Eye-movement Measures between Young Novice and Experienced Drivers when Conducting Subtasks

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The present study aimed to identify the specific eye movement difference between novice and experienced drivers when conducting subtasks. As well as when subtasks changes, how the eye movement changes with different level of subtask. Participants were 33 drivers from the age 18 to 60, with valid driver's license. Based on a simulator and an eye tracker, eye movement measures including fixation, blink, saccade and pupil size were being gathered and analyzed. Experienced group and novice group were being divided by the time they get their driving license; the time is less than 6 months belongs to novice group. N-back experiment were being used as subtask, from no subtask to 2-back experiment, there are four types of difficulty level.

Results show first, there are significance difference between novice and experienced drivers in fixation measures, to be specific, both two types of drivers shown a centralization phenomenon with subtask difficulty increase, the novice drivers were severely centralized compared to experienced drivers. Second, there are significance difference between novice and experienced on blink total time, pupil size and saccade speed. The blink time of novice drivers is longer than experienced ones; pupil size is larger than experienced group, and saccade peak speed is faster than experienced group. The difference in one specific group among each experiment were also been analyzed. These distinctions were critical for understanding the distinction of novice drivers to experienced drivers, there are two ways to apply these findings, one is for planning educations for novice drivers to make up the inferiority due to lack of experience, one is for improvement of distraction detection device to help more types of drives.

Key Words : *young novice driver, n-back subtask, eye movement measures, car simulator, eye tracker*

1. INTRODUCTION

It has been well established by studies and accident database from various countries that young novice drivers are more frequently involved in traffic accidents than experienced drivers[1)-4)]. Crash rate of drivers ages 18-19 was nearly 2.25 times that of drivers ages 30-39,40-49 and 50-59 groups[5)]. Newly licensed drivers are about eight times more likely to be involved in fatal crashes during their first six months than experienced drivers. Even after more than six months licensed to drive alone, teens are two to three times more likely to be in fatal crash than the most experienced drivers[6)]. Tefft[7)] found that drivers in young age and early driving period experienced a higher percentage of traffic accident involvement by analysis the police-reported data about drivers between 1995-1996, 2001-2002 and 2008-2009. Meanwhile, there is a severely problem also result in significant morbidity and mortality, which is driving as well as conducting subtasks, especially cellphone related subtasks [8),9)]. In USA, there are 3,166 people died because of distracted driving in 2017 alone[10)], and in Japan, according to the government, the number of traffic accidents related cellphones usage during 2018 was 2,790, increased approximately 1.4 times in past five years, in comparison, the fatal accident data of using cellphone was about 2.1 times of that not using cellphone. Law restrictions on forbidden using cellphone have been implied in many countries but the results are far more from satisfied. A report from the center of disease control and prevention showed 69% of respondents used a mobile phone and 31% of respondents dealt with text messages or emails while driving at least once in the past 30 days in the united states[11)], and in a research did in

japan, about 36.5% of drivers admitted they using cellphone while driving[12].

Given the situation that novice drivers as well as experienced drivers both are using cellphone while driving, then whether there is different effect on them when conducting same subtasks is necessary to be researched.

The objectives of this study are two, one is figure out the difference between novice drivers and experienced drivers when they are conducting subtasks, another is about the eye movement feature when conducting difficulty level of subtasks changes.

The rest of study is organized as follows, chapter 2 reviews the related literature and states the innovation point of this research. Chapter 3 demonstrates the methodologies and data collection. Chapter 4 performed the experiment results, finally chapter 5 provide discussion and conclusions.

2. LITERATURE REVIEW

(1) The comparison of young novice drivers and experienced drivers

Comparison of young novice drivers and experienced drivers has been widely studied by many scientists. Some of them[13)-15)] used the simulator method to compare novice drivers and experienced drivers, found there are significance differences in horizontal spread of search, mean fixation duration, number of fixations between these two types of drivers. Others[16)-17)] using video clips method, Jiang et al.[18)] and Lehtonen et al. [19)] using on-road experiment also got similar results. There are limitations on each kinds of research methods, on-road experiment is difficult to reduce external influences and may affect the drivers' eye movement; video clips cannot afford an immersive environment; simulator methods have the similar disadvantage with video clips if the equipment is not advanced enough, but with the highly development technology, simulator is the best research method to get the data of eye movement measure.

