reaction times in the invalid than in the valid conditions in both peripheral environment illuminances (bright and twilight conditions). These results suggested that reaction times were affected by cue validity, in other words, cue influenced the reaction time of subjects. The results demonstrated prior information concerning the spatial location of a subsequent target facilitates the selection of that target for further visual processing, and were consistent with the results of previous researches (Posner 1980; Posner et al. 1978).

The second issue concerned whether visual attention of young subjects is affected by peripheral environment illuminance. The results showed the difference of reaction time was not greater between both peripheral illuminances (in valid: 391 vs. 392 ms (bright vs. twilight); in invalid: 478 vs. 479 ms (bright vs. twilight)). This result suggested the peripheral illuminance has no influence on the response to observing targets. However, there were a lot of traffic accidents in twilight conditions from statistic data in real traffic environment. It is possible to explain the above pattern of result purely in terms of physiology theory, physiology exhaustion result in response lag to targets after all daylight working, low illuminance only becomes a useful in the twilight condition. According to this interpretation, illuminance information is redundant to visual attention.

The third issue concerned the discrepancy between the findings of asymmetries of attention along the depth. Investigations of attention using valid/invalid cuing paradigms have found that the reorientation of attention occurs more quickly when shifting from a far location to a near location than when shifting from a near location to a far location (in bright: 461 vs. 499 ms; in twilight: 453 vs. 503 ms). The results showed consistent with the results of previous researches (Downing & Pinker, 1985; Gawryszewski et al., 1987). This pattern of results can be interpreted in terms of a steeper gradient beyond the focus of attention in depth. Thus, it might be assumed that attention is distributed, in a viewer-centered fashion, from the observer to fixation. Therefore, the processing of objects between the observer and fixation should be relatively easy, whereas the processing of objects beyond fixation may necessitate the redeployment of attention. In addition, the results also showed the difference of reaction time was not greater between both peripheral illuminances (from far to near: 461 vs. 453 ms (bright vs. twilight); from near to far: 499 vs. 503 ms (bright vs. twilight)). This result suggested the peripheral illuminance has no influence on asymmetry of attention.

In a word, our experimental results in two peripheral illuminanc conditions are consistent with the results of the mention-above experiments. Only difference in our experiments is the observing conditions, there are two illuminance conditions in our experiments: (bright and twilight conditions. The experimental results support “viewer centered representation of three-dimensional space”. Our results proved the following view: 1) the main effect of validity of cue was significant, attention has depth information, this result suggested that the cue validity can produce an impact, the valid cues are sufficient for fast accurate detection responses, in contrast, the accurate responses have no sufficient time in invalid cues than in the valid cues; 2) The main effect of illuminance condition was not significant; the results suggested that the illuminance conditions of the experiments only produce a physiology sense to visual response, not effect for accurate responses; 3) Attention shift from far location to near location was faster than the reverse; the reallocation of attention is asymmetry. That is, the response to nearer targets was faster than to further targets, this result suggested that orientation of attention shifts.

Although some characteristics of attention are revealed, the experimental results what we found is also consistent with the results of Miura et al.’ research (2002).

7.2 Discussion of our results for low-vision subjects’ attention

Our investigation in Chapter 4 showed that the prior information concerning the spatial location of a subsequent target facilitates the selection of that target for further visual processing, precuing paradigm is not only an efficient way of controlling input variables, but may provide unique information. In particular, we found the peripheral illuminance has no influence on the shift of attention. Based on these results, two related issues were investigated in Chapter 4, we designed three kinds of peripheral illuminance and two kinds of observing conditions to examine the shift of attention of subjects simulated low-vision, the aim is further to research whether visual attention of subjects is affected by peripheral environment illuminance in both dynamic and static observing conditions.

The first issue concerned whether visual attention of subjects was affected by peripheral environment illuminance. The results showed the difference of reaction time was not obvious between bright and twilight conditions, but the difference was greater between the dawn and bright condition than between the twilight and bright conditions. This result suggested the high peripheral illuminance has no influence on the response for observing targets, but low illuminance has influence on the response. It is possible to explain the above pattern of result purely in terms of vision theory, a few lights that enter the eye result in response lag to targets in dawn condition. The second issue concerned whether asymmetries of attention along the depth is affected by peripheral environment illuminance. The results found asymmetry of attention in various illuminance conditions and observing conditions. The results also showed the difference of reaction time was also not obvious between bright and twilight conditions, but the reaction time was longer in the dawn condition than in bright and twilight conditions. The results suggested high peripheral illuminance has no influence to asymmetry of attention; low peripheral illuminance has influence on asymmetry of attention. The third issue concerned whether observing condition of subjects influences the shifting of spatial attention. It is interesting to note that, the results showed that attention can operate more rapidly to targets in the dynamic condition than in the static condition, reaction time was shorter in the dynamic condition than in the static condition. This implies that observers rely much more on their expectancy in the dynamic condition than in the static condition. The results were not consistent with the results of previous research (Miura et al., 2002). However, reaction time was shorter in the static condition than in the dynamic condition.

