■ORIGINAL ARTICLE

Development of a Video-Based Hazard Detection Task: Preliminary Study in Younger Drivers

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Abstract: We are developing tasks on a laptop computer to enable cheaper and easier driving assessments at medical institutions. The aim of this preliminary study is to characterize the performance of young drivers in the developed tasks. The participants were 42 young licensed drivers who performed a video-based hazard detection task and a visual searching task (Trail Making Test). In the hazard detection task, they were instructed to touch the hazardous events on the computer screen that was likely to become involved in a traffic conflict during a driving video. Results showed that the video included 11 hazards and young drivers detected hazardous events during a particular period of time. For the visual searching tasks, our computer-based TMT had proper cognitive load, which was not found in existing paper-based TMT. Further investigations recruiting subjects from other age groups should be necessary to validate our driving assessment programs.

Keywords: driving, assessment, hazard detection, young drivers

Introduction

Automobiles are an essential means of transportation for modern daily living [1]. Difficulty with driving automobiles due to a disability is known to significantly reduce quality of life [2−4]. In Japan, the Road Traffic Law was revised in 2002 to stipulate that many medical conditions constituted relative grounds for disqualification. In light of this change, occupational therapists now have more opportunity, and greater responsibility, to perform driving assessments for patients with stroke and brain injury. Typically, the determination of fitness to drive after a brain damage is made by a public safety

commission based on an off-road evaluation performed at a medical institution and an on-road evaluation carried out at a driving school. As public safety commissions defer to the judgments of medical institutions, specifically doctors' diagnoses, these medical institutions must provide appropriate evaluations and assistance. In particular, although adaptive driving devices can be used to compensate for a decline in driving ability due to motor disability, it is not easy to compensate similarly for cognitive disability, and an appropriate assessment of this type of disability is therefore required [5].

The off-road evaluations currently carried out in medical institutions mainly consist of neuropsychological tests performed by occupational therapists. The tests most often used for driving assessments include visual searching tasks [6−8], reaction time tasks [9−11], visuospatial recognition tasks [12−14], the useful field of view test [15−16], and the Stroke Drivers Screening Assessment (SDSA) [17−20]; however, as these are static tests, they are all far removed from the actual experience of driving. We believe that dynamic tasks using moving

images are more appropriate for driving assessments. In fact, assessments using driving simulators have been shown to be highly valid as driving assessments [21−23], but these are too expensive and require too large an installation site to be of practical use.

We have, therefore, used actual driving footage to develop a hazard detection task on a laptop computer. We also developed a visual searching task capable of assessing visual searching ability, which is regarded as the most important element in driving [24]. The objective of the present study was to evaluate the characteristics of young holders of driver's licenses in the performance of these two tasks.

Methods

Participants

The participants were 42 young driver's license holders (15 male and 27 female; mean age 21.7 ± 2.4 years, range 19−33 years). None had any history of neurological disease, ophthalmic problems, or other issues that might affect their participation in the study. Nine participants had obtained their driver's license within the previous year, 14 within the previous 1−2 years, 9 within the previous 2−3 years, 6 within the previous 3−4 years, and 4 at least 4 years previously. In terms of driving frequency, 2 participants drove every day, 3 drove once every 2−3 days, 5 drove once a week, 21 drove several times a year, and 11 reported driving almost never. One participant each had either experienced accidents involving skidding on a snowy road, or reversing into an object while parking, or colliding with an object due to not paying attention to what was in front of them. Both verbal and written informed consent were obtained from all the participants. This study was approved by the Ethics Committee of Shinshu University's Faculty of Medicine (approval no. 2081).

