Effectiveness of Information Sharing to Improve Elderly Drivers’ Acceptability for Proactive Intervention Systems

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ABSTRACT: This study focuses on improving the acceptability of elderly drivers for proactive intervention systems using information sharing. Based on the observations of our previous studies, we modify the visual contents for avoiding information overload. To evaluate them, we conduct a driving simulator experiment that 12 elderly drivers participate in. The results confirm that the modified contents basically maintain or improve the evaluation of conveying the intended meanings, reducing disturbance, and improving feeling of trust without causing information overload. In addition, we also confirm a significant effectiveness of information sharing to improve the acceptability under the 5% significance level using the Wilcoxon signed-rank test.

KEY WORDS: Safety, protection of older people, driving support Acceptability, Human Machine Interface [C1]

1. Introduction

To reduce traffic accidents caused by elderly drivers, which is currently a major problem in Japan (1), more advanced safety technologies that can assist such drivers are required (2)(3)(4)(5). Because both physical and cognitive abilities of elderly drivers decline due to their aging, advanced driving assistance systems in the intelligent vehicle with a certain level of autonomy seems desirable. Given these motivations, our research group (6) has been developing intelligent systems for automated vehicles. As discussed in our previous study (7), systems that can control vehicles to avoid potential dangers by proactively intervening the drivers’ operations seemed suitable for elderly drivers because such systems could avoid the large acceleration due to emergent collision avoidance systems, which might cause damage to elderly drivers owing to their declined physical resistance. To utilize and further develop such proactive intervention systems, the investigation of driver acceptance is as important as technological development. Thus, in our previous study (7), we focused on the acceptability of proactive intervention systems for elderly drivers. Figure 1 shows the flow diagram of our research project including the previous studies and the current study. As a result of the experiment using a driving simulator, we confirmed that the proactive intervention systems had certain problems regarding acceptability due to the uncertainty of their behaviors.

In our other studies (8)(9), based on the results of the initial investigation (7), we proposed information sharing to provide visual contents of the internal data of the systems to the drivers. In contrast to existing warning systems, which aim to make drivers behave appropriately, information sharing aims to provide drivers with the information to accept the behaviors of the proactive intervention systems. In addition, we implemented prototype contents for information sharing using visual modalities, and investigated the basic characteristics, such as the capability of conveying the intended meaning, reducing disturbance to the driver, and providing the feeling of trust. We confirmed the necessary types of visual content via the experiments using a driving simulator. On the contrary, we also confirmed certain unsolved problems regarding information overload. In addition, the effectiveness of information sharing in improving the acceptability was not yet confirmed. Thus, in this study, we focus on modifying the visual contents implemented in our previous studies. Regarding the modified visual contents, the objectives of this study are roughly classified into two: investigation of the basic characteristics of the modified visual contents, and investigation of the effectiveness of information sharing to improve the acceptability of the proactive intervention systems. Through an experiment using a driving simulator, we aim to investigate these points in this study.

2. Modification of Visual Contents for Information Sharing

2.1. Proactive Intervention systems

Figure 2 shows the schematic of an overhead view of a situation involving a proactive braking intervention. Unlike in several other countries, vehicles are driven on the left side of the road in Japan. Thus, as shown in Fig. 2, the self-vehicle drives on the left side. In this situation, the self-vehicle detects the blind spot caused by the parked truck and predicts a pedestrian walking into its path. The self-vehicle proactively intervenes by braking, resulting in soft deceleration. In contrast to the existing automatic emergency braking systems, our proactive intervention systems aim to avoid risky situations by predicting the surrounding traffic situation. Because our collaborator (10) was simultaneously developing the details of vehicle controls for situations similar to our trials, we conducted this study using the simplified vehicle controls imitating the proactive concept, which are described in the following section.
steering intervention, which are described in the following section. For proactive braking intervention, we used simplified controls for the self-vehicle to steer with soft yawing motion. As in the case of the proactive steering intervention, the self-vehicle detects a cyclist and a parked car. Subsequently, the self-vehicle proactively intervenes by steering with soft yawing motion. As in the case of the proactive steering intervention, we used simplified controls for the steering intervention, which are described in the following section.

Fig. 1 Flow diagram for research to improve acceptability of proactive intervention systems.