7.3 Discussion of our results for older subjects' attention

Our investigation in Chapter 5 showed that the attention of older subjects was affected by the cue validity, reaction time was longer in the invalid than in the valid. And the reaction time, compared with the reaction time of younger subjects, was evident longer, approximately 200 ms longer. It is possible to explain the experimental results of older subjects in terms of visual function of older people. Although there are neural losses to older drivers, the major decline is due to changes in the eye's optics. First, the lens becomes yellower, making discrimination of targets that are continuously changed more difficult. More importantly, less light entering the eye reaches the photoreceptors. One problem is that the lens and other optical media become opaque. Further, the pupil shrinks, allowing less light to enter the eye. The following table shows how the pupil size shrinks with age. Note that the pupil's response to dim light also decreases with age and becomes virtually nil by age 80. This means the older have especially large vision problems in low light environments. Moreover, the visual function test' results of older subjects also showed that there were low kinetic visual acuity and low dynamic discrimination, low visual function of older people is one of causes result in slow reaction time to targets. In addition, the results also showed that there was also an asymmetry characteristic of attention shifting. Why asymmetric switching of attention was shown? One potential explanation of this result was that the switching speed of attention might be a cause when attention should shift from certain location to another. The switching speed of attention of older subjects is slower when switching from near location to far location than from far location to near location.

7.4 Discussion of our results on location and color cues

Over the last couple of decades there has been considerable debate about the importance of effect of location and color on detection task in three-dimensional space. There are two views: first view considered that the effect of spatial location on detection task is primary; another considered that the effect of spatial location on detection task is subordinate, location is just one selection attribute, and color information is all-important for visual detection.

Two related issues in Chapter 6 were investigated that location and duration cueing effects as well as location and color cueing effects. The first issue concerned whether cue duration of subjects influences the shifting of spatial attention. The results showed that the main effect of cue validity was significant [$F(2,81)= 7.85$, $p<.005$], the main effect of cue duration was not significant [$F(1,81)=1.71$, $p>.1$]. The interaction of cue validity and duration was not significant [$F(2,81)=1.31$, $p>.1$]. Mean reaction time was longer for 600 ms duration than for 1000 ms duration. The 1000 ms cue duration condition, as compared with the 600 ms condition, resulted in benefit with the correct response. The second issue concerned that the stimulus selection via spatial location is primary or stimulus selection via stimulus's color is primary. The results showed that the main effect of color validity was not significant [$F(3, 243)=13.12$, $P>0.1$], although there was no effect of color validity when location cues were valid, there was a significant effect of color validity when location cues were invalid ($P<0.05$). The interaction between the cue duration and the color validity [$F(3, 243)=1.02$, $p>.1$] was not significant. In a word, mean reaction time of subjects was affected by the cue validity and duration, color validity effects were significant only when location cues were invalid (indicated by a significant interaction between location and color validity effects). Although these results showed location information importance, our experiment only is conducted in certain conditions; importance of color information on detection task also pays attention to visual attention research.

Chapter 8 Conclusion and Future outlook

This last part of the present thesis summarizes our experimental programs and findings as well as future works in terms of the experimental results and analyses of the experimental data.

8.1 Conclusion

In chapter 1 of this thesis, we introduced the background of the present study, and analyzed the factors influenced driving related to drivers and the relationship of human error and road traffic accidents during driving, that is, cognition and judgment as well as operation of drivers, and analyzed the time occurred accident. The analyses suggested that cognition mistakes is mainly considered one of reasons result in the accident apparitions, and indicated that there were many accidents in the twilight time and a high proportion accident for older drivers by statistic data. Based on the traffic accidents actuality, the study of visual attention of drivers during driving will be became our investigative issue. The purpose of investigative is to reveal the characteristics of visual attention in depth of drivers during driving, so as to improve the traffic safety education. In addition, we showed the connotation of visual attention and history of the research of visual attention, and summarized the spatial theories of visual attention, spotlight theory, zoom lens theory and gradient theory. At the same time, we showed the connotation of a three-dimensional space: stereoscopic space and real space as well as the actuality of attention researches in the current through previous experiments, for example, Downing & Pinker, Gawryszewski et al., Miura et al., Kimura et al. and Nakayama& Silverman. A few cases on visual attention research simulated traffic environment were enumerated, for example, Crundall et al. (2002), Andersen & Ni (2005) and Ochiai & Sato (2005). According to the above-mention, we clarified the aims and projects of present thesis, that is, our focus are to reveal the characteristics of visual attention in depth of subjects in supposed traffic environment by means of a three-dimensional attentional measurement system, using typical precuing paradigm.

In chapter 2 of this thesis, we conducted basic experiments and, showed the experimental apparatuses. Firstly, adjusting and focusing of the eye for light and focusing was introduced, and then vision adaptability test was conducted, including the test of visual functions in two-dimensional (2-D) space and three-dimensional space. The experiments used kinetic visual measurement apparatus (AS-4D), multifunctional sight inspection apparatus (STN-04), dynamic visual check system MMO-DVC-2011 and depth perception check apparatus (Made in Wu lab). Fifteen students and seventeen older drivers participated in these experiments. The results of experiments suggested the difference of visual adaptability of subjects, including dynamic discrimination, depth perception. The visual function of older people was lower than young students. According to the results, the subjects were apart into two groups, that is, high visual adaptive ability and low visual adaptive abilities. The subjects with low visual adaptive ability will conducted the superaddition experiment in Chapter 3, the aims are to investigate that whether visual adaptability of the subjects with low visual adaptive ability can be improved through visual trainings.