Hazard detection task

We used a dashboard camera (Venture Craft, Paparazzi) to record actual video footage of driving and extracted and edited segments from this recorded footage in which hazard prediction was used to produce a driving scenario. The maximum speed during the recording of this driving footage was approximately 40 km/h. MovieWriter2010 Pro (CORE) was used to edit the videos. The completed driving scenario comprised an eight-scene (four in the city center and four in residential areas) video lasting approximately two minutes. Each of the scenes was between 15 s and 40 s long. The four city-center segments included scenes that required drivers to watch carefully for oncoming vehicles, buses stopping to allow passengers to alight and board, pedes-

trians walking along the sidewalk and crossing the road, and oncoming traffic when either entering or turning right at an intersection, turning right at the intersection. The four residential area video segments included scenes requiring drivers to watch out for pedestrians and cyclists unexpectedly entering their path as they drove along narrow streets, and entered the main road. Both the city-center and residential scenes required drivers to drive forward, negotiate curves, stop, and to proceed slowly.

The participants had to identify scenes of predicted risk during the two-minute driving scenario. They were instructed to touch the touch panel on a laptop computer (Let's Note CF-C1B, Panasonic, 12.1-inch) every time they identified such a scene (Fig. 1). Every time they touched the panel, the video stopped, and the onscreen still image was captured. At this point, the authors asked the participants about the identified elements and recorded them on an assessment monitor (Plus One, LCD-10000U, Century, 10-inch). Touching the panel again restarted the driving scenario. The participant-identified elements, still images marked with the exact locations, and the times they touched the screen were saved on the computer. The hazard detection task program was developed by Nishizawa Electric Meters Manufacturing Co., Ltd. The results were used to evaluate the characteristics of the locations and touch on the screen, the elements the participants identified, the frequencies with which they were identified, and the times at which they were detected.

Visual searching task

The trail-making test (TMT) was used for the visual searching task illustrations. The TMT is a test designed to evaluate visual searching ability, and it consists of two parts—Part A (TMT-A) and Part B (TMT-B) [25]. In TMT-A, the participants saw the numerals 1 through 25 on a computer screen, and they were asked to touch them in ascending order. In TMT-B, they were shown the numerals 1 through 13 and the Japanese *hiragana* characters あ (a) through し (shi) on the screen, and they were asked to touch the numbers and *hiragana* alternately in the order 1 → あ → 2 → い, and so on to the end. The participants started the tasks themselves by touching the "Start" button, and the characters 終了 (*shuūryō*, "end") appeared immediately after the final target was touched. For both tasks, sounds indicating either a correct or incorrect target were played when each target was touched. Even after a target had been touched correctly, it remained on the screen. The time required, time to touch for each target, and the numbers of correct and incorrect answers were saved on the computer. The results were used to calculate the time re-
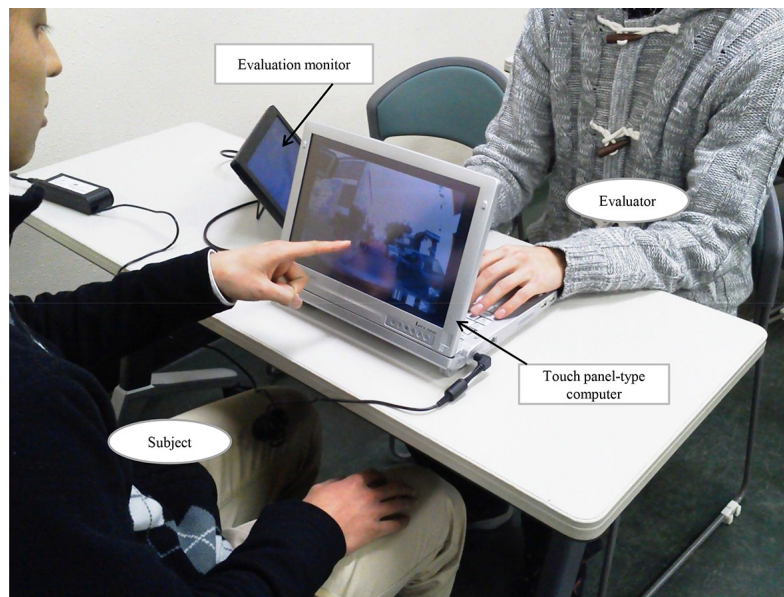
Fig. 1. Experimental setup.