(2) Effect of subtasks on eye movement measures

Previous researchers have studied the eye movement measures of drives when conducting auditory and visual tasks. In the research did by Recarte et al. [20)]and Trent W. et al. [21)] found the eye movement change with in-vehicle task difficulty, results shown subtasks cause drivers to increase their road viewing time and spatially concentrate their gaze at the road center area at the expense of peripheral glances, but the impact on other indicators such as blink and saccade is still not clear and the task may cause different workload which effect the validity of experiment.

(3) The novelty of this study

To summary, existing literature offers incomplete information on the problem: what the specific difference between novice drivers and experienced drivers when they are facing same subtask while driving, and for one type of drivers, what will their eye movement change to adapt to distracting tasks of different difficulty. At the same time, it is very important to ensure that distraction tasks cause the same degree of distraction for all participants. This study attempt to fill in these gaps. The eye movement measures between the two groups of subjects were systematically compared, and among in one type, the subjects were also compared in the same way. The n-back experiment was adopted as a subtask to ensure that the degree of distraction caused to all people was no indiscriminate and comparable.

3. METHODS

(1) Participant drivers' infromtaion

A total of 33 drivers participated in the experiment, due to the data gather problem and virtual reality sickness, 20 drivers' data was being analyzed, among them, experienced drivers were 12 and novice drivers were 8, the average age of experienced drivers is 38.25, standard is 13.10, novice drivers is

Table 1 Drivers' information

Item	Contains	Experienced Driver	Novice Driver
Gender	Male	10	5
	Female	2	3
Age	Below 30	3	8
	31 Above	9	0
Accident involvement	None	9	7
	Have	3	1
Driving frequency	Everyday	9	2
	Not Everyday	3	6

23.63,standard is 3.11, the basic information of participants are shown in **Table 1**. Novice drivers were drive less than 6 months, and age below 30. Experienced drivers drive more than one year. Participants have a valid driver license and in good health condition, they are gathered through Wechat advertisements in Urumqi, and received financial compensation after experiment.

(2) Experiment setup

The drivers were being required to driving in a simple three-lane road, when vehicle traveled to a certain position(position1), triggered a subtask, drivers complete the driving and subtasks, after finish, the driving keep go on, after reaching to a designated position(position2), one set of experiment is finished. The road is simple without any other kinds of road users such as cars, pedestrians. One set of subtasks last for about 55 seconds, and in order to ensure the accuracy of the data, reduce the impact of cellphone connecting time, select a period of 35 s as analysis data. The schematic diagram is shown in **Fig.1**.

(3) Subtasks setup

N-back working memory tasks were being used as the subtask in this experiment, during the driving, they need to answer a call, in 0-back experiment which is the most easily one, the participants are being asked to answer a call while driving, and they will hear a series of randomly ordered auditory stimuli which is single digits from 0 to 9, and they react by repeat the number they heard immediately. In 1-back experiment, the number they heard is single digits from 0 to 9 but they need to take in and hold in memory each new number as it was presented and respond verbally with the number 1 position back in the presentation sequence. In 2-back experiment, they need to remember the number as well as repeated the number 2 position back in the presentation sequence. The difficulty increased from 0-back to 2-back experiment, the procedure is shown in **Table 2**. After understood the subtask, all participants were asked to practice, only after a certain accuracy rate is reached can the experiment process begin.