In chapter 3 of this thesis, fifteen students served as participants. The aim of the present chapter is to reveal the characteristics of attention in depth of subjects when peripheral environment illuminance is changed. Two experimental illuminances were designed: bright (480-680 lx) and twilight (95-135 lx) conditions. Three within-observe variables were used: cue validity (valid: V, invalid: I, neutral: N). The results showed that the mean reaction time was shortest in the valid than in the neutral and invalid, the difference of the mean reaction time was greater between the bright and twilight conditions in both groups (high and low visual adaptive ability), and the mean reaction time was more faster in “from far to near” cases than in “from near to far” cases in both groups. The reaction time of subjects with high visual adaptive ability was shorter than subjects with low visual adaptive ability. Based on the difference of visual response in both high and low visual adaptability groups, we conducted a superaddition experiment to low visual adaptability subjects, two subjects served this superaddition experiment, the results indicated that the tendency will be shown to shorten the reaction time delay to the subjects with low visual adaptability by training which the direction of the attention switching was imparted.

In chapter 4 of this thesis, fourteen students served as participants. The aim of the present chapter is to reveal the characteristics of attention in depth of subjects with low-vision when peripheral environment illuminance is changed. Three experimental illuminances were designed: bright condition (480-680 lx), twilight condition (95-135 lx) and dawn condition (5-8 lx). A special test eyepiece, there was a yellow plastic film in front of eyepiece, have been fabricated, it can simulate the dark field or low-vision. The results showed that the mean reaction time was shortest in the dawn condition than in the bright condition and twilight condition. If compared with the results of chapters 3, we found that the reaction times of subjects with low-vision were longer than that the subjects in chapter 3 in both bright and twilight conditions. These results suggested visual response deficiency in the dawn condition, and it is dangerous tendency to the subjects with low-vision during driving.

In chapter 5 of this thesis, fifteen older subjects served as participants. The experimental conditions were same as the experimental conditions in chapter 3. The results showed that, compared with the results of younger subjects in chapter 3, the reaction time of older subjects was evident longer than younger subjects. Cue validity and asymmetries of attention were presented in the characteristics of visual attention of old subjects.

In chapter 6 of this thesis, ten students served as participants. The aim of the present chapter is to reveal the characteristics of attention in depth of subjects when cue attend duration and targets color are changed. In cue duration experiment, two cue durations were used: 600 and 1000 ms, two experimental observing conditions were designed: static and dynamic (0.44 m/s moving speed) conditions. The shape of cue was "U", "∩"or "H" with yellow color, the shape of stimuli in target locations (T1, T2, T3 and T4) was "E" or "3" with red color digital LED. The results showed that there was no nearly evident difference for the mean reaction time in both 600 and 1000 ms durations under the static condition, and also no evident difference (difference values: approximately 8 ms). The results suggested that cue duration and observing condition have no significant effect. In color experiment, two cue durations were used: 600 and 1000 ms, and two colors were used: red and green. We designed four color combination conditions: (1) cue was red, and stimulus was red; (2) cue was green, and stimulus was green; (3) cue was red, and stimulus was green; (4) cue was green, and stimulus was red. A three-factor analysis (location validity, cue duration and color configuration of cue) of variance showed that the main effect of cue location validity was significant, main effect of cue duration was also significant. Subjects were on average 24 ms and 26 ms faster responding to targets following val id as opposed to invalid location cues in 600 ms and 1000 ms duration conditions, respectively. The main effect of color validity was not significant. However, there was a significant interaction between the effects of location and color validity [F (6, 81) =17.32, P<0.035], indicating that the effect of color validity differed depending on the location validity. So, although there was no effect of color validity when location cues were valid, there was a significant effect of color validity when location cues were invalid (P<0.05).

As described above, we summarized the main researches of the present thesis in brief, in fact, the purposes of the present study is to research the spatial attention of drivers in traffic environment, and to examine the influence of the environmental factor (including driving environment and in-vehicle environment) and visual function of drivers on the spatial attention shifting (in Chapters 3, 4 and 5). Some results are found for three categories research objects (young, low-vision and older subjects) (see Table 8-1). We found that the peripheral environmental illuminance has no influence to the reaction time of subjects, but low illuminance has greater influence on the reaction time. The results showed: 1) the environmental illuminance only is affixation factor to attention, the environmental illuminance could happen effect to the response of attention only when the environmental illuminance is evident low. This is a few lights that enter the eye resulting in response lag to targets in low illuminance condition;

Table 8-1 Compare of reaction times of three kinds of experimental subjects (ms)

	Valid	Invalid	Neutral	From far to near	From near to far
Young subjects	391	478	424	461	499
Low-vision subjects	407	483	427	469	518
Older subjects	608	649	619	679	757

2) the reaction time of older subjects is obvious long, this result showed that visual function, visual impairment and physical functioning (increased prevalence of systemic disease and physical frailty) of older subjects have greater influence on cognitive ability.