quired, the number of incorrect answers, and the cognitive load value (the time required for the TMT-B divided by the time required for the TMT-A). The cognitive load is an index of the difference in difficulty between the TMT-A and TMT-B, and as the TMT-B is more difficult than the TMT-A (Lehrner et al., 2008), the cognitive load is > 1 if the TMT is valid. In addition to the computer-based TMT, we also administered the paper-based TMT to examine the validity of the computer-based TMT as a task to evaluate visual searching ability. The order of the task conditions (computer-based TMT and paper-based TMT) was counter balanced between subjects. The visual searching task program was developed by Nishizawa Electric Meters Manufacturing Co., Ltd.

Results

Hazard detection task

The mean number of participant-identified hazards during the eight-segment, two-minute-long driving scenario was 5.5 ± 2.3 (range 2−11) per person. After scenes identified by < 10% of the participants (≤ 4/42) were excluded from all the hazards identified, 11 scenes were left. These comprised watching out for oncoming vehicles and traffic lights when entering an intersection (17%), watching out for incoming vehicles from the left (62%), watching out for a stopped bus preparing to start up again (43%), watching out for an incoming vehicle making a wide turn (93%), complying with the requirement to stop when entering a main road (38%), watching out for oncoming traffic when turning right at an intersection (38%), being careful not to run over pedestrians when turning right at an intersection (19%), watching speed when driving down a narrow road (71%), watching out for pedestrians on the left stepping out unexpectedly (24%), watching out for an oncoming vehicle stopped across the center line (50%), and watching out for a bicycle crossing against the lights (64%). The hazard "watching out for oncoming vehicles and traffic lights when entering an intersection" (17%) was identified during a 5-s interval 18−23 s after the video began, and "watching out for a vehicle making a wide turn" (93%) was identified during a 14-s interval 38−52 s after the video began, indicating that the time range during which hazards were identified varied depending on the specific hazard (Table 1).

Visual searching task

One participant was excluded due to missing values, and the results from 41 participants were therefore analyzed. Non-repeated measure two-way ANOVA showed the interaction between condition (computer versus paper) and type (TMT-A versus TMT-B) ($F_{(1,80)}$ = 26.6, $p < 0.0001$). A simple main effect analysis revealed that the time taken in computer-based TMT-A was significantly shorter than in computer-base TMT-B ($F_{(1,80)} = 50.6$, $p < 0.0001$), and in paper-based TMT-A ($F_{(1,80)} = 53.0$, $p < 0.0001$) (Fig. 2). The number of incorrect answers was found only in computer-based TMT-B, and a significant interaction was found between condition and type ($F_{(1,80)} = 33.1$, $p < 0.0001$). A simple main effect analysis revealed that the number of incorrect answers in computer-based TMT-B was significantly greater ($F_{(1,80)} = 16.6$, $p < 0.0001$). As for

Table 1. Results of hazard detection task.

| Hazard	Hazard location	Detection frequency	Detection time (s) (range)	Type of hazard
1		17%	20.1 ± 1.6 (18−23)	Watching out for oncoming vehicles and traffic lights when entering an intersection
2		62%	27.6 ± 1.0 (26−29)	Watching out for incoming vehicles from the left
3		43%	28.9 ± 2.1 (26−35)	Watching out for a stopped bus preparing to start up again
4		93%	40.7 ± 3.2 (38−52)	Watching out for an incoming vehicle making a wide turn
5		38%	47.8 ± 6.5 (39−58)	Complying with the requirement to stop when entering a main road
6		38%	64.9 ± 1.8 (62−69)	Watching out for oncoming traffic when turning right at an intersection
7		19%	66.3 ± 1.7 (64−69)	Being careful not to run over pedestrians when turning right at an intersection
8		71%	82.5 ± 6.0 (72−89)	Watching speed when driving down a narrow road

Table 1. Results of hazard detection task (continued).