Table 2 N-back experiment

Item		Reaction	Stimulus					
Call	0-back	Heard	1	6	5	7	9	…
		Repeat	1	6	5	7	9	…
	1-back	Heard	1	6	5	7	9	…
		Repeat	-	1	6	5	7	…
	2-back	Heard	1	6	5	7	9	…
		Repeat	-	-	1	6	5	…

(4) Driving simulator and eye tracker

The study was performed on a high-fidelity driving simulator. The simulator is QJ-4B1 with a six degrees of freedom motion, which manufactured by the OKTAL Company. A 180°front view of a display system is used to project the simulated environment, which located approximately 2 meters in front of the drivers. The driving simulator is shown in **Pic. 1**. The simulator equipment offered a three-lanes driving environment without other cars or pedestrians.

A hat type eye tracker illustrated in **Pic. 2**, was also used to gather eye movement data. The unit is capable of sampling the position of the eye at 50Hz, the

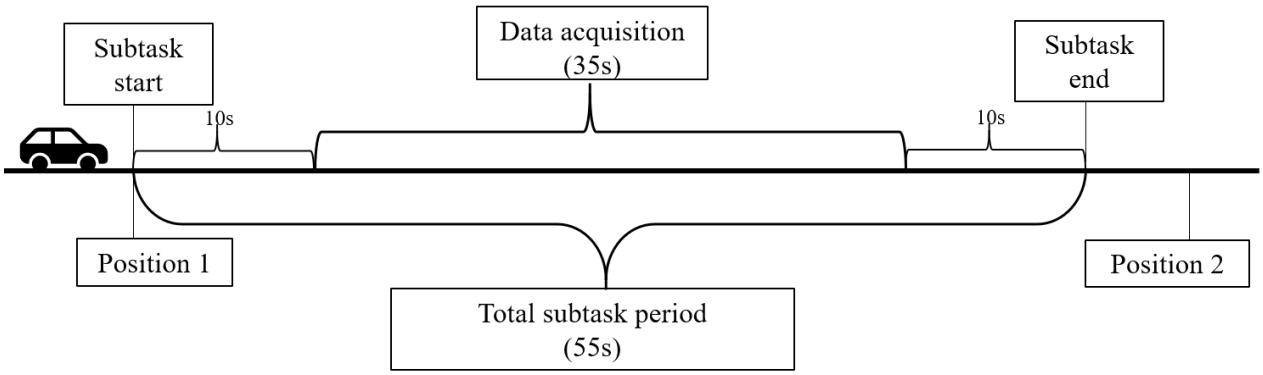

Fig.1 Experiment setup

Pic.1 Driving simulator

Pic.2 Eye-tracker

collected data are being analyzed on BaGaze software, which built-in saccade, fixation and blink detector.

(5) Subtask related device

To reduce the difference caused by unfamiliar equipment, all the distracting devices used by the subjects were their own mobile phones. To avoid other distractions, all mobile phones have shut the network function, only functions such as making calls and sending and receiving text messages can be used. and before experiment, all participants understood the procedure clearly.

(6) Eye movement measures

Eye movement measures were being analyzed including fixation, blink and saccade. (1)Fixation describes the transition of the eyes to a given area; in this experiment, the min duration is 80ms, the fixation range is horizontal from 0 to 752, vertical from 0 to 480. Due to the aging of the acquisition equipment, the fixation data that longer than 2s was removed. (2)Blink is a semi-autonomic rapid closing of the eyelid, the case where the pupil diameter is less than 1pixel, or the horizontal and vertical gaze position equals 0 is being taken as blink. Blink case and duration were being collected. (3)A saccade is defined as a rapid change in gaze location, the data collected by BeGaze software including saccade duration, start/end position, amplitude, acceleration average, acceleration peak, deceleration peak, and saccade case. (4) pupil diameter enlarges proportionally with the mental load increase. Eye tracker collected the size of pupil when gazing, the data were divided into two sizes in horizontal and vertical directions. For the sake of simple calculation, the pupil size takes the average of the two direction when analyzing.