On the other hand, the responses to targets at cued locations are faster than those at uncued locations for the characteristics of attention; reaction time was affected by cue validity. This pattern of results suggested that there were attentional benefits when the valid cues were presented; in contrast, there were attentional costs when the invalid cues were presented, resulting in main effect of cue validity. The results demonstrated the prior information concerning the spatial location of a subsequent target facilitates the selection of that target for further visual processing, and is contest with the results of Posner (1980) and Posner et al. (1978). Because some drivers behaved an insufficiency of visual performance in driving, we utilized this characteristic of attention to conduct the experiment of changing forecast degree, the aim is to examine whether training of visual attention could ameliorate responses to targets in traffic environment. The result suggested that the characteristic of attention in depth switching received not only the visual adaptive ability but the influence of the cue. Judgment ability of subjects can be improved by training of visual attention. Concerning asymmetries characteristics of attention, the experimental results in Chapters 3, 4 and 5 showed that the reorientation of attention occurs more quickly when shifting from a far location to a near location than when shifting from a near location to a far location, it can be interpreted in terms of a steeper gradient beyond the focus of attention in depth, the processing of objects between the observer and fixation should be relatively easy, whereas the processing of objects beyond fixation may necessitate the redeployment of attention from the observer to fixation. Our experimental results are also consistent with the results of Downing & Pinker (1985), Gawryszewski et al. (1987) and Miura et al. (2002).

In addition, the purpose of the present research is also practical, and that is examining the influence of visual aids such as the screen display with automobile navigation system and speedometer in-vehicle environment in Chapter 6. It is almost self-evident that visual attention deteriorates during observation of a navigation display, because sight lines deviate from the forward environment. Furthermore, the rapid and efficient switching of attention between the forward environment and the inside display of a car is crucial for safety. The aim is to reveal the importance of effect of location and color during driving as well as whether visual attention of subjects is affected by cue duration. The experimental results can be generalized as the following:

1) The reaction time is affected by cue validity. This pattern of results suggested that there were attentional benefits when the valid cues were presented; in contrast, there were attentional costs when the invalid cues were presented, resulting in main effect of cue validity. In addition, reaction time was not affected by cue duration and no interaction between the cue validity and cue duration; subjects were on average only 5 ms faster responding to targets following 600 ms duration as opposed to 1000 ms duration (389 ms vs. 394 ms). One potential explanation of this result was that the visual detection tasks used in this experiment did not require the reallocation of attention since the targets were easily distinguishable, regardless of cue durations.

2) The results indicated that effects of location validity would be greater than effects of color validity. There was a main effect of location validity, but color validity effects were significant only when location cues were invalid. One interpretation of this result was that it is due to hierarchical processing of visual information. In other words, valid location cues are sufficient for fast accurate detection responses, so under these circumstances additional color information is redundant. Color information only becomes useful if location cues are invalid, when it facilitates detection of targets appearing at unexpected locations. Selection by location is not only faster, but also an essential and primary stage of visual attention. Another interpretation was that it is due to faster processing of location information, without arguing for the primacy of selection by location. According to this interpretation, color information is redundant when location cues are valid only because location cues are processed faster than color cues, which means that a response is made before color cues can be processed sufficiently to facilitate performance. In contrast, when location cues are invalid, attention must be shifted to a new location in order to locate the target, resulting in a delay before a response can be made. The extra processing time available because of this delay may be sufficient for subjects to use color cues to help locate the target.

In conclusion, concerning the experiment of location and color, we used three cue conditions in order to examine attentional processing of location and color cues during driving, and measured reaction time of attention shifting. Subjects were required to judge whether the stimulus appeared nearer than the fixed point or further in the cue duration and cue type (location vs. color cues). The results showed that the valid effects were smaller than the invalid effects, that is, reaction time was shorter in the valid than that in the invalid. These results provided support for the hypothesis in which detection task were facilitated when the position of the target was known, and these results were consistent with results from early experiments (Eriksen and Hoffman 1973; Jonides 1981; Posner 1980; Posner et al. 1978). In addition, according to the results, asymmetry of switching of attention in depth was found, that is, reaction time was longer from nearer space to further space than the reverse. These results suggested that attention resources may be distributed more densely in a near area relative to a fixed point, the results were consistent with results from other studies (Andersen, 1990; Andersen & Kramer, 1993; Miura, Shinohara & Kanda, 2002; Kimura & Miura, 2004). The results showed also that there was a main effect of location validity, but effects of color validity were significant only when location cues were the invalid. Concerning the effects of location and color validity on the detection task, the results supported the hypothesis that effects of location validity would be greater than effects of color validity, and two interpretations were made. We tend to support the second interpretation as a function of duration. At the shorter duration (600 ms) there was no evidence of color validity effects associated with either valid or invalid location cues, suggesting that there was insufficient time for subjects to use color cues. At the longer duration (1000 ms) there was a larger color validity effect when location cues were invalid, and a small color effect in association with valid location cues. Thus when duration is short, and location cues are valid, color cues are redundant in the sense that there is insufficient time to use them for target detection. In contrast, when duration is long, the target does not appear until sufficient time for some processing of color cues has elapsed.