Hazard	Hazard location	Detection frequency	Detection time (s) (range)	Type of hazard
9		24%	108.5 ± 1.0 (107−110)	Watching out for pedestrians on the left stepping out unexpectedly
10		50%	116.9 ± 0.7 (116−118)	Watching for an oncoming vehicle stopped across the center line
11		64%	128.0 ± 1.2 (124−130)	Watching out for a bicycle crossing against the lights
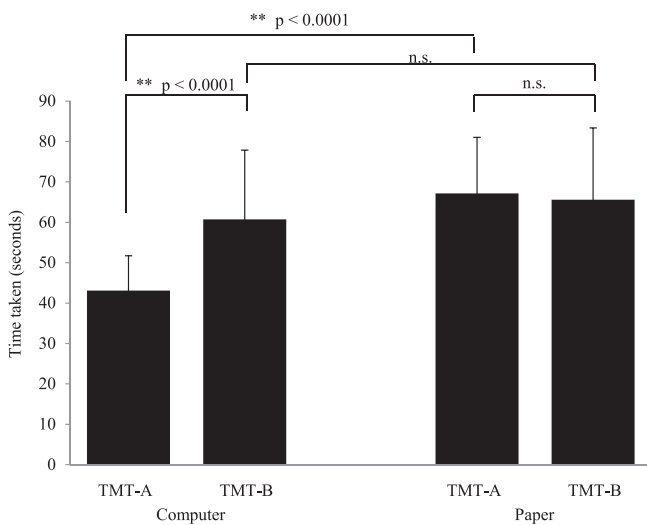
Fig. 2. Comparisons of time taken in visual searching task.
Non-repeated measure two-way ANOVA revealed significant interaction between task conditions (Computer vs. Paper) and task types (TMT-A vs. TMT-B). Analysis of simple main effect showed that time taken in the computer-based TMT-A significantly shorter than the computer-based TMT-B, and the paperbased TMT-A.
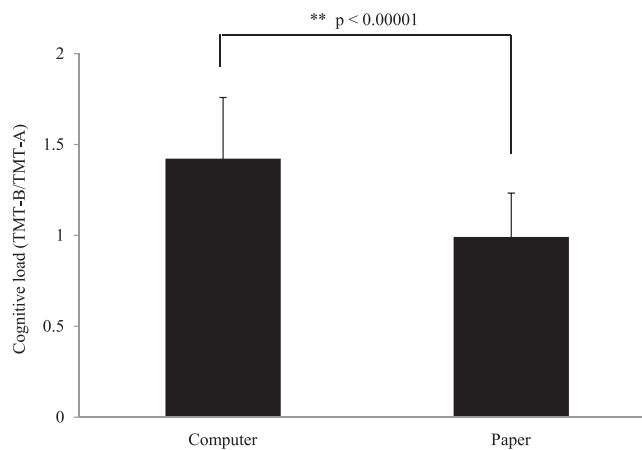
Fig. 3. Comparisons of cognitive load in the visual searching task.
Cognitive load of the computer-based TMT is significantly higher than the paper-based TMT.

the cognitive lead, the computer-based TMT showed a significant higher cognitive load than the paper-based TMT (t(40) = 6.4, *p* < 0.00001) (Fig. 3).