4. RESULTS

(1) Fixation

Fixation data including fixation case, each fixation lasting time and area where the fixation located. In order to understand the gaze distribution, divided the gaze area into 6 parts, the division is shown in **Fig.2**. Making a comparison of the fixation time distribution on each section between novice and experienced groups, control experiment is shown in **Fig.3**. 0-back experiment is shown in **Fig.4**; 1-back experiment is shown in **Fig.5**; 2-back experiment is shown in **Fig.6**. Both experience and novice drivers shared a similar graphic trend which is gaze at the central area most comparing to surrounding area; specifically, in control, 1-back and 2-back experiment, experienced drivers' fixation time in each area is longer than novice drivers, especially the time gazed at section 4 and section5, in n=1 experiment, novice drivers spend more time than experienced group in section3, but other sections, the experienced group spend more time.

<table>
<tr><th>X / Y</th><th>0-150</th><th>150-300</th><th>300-450</th><th>450-600</th><th>600-752</th></tr>
<tr><td>0-80</td><td rowspan="6">1</td><td colspan="2" rowspan="2">2</td><td rowspan="6">5</td><td rowspan="6">6</td></tr>
<tr><td>80-160</td></tr>
<tr><td>160-240</td><td colspan="2" rowspan="2">3</td></tr>
<tr><td>240-320</td></tr>
<tr><td>320-400</td><td colspan="2" rowspan="2">4</td></tr>
<tr><td>400-480</td></tr>
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Fig.2 Fixation area distribution