We demonstrate the integration of location and color information in detection task using a precuing paradigm, supporting the notion that selection by location is faster and has a greater facilitatory effect than selection by color. The results of the present investigation provide the first direct evidence of color validity effects using a detection task.

8.2 Future outlook

Although the experiments above-mentioned are conducted, and exposed a few characteristic of depth attention about environment illuminance and colors of targets and attended duration in three-dimensional space, much attentional characteristics in the three-dimensional space keep unclear, for example, as described above, reaction time is affected by red color and green color of cue and stimuli, if colors of cue and stimulus are different (e.g., orange or blue, etc.), whether reaction time will change. In order to reveal more characteristics of focused attention in the three-dimensional space, future research is needed, in which the orientation feature information (vertical and horizontal separations) is varied between the cue and the target. In addition, if the attended duration of cue is decreasing, or increasing (e.g., 200 ms, 1800 ms or 2400 ms, etc.), whether reaction time will change. Visual perception will be examined according to the characteristic of ocular convergence and a person's the depth visual function for the future. Furthermore, it will be examined that a low-luminance environment such as nighttimes or foggy day produces an impact on the attention switching characteristic of drivers in the future. Moreover, it will be investigated about the influence of the background luminance of stimulus on the attentional characteristics of subjects, and it will be investigated to develop traffic safety education system during driving for the aged drivers. Older people are slower to respond when driving. The best estimate is that they are about 0.2-0.3 seconds slower than younger drivers. However, as tasks become more complex, the effect of aging may be bigger.

As result of this study, it is considered about the classification older drivers, because there is very wide capability and many differences of declines. The classification is as below: 1) Excellence Elderly Drivers: They are a countermeasure of safety drivers, but the most of elderly has disease. So it is required good quality safety education for them and they need to know the characteristics of own driving; 2) Average: It is only required countermeasures for excellence driver, but also to secure of sight, reduction of response time, large size of traffic signs and road lane width. It is need to built up good environment for driving; 3) The Other: It is classified decline or impairment persons. Especially, impairment (i.e. dementia or cognitive impairment) persons required medical step. But it is no measurement, and there is no systems how to decide driving giving up softly. These are the most important subject for elderly drivers in Japan.

References

[1] Traffic Accident Statistic Annals of the People's Republic of China. 2000-2007, Traffic Management Bureau of the Ministry of Public Security.

[2] Posner, M.I. (1994), Visual attention, in *The Neuro-psychology of High-level Vision: Collected Tutorial Essays*, edited by J.F. Martha and G. Ratcliff, pp. 217-239.

[3] Ballard, D. (1991),Animate vision, *Artificial Intelligence*, 48, pp. 57-86.

[4] Posner, M. I. (1980), Orienting of attention, *The Quarterly Journal of Experimental Psychology*, 32(1), pp. 3-25.

[5] Kosslyn, S.M. (1980), *Image and mind*, Harward Univ. Press, Cambridge, MA.

[6] Treisman, A. and Gelade, G. (1980), A feature integration theory of attention, *Cognitive Psychology*, 12, pp. 97-136.

[7] Tsotsos, J.K. et al (1995), Modeling visual attention via selective tuning, *Arti. Intell*, 78, pp.507-545.

[8] Treisman, A.and Paterson, R. (1984), Emergent features, attention and object perception, *J. Exp. Psychol: Human Perception and Performance*, 10, pp.12-31.

[9] Perry, R.J. and. Hodges, J.R. (1999), Attention and execution deficits in Aliheimer's disease: a critical review, *Brain*, 122, pp.383-404.

[10] Postma, E.O. et al, (1997), SCAN: a scalable model of attentional selection, *Neural Networks*, 10(6), pp. 993-1015.

[11] Phaf, R. H. et al, (1990), SLAM: a connectionist model for attention in visual selection, *Cognitive Psychology*, 22(3), pp. 273-341.

[12] Humphreys, G.W. and Miiller, H.J. (1993), Search via recursive rejection (SERR): a connectionist model of visual search, *Cognitive Psychology*, 25(1), pp. 43-110.

[13] Wolfe, J.M. (1994), Guided search 2.0: a revised model of visual search, *Psyonomic Bulletin and Review*, 1(2), pp. 202-238.

[14] Ahmad, S. (1992), VISIT: a neural model of covert visual attention, in *Advances in Neural Information Processing Systems*, edited by J.E. Moody, et.al., 4, pp. 420-427, San Mateo, CA: Morgan Kaufmann.

[15] Olshausen, B.A. et al, (1993), A neurobiological model of visual attention and invariant pattern recognition based on dynamic routing of information, *The J. of Neuroscience*, 13(1), pp. 4700-4719.

[16] Carpenter, G.A. et al, (1998), The what-and-where filter: a spatial mapping neural network for object recognition and image understanding, *Computer vision and Image Understanding*, 69(1), pp. 1-22.

[17] Aloimonos, Y.et.al., (1988), Action vision, *Int'l. J. Comp. Vision*, 7: pp. 333-356.