Correlation between hazard detection task and visual searching task

To examine the relationship between the hazard detection task and the visual searching task, we calculated Pearson correlation coefficient (r) as a function of the number of detection in the hazard detection task and the time taken in the visual searching task. Results showed
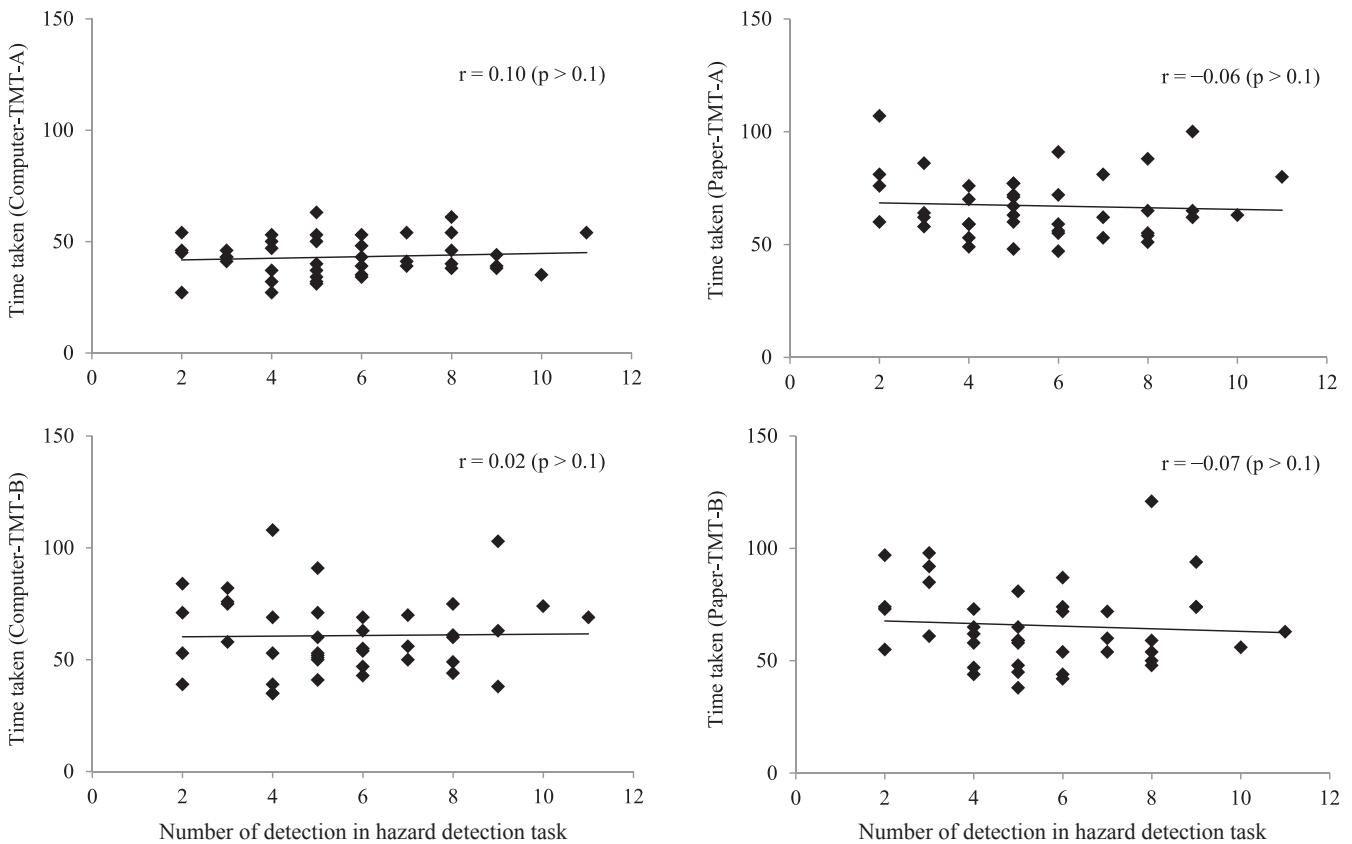
that no significant correlation was found for the number of detection versus the computer-based TMT-A ($r = 0.10$, $p > 0.1$), the TMT-B ($r = 0.02$, $p > 1.0$), the paper-based TMT-A ($r = -0.06$, $p > 0.1$), and the TMT-B ($r = -0.07$, $p > 1.0$) (Fig. 4).

Discussion

In this study, we reported that the characteristics of young licensed drivers in newly developed hazard detection task, and examined the validity of the computer-based visual searching task as a measure of cognitive lead.