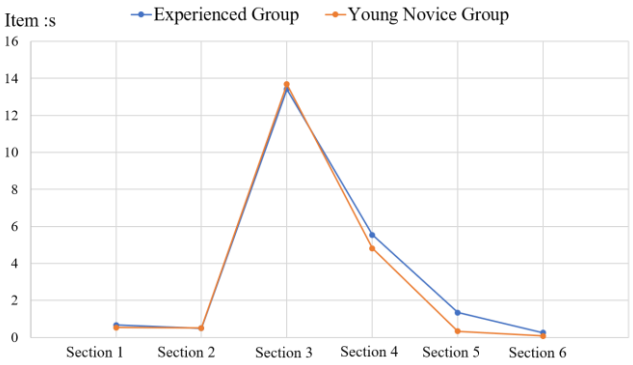


Fig.3 Fixation time distribution of control experiment

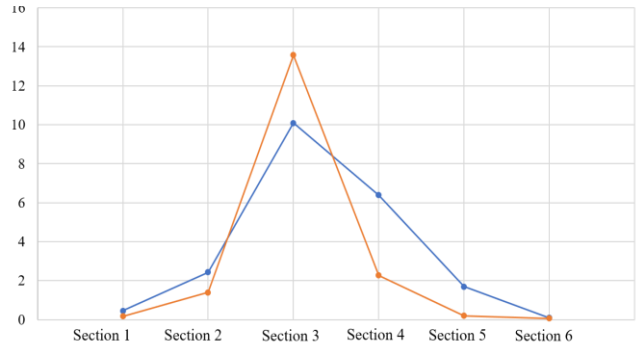


Fig.4 Fixation time distribution of 0-back experiment

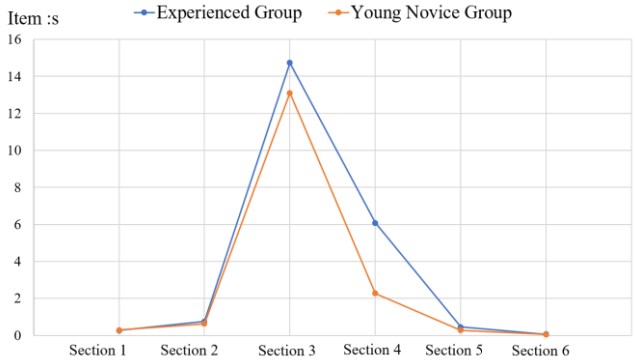


Fig.5 Fixation time distribution of 1-back experiment

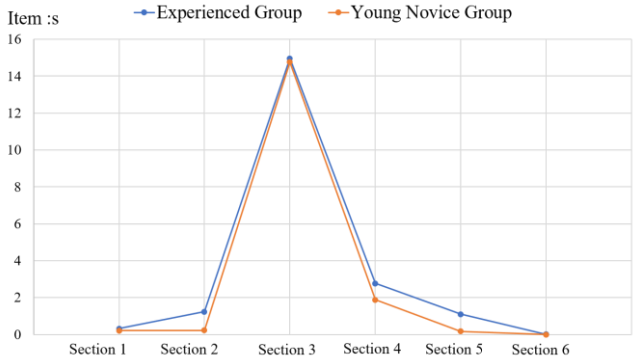
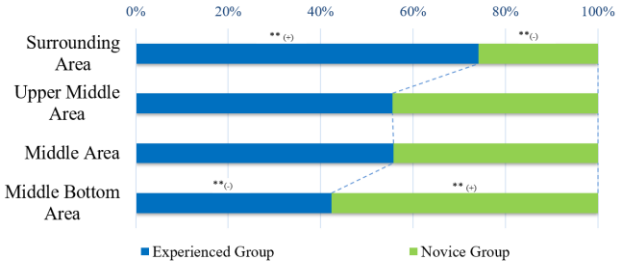


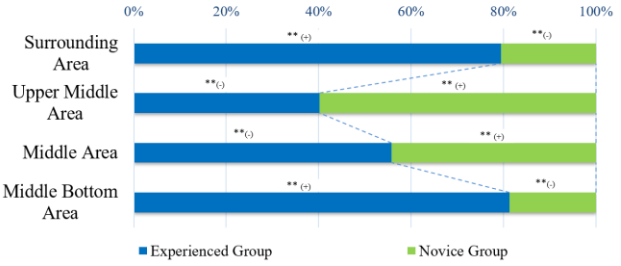
Fig.6 Fixation time distribution of 2-back experiment

Since the most of gaze happens in area 3 and 4, and section 1.5.6 are surrounding areas comparing to section 2,3,4. To understand more clearly of the gaze feature, combine the section 1,5.6 into one area name it as surrounding area, section 2 as upper middle area,



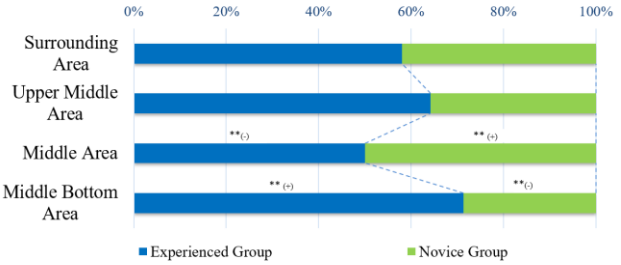
P value：0.0000　significance at 1%
Residual analysis of crosstab:　**1%　*5%
(+) High proportion　(-) Low proportion

Fig.7 Fixation case of control experiment



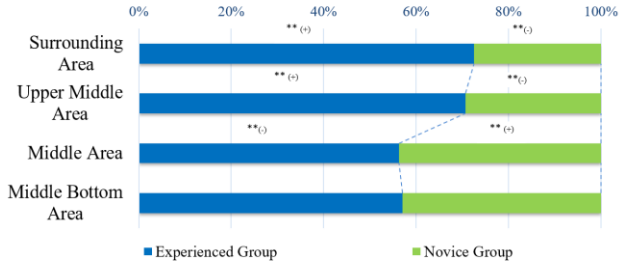
P value：0.0000　significance at 1%
Residual analysis of crosstab:　**1%　*5%
(+) High proportion　(-) Low proportion

Fig.8 Fixation case of 0-back experiment



P value：0.0000　significance at 1%
Residual analysis of crosstab:　**1%　*5%
(+) High proportion　(-) Low proportion

Fig.9 Fixation case of 1-back experiment



P value：0.0000　significance at 1%
Residual analysis of crosstab:　**1%　*5%
(+) High proportion　(-) Low proportion