[18] Posner, M. I., Snyder, C. and Davidson, B. (1980), Attention and the detection of signals, *Journal of Experimental Psychology: General*, Vol.109, pp.160-187.

[19] Lavie, N., & Tsal, Y. (1994), Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics*, 56, pp. 183-197.

[20] Chun and Wolfe. (2001), Visual Attention In B. Goldstein (Ed). Blackwell Handbook of Perception, pp. 272-310.

[21] Yantis, S. (1998), Control of visual attention. In H Pashler (Ed), Attention Hove Psychology Press, pp. 233-256.

[22] Eriksen, B.A. and Eriksen C.W. (1974), *Effects of noise letters upon the identification of a target letter in a nonsearch task*. Perception and Psychophysics 16, pp. 143–149.

[23] Eriksen CW, Hoffman JE (1973), *The extent of processing of noise elements during selective encoding from visual displays*. Percept Psychophys 14, pp. 155–160.

[24] Humphreys GW (1981), *Flexibility of attention between stimulus dimensions*. Percept

Psychophys 30:291–302.

[25] Posner, M. I., Nissen, M. J. and Ogden, W. C. (1978), *Attended and unattended processing modes: The role of set for spatial location*. In Pick, H. L. and Saltzman, E. J. (Eds.) Modes of perceiving and processing information, pp. 171-187.

[26] LaBerge, D. (1983), Spatial extent of attention to letters and words. *Journal of Experimental Psychology*: Human Perception and Performance, 9, pp. 371-379.

[27] Eriksen and Yeh,(1985), *Allocation of attention in the visual field*. Journal of Experimental Psychology, Human Perception and Performance 11, pp. 583-597.

[28] Eriksen and Murphy, (1987), *Movement of attentional focus across the visual field: A critical look at the evidence*. Perception & Psychophysics, 42, pp. 299-305.

[29] Sperling, G. and Weichselgartner, E.(1995), *Episodic theory of the dynamics of spatial attention*. Psychological Review, 102, pp. 503-532.

[30] Miura, T. (1990). Active functions of eye movement and useful field of view in a realistic setting. In R. Groner, G. D'dewali, & P. Parham (Eds.), *From eye to mind* (pp.119–127). North Holland: Elsevier.

[31] Williams L J, (1982), Cognitive load and the functional field of view, *Human Factors* 24, pp. 683-692.

[32] Williams L J, (1985), Tunnel vision induced by a foveal load manipulation, *Human Factors* 27, pp.221-227.

[33] Williams L J, (1988), Tunnel vision or general interference? Cognitive load and attentional bias are both important, *American Journal of Psychology* 101, pp.171-191.

[34] Hammond KR. (2000), Judgments under Stress. Oxford University Press: New York.

[35] Janelle CM, Singer RN, Mark AM. (1999), External distraction and attentional narrowing: Visual search evidence, *Journal of Sport and Exercise Psychology* 21, pp. 70-91.

[36] Crundall D, Underwood G, Chapman P. (1999), Driving experience and the functional field of view. *Perception* 28, pp. 1075–1087.

[37] La Berge D, Brown V, (1989), Theory of attentional operations in shape identification, *Psychological Review* 96, pp. 101-124.

[38] Andersen, G. J. (1990), Focused attention in three- dimensional space. *Perception & Psychophysics* 47, pp. 112-120.

[39] Andersen, G. J. and Kramer, A. F. (1993), Limits of focused attention in three-dimensional space. *Perception & Psychophysics*, 53, pp. 658-667.

[40] Gawryszewski, L., Riggio, L., Rizzolatti, G. and Umiltá, C., (1987), Movements of Attention in the three dimensions and the meaning of "Neutral" cues. *Neuropsychologia*, 25, pp. 19-29.

[41] Miura, T., Shinohara, K. & Kanda, K. (2002), Shift of attention in depth in a semi-realistic setting, *Japanese Psychological Research*, vol.44, No.3, pp.124-133.

[42] T. Kimura, T. Miura, S. Doi and Y.Yamamoto, (2002), Top-down and bottom-up allocation of attention in three-dimensional space when observers are moving forward, *Technical Report on Attention an d Cognition*, No.16.

[43] Nakayama, K., & Silverman, G. (1986), Serial and parallel processing of visual feature conjunctions. *Nature*, 320, pp. 264-265.

[44] Crundall, D., Underwood, G. & Chapman, P. (2002), Attending to the Peripheral World While Driving, *Applied Cognitive Psychology*, 16, pp. 459-475.

[45] Andersen, G.J.and Ni, R. (2005), The spatial extent of attention during driving. *Proceedings of the third international driving symposium on human factors in driver assessment.* pp.403-408.

[46] Ochiai, N. & Sato, M. (2005), Effects of Surrounding Brightness on Visual Search for Safety Colors. *Color research and application*, 30(6), pp. 400-409.

[47] Downing, C. and Pinker, S. (1985), The spatial structure of visual attention. In: Posner, M. I. and Martin O. (Eds.): attention and performance, XI, Hillsdale, NJ: Erlbaum: pp.171-187.

[48] Ghirardelli and Folk (1996), Spatial cuing in a stereoscopic display: Evidence for a

"depth-blind" attentional spotlight. *Psychonomic Bulletin & Review*, 3 (1), pp. 81-86.