Recently, the road sign recognition task has shown correlations with on-road driving evaluations, enabling assessments of an individual's ability to read driving-related situations [19, 26−27]. In this task, driving situations are displayed as photographs or illustrations, and the participant is asked to choose the road sign most appropriate to each situation. This task, however, only evaluates the participant's understanding of the situation and his or her knowledge of road signs without assessing their ability to predict hazards. Actual driving also requires the ability to deduce the situation after having seen the road sign, the opposite process from what is assessed in this test. In addition, as this test uses photographs or illustrations, rather than video footage, it is far removed from actual driving situations in which visual information changes moment by moment. Nouri and Lincoln (1992) [28] have described a task in which participants are shown a 3-min driving video and are asked to predict hazards. That test, however, requires participants to recall of hazards at the end of the driving video, meaning that it does not evaluate the immediate ability to predict risk. The hazard detection task we have developed, however, assesses the ability to predict risk in real time during a driving video, meaning that it is capable of evaluating the ability to judge situations in an environment similar to that of actual driving. Although hazard detection ability assessment using driving videos has previously been reported [29], these assessments were not designed to be conducted in medical institutions. To our knowledge, in Japan, there are no previous reports on hazard detection ability assessment using video. Furthermore, video-based assessment procedures reflective of Japanese traffic conditions, scenery, and

Fig. 4. Correlation between hazard detection task and visual searching task.
No significant correlation is found between number of detection in hazard detection task and time taken in visual searching task.

traffic rules are necessary.

We found that when young licensed drivers completed our hazard detection task, their responses were characterized by variations in the frequency with which different hazards were detected, but there was a consistent time range during which they were detected. The fact that the detection frequency varied indicates that there is a priority order for those hazards that should be detected in the driving scenario. This suggests that hazard detection failure of frequently identified objects may indicate low ability in predicting hazards. A clear delay in hazard identification beyond the normal time range, as found in this study, may also indicate low hazard prediction ability. However, it should be noted that the hazard detection task has limitations. One of the most important limitations is that this task is not capable of evaluating the ability of actual behavioral response to avoid accidents. Therefore, the relation to the performance in on-road assessments such as road test [30] should be examined.

As for the visual searching task, the TMT is a well-known neuropsychological test for assessing visual searching ability, and its results are known to be correlated with on-road driving evaluations [25, 31−32]. Reports vary concerning the time required to perform the TMT tasks [12, 33−34], and no standardized data are available, but the TMT's most important characteristic is that the TMT-B must have a higher cognitive load than the TMT-A [35]. Accordingly, the TMT-B should require more time to complete than does the TMT-A, and its performance should result in more errors. In our study, this was definitely the case. Unlike existing paper-based TMT, the computer-based TMT-B required more time than did the TMT-A, and the number of errors was greater. The cognitive load of the TMT-B was, therefore, greater than that of the TMT-A, demonstrating that the tasks in our TMT are valid. This task is also performed solely by touching the screen, making it more useful for assessing pure visual searching ability than existing TMTs, which also involve motor function by requiring participants to join targets with a pencil.

Another important result of our study was that the number of detections in the hazard detection task did not correlate to the time required in the visual searching task. This would suggest that the hazard detection task measures different ability from the visual searching task. Successful TMT performance requires rapid visual processing, on the other hand, the hazard detection task requires not only visual processing but also the ability to predict hazardous events. As safety driving involves a wide variety of cognitive abilities [36−38], the development of tasks in addition to those used in the present study might enable the development of a low-cost driving assessment program that does not require the installation of any equipment.

Conclusions

This pilot study showed that the video-based hazard detection task included 11 hazardous events to be detected at various times, and that young drivers detected hazardous events during a particular period of time, and also that the computer-based TMT was valid to evaluate visual searching ability. The results of this study, however, only illustrate the characteristics of young driver's licenses holders. Future research is needed to ascertain the relevant characteristics of other age groups. Young people and the elderly cause more traffic accidents than do other age groups [39], and a study of elderly licensed drivers' hazard detection task performance, in particular, will be important for developing a more thorough picture of drivers and their cognitive capabilities.

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