Fig.10 Fixation case of 2-back experiment

section 3 is middle and section 4 is middle bottom area. Using chi-square test to compare the difference between novice group and experienced groups between same subtasks. In control experiment, shown in **Fig.7**, experienced group gazed at surrounding area more often than novice group. Novice group hold a larger percentage in middle bottom area than experienced group (p=0.0000, x2=39.6494). In 0-back experiment, shown in **Fig.8**, experienced group shared larger percentage in surrounding area and middle bottom area, less in upper middle area and middle area than novice group (p=0.0000, x2=102.3281). In 1-back experiment, shown in **Fig.9**, the experienced group gazed at middle bottom more than novice group and less in middle than novice group (p=0.0000, x2=34.1620). In 2-back experiment, shown in **Fig.10**, the gaze located in surrounding area of experienced group is more than novice group, and so as the upper middle are, but middle area gaze case is less than novice drivers (p=0.0000, x2=24.6293).

(2) Blink

Blink case and blink duration were also been gathered, among each experiment, there is a significance difference between novice and experienced group, both the novice group and experienced group blinked longer when conducted subtasks, with the difficulty increase, the blink duration get longer and longer.

In experienced group, as the Kraskar-Wallis test shown, there are significance difference between control experiment and 1-back experiment(p<0.001); control experiment and 2-back experiment(p<0.001), 0-back experiment and 1-back experiment(p<0.001), 0-back and 2-back experiment(p<0.001).

In novice group, there are significance difference between control experiment and 0-back experiment(p=0.0095); control experiment and 1-back experiment(p=0.0014); control experiment and 2-back experiment(p<0.001).

Make a comparison between novice group and experienced group in same experiment, there is also a significance difference, the result is shown in **Fig.11**. the blink duration of novice group is longer than experienced in all experiments, and shown a significance difference in 0-back, 1-back and 2-back experiment.

(3) Saccade

Saccade peak speed was been recorded, result shown in **Fig.12**. among each experiment, there is a significance difference between novice and experienced group, the peak speed of young novice group is larger than experienced drivers in every experiment(p<0.001). In experienced group, the speed of control experiment is the fastest, there is significance difference between control experiment and 0-back experiment; control experiment and 1-back experiment; 0-back experiment and 2-back experiment.

(4) Pupil

As shown in **Fig.13**, there is a significance difference between novice and experienced group, in each experiment, the pupil size of novice drivers is larger than experienced drivers. in experienced group, there is a significance difference between control and 1-back experiment(p<0.001);control and 2-back experiment(p<0.001); 0-back and 1-back experiment(p<0.001); 0-back and 2-back experiment(p=0.0016). There is no significance difference of novice group in each experiment.