[49] Atchley, Kramer, Andersen and Theeuwes (1997), Spatial cuing in a stereoscopic display: attention remains "depth- aware" with age, *Psychonomic Bulletin & Review*, 4 (4), pp. 524–529.

[50] Miura. T., Shinohara K. and Kanda, K. (1994), Attentional shift in three-dimensional space for moving observers. *Perception*, vol.23: pp.43.

[51] Faubert, J. (2002), Visual perception and aging. *Canadian Journal of Experimental Psychology*, 56(3), pp. 164–176.

[52] Sekuler, R., & Sekuler, A. B. (2000), Age-related changes, optical factors, and neural processes. In A. E. Kazdin (Ed.). *Encyclopedia of Psychology*, Vol. 8, pp. 180–183.

[53] Spear, P. D. (1993), Neural bases of visual deficits during aging. *Vision Research*, 33(18), pp. 2589–2609.

[54] Hua, T., Li, X., He, L., Zhou, Y., Wang, Y., & Leventhal, A. G. (2006). Functional degradation of visual cortical cells in old cats. *Neurobiology Aging*, 27(1), pp. 155–162.

[55] Nguyen-Tri, D., Overbury, O., & Faubert, J. (2003), The role of lenticular senescence in age-related color vision changes. *Investigative Ophthalmology and Vision Science*, 44(8), pp. 3698–3704.

[56] Shahidi, M., & Yang (2004), Measurements of ocular aberrations and light scatter in healthy subjects. *Optometry and Vision Science*, 81(11), pp. 853–857.

[57] Weale, R. A. (1992), The senescence of human vision. Oxford: Oxford University Press, p. 272.

[58] Winn, B., Whitaker, D., Elliott, D. B., & Phillips, N. J. (1994), Factors affecting light-adapted pupil size in normal human subjects. Investigative *Ophthalmology Visual Science*, 35(3), pp. 1132–1137.

[59] Ball, K., & Sekuler, R. (1986). Improving visual perception in older observers. Journal of Gerontology, 41(2), 176–182.

[60] Bennett, P. J., Sekuler, A. B., & Ozin, L. (1999). Effects of aging on calculation efficiency and equivalent noise. Journal of the Optical Society of America A Optical Image Science Visual, 16(3), 654–668.

[61] Herbert, A. M., Overbury, O., Singh, J., & Faubert, J. (2002). Aging and bilateral symmetry detection. Journal of Gerontology Series B: Psychological Science and Social Sciences, 57(3), P241–P245.

[62] Sekuler, A. B., Bennett, P. J., & Mamelak, M. (2000). Effects of aging on the useful field of view. Experimental Aging Research, 26(2), 103–120.

[63] Sekuler, R., & Ball, K. (1986). Visual localization: Age and practice. Journal of the Optical Society of America A, 3(6), 864–867.

[64] Bennett, P. J., Sekuler, R., & Sekuler, A. B. (2007). The effects of aging on motion detection and direction identification. Vision Research.

[65] Habak, C., & Faubert, J. (2000). Larger effect of aging on the perception of higher-order stimuli. Vision Research, 40(8), 943–950.

[66] Yu, S., Wang, Y., Li, X., Zhou, Y., & Leventhal, A. G. (2006). Functional degradation of extrastriate visual cortex in senescent rhesus monkeys. Neuroscience, 140(3), 1023–1029.

[67] Duncan J (1981), Directing attention in the visual field. *Percept Psychophys* 30: pp. 90–93

[68] Humphreys GW (1981), Flexibility of attention between stimulus dimensions. *Percept Psychophys* 30: pp. 291–302

[69] Johnston JC, Pashler H (1990), Close binding of identity and location in visual feature perception. *J Exp Psychol Hum Percept Perform* 16: pp. 843–856

[70] Schneider WX (1995), VAM: a neuro-cognitive model for visual attention control of segmentation, object recognition, and space-based motor action. Vis Cogn 2:331–375

[71] Tsal Y, Lavie N (1988), Attending to colour and shape: the special role of location in selective visual processing. *Percept Psychophys* 44:pp. 15–21.

[72] Tsal Y, Lavie N (1993), Location dominance in attending to colour and shape. J Exp