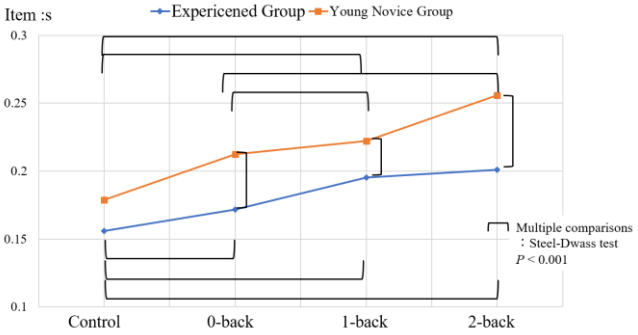


Fig.11 Blink duration of each experiment

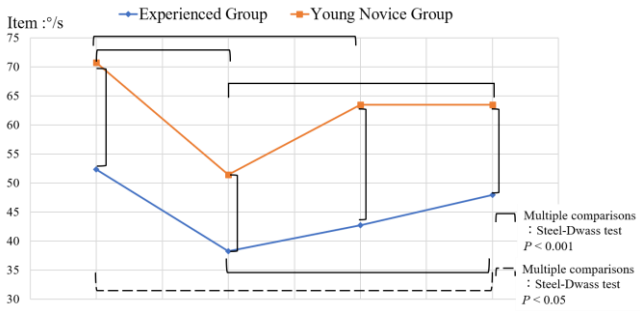


Fig.12 Saccade peak speed of each experiment

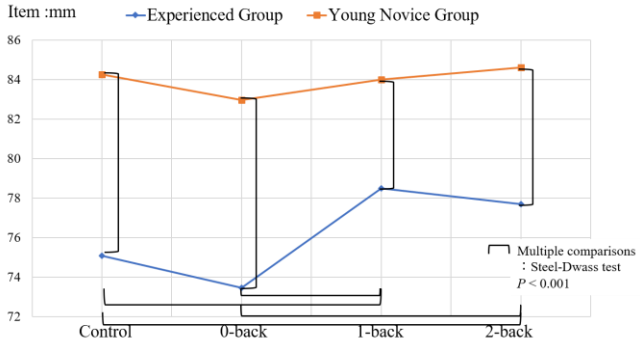


Fig.13 pupil size of each experiment

5. DISCUSSION AND CONCLUSIONS

In this study, the eye movement measures of young novice and experienced drivers were being analyzed when conducting n-back experiment. The difference among each level of subtasks were also being compared. It is found that eye movement measures and difficulty of subtask is relevant when trying to differentiate between drivers with different levels of experience. Results are conclude in below.

- Fixation: all drivers in both group (experienced/ novice) gazed at the middle area the most. Second, when the difficulty of subtask increase, the centralization of novice drivers is much severely than experienced drivers. The fixation distribution on each area were also been quantified. Many reseasrches using the amount of time drivers gaze at the percent road center to gauge distraction degree[22], the data of this reseach offers more possibility to test the novice and experienced drivers' driving mood, help them to keep safe driving.
- Blink: blink duration of two groups are getting longer with n-back experiment involvement, the time of young novice is longer than experience group. Mayhew et al[23]'s result shown that blink duration is related to cognitive distraction degree, blink duration is positively correlated with distraction degree. The result confirmed that when conducting same subtasks, the effect on cognitive is different, the effect to young novice drivers is larger than experienced drivers. since blink has no benefit for information gathering, more blink time cause a decrease of gaze and glance behavior, which result in more exploure to danger.
- Saccade: saccade peak speed is being studied, former research has shown the saccade peak speed is a significant index to detect the fatigue degree[24], the result of this study shown the Provides the possibility to monitor distractions in the future.
- Pupil: pupil size of young novice group are larger than experienced group, Demberg et al. [25]'s results shown, pupil size and distraction degree are related, with distraction degree increase, the pupil size will getting larger. Similar result with blink duration time, the distraction degree of young novice drivers are more severely than expericend drivers. both types of drvers have a smaller pupil size in 0-back experiment, the possibilitiy of this phenomenon could be 0-back experiment is quite easy for drivers, and conducting this subtask release the drivers' tension instead of make them more nervous, from this perceptive, subtasks are not always make damage on drivers.

This study provides that comparing to expericend drivers, the young novice drivers are have a narrower visual area, longer blink duration, faster saccade peak speed and larger pupil size. These are consistent with previous but more systematic, quantifiable and reliable. In addition to providing more accurate information on educating novice drivers, it is hoped that these results can be used in the development of distraction monitoring devices and autonomous driving systems, just like Catalbas et al. [26]'s and Stasi et al. [27]'s research.

The present study has some methodological limitations should be taken into account. First, the samples of the study were small. Second, the data gathered by eye tracker is not include the head angle when driving, this disadvantage is hoping to be compliszed by the simple driving environment, which all drivers do not need to change lanes or turn around, the rotation of head is negligible. Third, not all the eye movement measures are being analysize, such as saccade average speed and average acceleration. In future, our study will increase the sample size, set up more precise experiment processes, and provide a more comprehensive analysis of eye movement indictors.

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