Psychol Hum Percept Perform 19: pp.131–139.
[73] Bundesen C (1990), A theory of visual attention. *Psychol Rev* 97: pp. 523–547.
[74] Laarni J (1999) Control of attention in the visual field: effects of cue type and target-distractor confusability. *Acta Psychol* 103: pp. 281–294.
[75] Laarni J, Koski M, Nyman G (1996), Efficiency of selective attention: selection by colour and location compared. *Perception* 25:pp. 1401–1418.
[76] Tanaka Y, Shimojo S (1996), Location vs feature: reaction time reveals dissociation between two visual functions. *Vis Res* 36: pp. 2125–2140.
[77] Pisella L, Arzi M, Rossetti Y (1998), The timing of colour and location processing in the motor context. *Exp Brain Res* 121: pp. 270–276.
[78] Anllo-Vento L, Hillyard SA (1996), Selective attention to the colour and direction of moving stimuli: electrophysiological correlates of hierarchical feature selection. *Percept Psychophys* 58: pp. 191–206.
[79] Eimer M (1995), Event-related potential correlates of transient attention shifts to colour and location. *Biol Psychol* 41:pp.167–182.
[80] Hillyard SA, Münte TF (1984), Selective attention to colour and locational cues: an analysis with event-related brain potentials. *Percept Psychophys* 36:pp. 185–198.
[81] Luck SJ, Fan S, Hillyard SA (1993), Attention-related modulation of sensory-evoked brain activity in a visual search task. *J Cogn Neurosci* 5: pp. 188–195.
[82] Brouwer RFT, Heijden AHC van der (1996), Identity and position: dependence originates from independence. Acta Psychol 95:pp. 215–237.
[83] Laarni J, Häkkinen J (1994), Temporal properties of colour and shape priming: evidence of multiple components of attention. *Perception* 23:pp. 1395–1408.
[84] Isenberg L, Nissen MJ, Marchuk LC (1990) Attentional processing and the independence of colour and orientation. *J Exp Psychol Hum Percept Perform* 16: pp. 869–878.
[85] Nissen MJ (1985) Accessing features and objects: is location special? In: Posner MI, Marin OSM (eds) Attention and performance XI. Erlbaum, New Jersey, pp 205–219.
[86] Treisman A (1988) Features and objects. QJ Exp Psychol 40A:pp. 201–237.
[87] Treisman A, Sato S (1990) Conjunction search revisited. J Exp Psychol Hum Percept Perform 16:459–478.
[88] Cave KR, Pashler H (1995) Visual selection mediated by location: selecting successive visual objects. Percept Psychophys 57:pp. 421–432.
[90] Goodale MA, Milner DA (1992), Separate visual pathways for perception and action. *Trends Neurosci* 15: pp.20–25.
[91] Ungerleider LG, Mishkin M (1982), Two cortical visual systems. In: Ingle DJ, Goodale MA, Mansfield RJW (eds) *Analysis of visual behaviour*. MIT Press, Cambridge, MA, pp.263–299.
[92] Maunsell JHR, Nealey TA, DePriest D (1990), Magnocellular and parvocellular contributions to responses in the middle temporal visual area (MT) of the Macaque monkey. J Neurosci 10: pp.3323–3334.
[93] Nowak LG, Bullier J (1997), The timing of information transfer in the visual system. *Cereb Cortex* 12: pp.205–241.
[94] Rossetti Y (1998), Implicit short-lived motor representation of space in brain-damaged and healthy subjects. *Conscious Cogn* 7: pp.520–558.
[95] Heijden AHC van der, Kurvink AG, Lange L de, Leeuw F de, Geest JN van der (1996) Attending to colour with proper fixation. Percept Psychophys 58:pp.1224–1237.
[96] Lambert AJ, Corban R (1992) Spatial attention and expectancy for colour, category and location: further evidence against the spotlight model. Acta Psychol 81:pp.39–51.

Publications List

Journal Papers

[1] **Ruting Xia**, Masato Fukushima, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *Influence of Peripheral Environment Luminance and Visual Performanceon Shifts of Depth Attention in Three-dimensional Space*, Journal of Mechanical Systems for Transportation and Logistics, Vol.1, No.1, pp.55- 64, 2008.

[2] **Ruting Xia**, Masato Fukushima, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *Attentional processing of location and color cues during driving*, Scandinavian Journal of Psychology, accepted, 2008.

International Conference Papers

[3] **Ruting Xia**, Masato Fukushima, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *The Study of Characteristic of Attention in Depth of Drivers in Supposed Traffic Environment*, Proceedings of the IEEE/ICME International Conference on Complex Medical Engineering, pp.1413-1418, 2007.

[4] **Ruting Xia**, Masato Fukushima, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *Characteristic of Depth Attention when Observer is in Dark Field under Supposed Traffic Environment*, Proceedings of the SICE International Conference on Instrumentation, Control and Information Technology, pp.1144-1149, 2007.

[5] **Ruting Xia**, Masato Fukushima, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *Effect of the color configurations of cue and stimuli on depth visual attention of drivers*, Proceedings of SCME The Second International Symposium on Complex Medical Engineering, pp.75-78, 2008.

[6] **Ruting Xia**, Yifan Zeng. *Effect of Machining Processes on Surface Quality and Precision of Three Acclivitous Holes*, Proceedings of IEEE/ICMA International Conference on Mechatronics and Automation, WA3-4, 2008.

Others

[7] Masato Fukushima, **Ruting Xia**, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *The effect of display color on the depth attention characteristic of drivers* (in Japanese), Proceedings of the JSME 16th Thansportation and Logistics Conference, pp.271-274, 2007.

[8] **Ruting Xia**, Masato Fukushima, Shun'ichi Doi, Takahiko Kimura and Toshiaki Miura. *Analysis of depth attention shifting characteristic of young, low vision and elderly subjects in three-dimensional space under tentative driving scene* (in Japanese), Proceedings of Japan Ergonomics Society, Chugoku and Shikoku Branch Conference, pp.38-39, 2007.