In contrast to Fig. 2, Fig. 3 shows a schematic of the overhead view of a situation involving a proactive steering intervention. In Fig. 3, the self-vehicle detects a cyclist and a parked car. Subsequently, the self-vehicle proactively intervenes by steering with soft yawing motion. As in the case of the proactive braking intervention, we used simplified controls for the steering intervention, which are described in the following section.

Fig. 2 Overhead view of situation involving proactive braking intervention.

Fig. 3 Overhead view of situation involving proactive steering intervention.

2.2. Information Sharing for Improving the Acceptability of Elderly Drivers

Because intelligent vehicles with various sensors are sometimes able to recognize the surrounding situations that elderly drivers would not observe due to their decreased abilities, elderly drivers may not accept the behaviors of the proactive intervention systems if they do not understand when, where, why, and how the systems avoid risky situations. Thus, it is important to provide elderly drivers with an explanation of the behaviors of the intelligent systems of automated vehicles. Therefore, we consider the information sharing system as the primary resource and auditory modalities as a secondary resource. Thus, we adopted a head up display (HUD) as the HMI device.

2.3. Basic Investigation of Information Sharing in our Previous Studies

The primary focus of our previous studies was to determine the types of visual contents that are necessary and the types that can be reduced. Thus, we prepared various types of elemental visual contents. Furthermore, because we wanted to make elderly drivers forcibly perceive the provided visual stimulation, we adopted relatively strong visual stimulation that possessed the possibility to annoy and disturb the driver. Using these constraints, we compared the effectiveness of single visual content with that of a combination of multiple visual contents.

The experimental results allow us to conclude the following with regard to improving the visual contents for each proactive intervention system.

- Although almost all of our previous visual contents could convey the intended meaning, certain visual contents had to be redesigned from the viewpoint of instinctive understanding.
- The combination of multiple visual contents was able to improve the trust of the driver on the assumption of redesigning certain components of the previous visual contents.
- The combination of multiple visual contents might result in the disturbance of driving due to the complexity of visual stimulation.

Because we designed the previous visual contents without adjusting moderately for actually confirming the potential problems, we had to modify them in this study to integrate the elemental components while reducing annoyance. Figure 5 summarizes the strategies of the previous phase 2 and current phase 3 of this research effort. Thus, we require reducing, redesigning, and moderately adjusting certain components of the previous visual contents in this study.

Fig. 2 Overhead view of situation involving proactive braking intervention.
2.4. Improvement of Visual Content for Proactive Braking Intervention

Figure 6 shows a schematic of the timeframe of proactive braking intervention with information sharing using previous visual contents, which are a simple mixture of contents in the previous study\(^9\). The horizontal axis indicates time, with 0.0 s indicating the time when the vehicle passed through the conflict point with a crossing pedestrian. In this proactive braking intervention, we assumed that the vehicle started decelerating 5.0 s before the vehicle passed through the conflict point. The schematics above the timeline illustrate the corresponding situations and examples of visual contents over time. Regarding information sharing in proactive braking intervention in the previous study, we designed the following four types of visual contents as shown in Fig. 6.

* Notification of potential risk of a pedestrian.
* Notification of system activation, and the remaining time of intervention, and detected risky traffic participants.
* The complete notification of intervention.

In addition, the system beeps at a moderate volume when icons are displayed to ensure perception. Experiments in the previous study revealed the following problems regarding the previous visual contents.

* The notifications for all detected traffic participants might result in disturbance while driving.
* The symbol for complete notification of braking intervention, which was a blue circle as shown in Fig. 6, was difficult for certain participants to understand the meaning.
* The stimulation of certain visual contents, such as needlessly vivid red color was so strong that the participants felt a disturbance.

Based on the abovementioned observations, we modified the visual contents of proactive braking intervention. Figure 7 shows a schematic of the timeframe of a proactive braking intervention with information sharing using modified visual contents. Compared to the previous visual contents, we reduced the notifications for all detected traffic participants, changed the symbol for complete notification of braking intervention, and weakened the stimulation of certain visual contents. As a result, we designed three types of visual contents in this study: notification of detected risky traffic participants as an advanced notification, notification of system activation and the remaining time of intervention, and the complete notification of intervention, as shown in Figs. 8, 9, and 10, respectively. First, an icon for the notification of detected risky traffic participants is displayed 2 s before the vehicle starts to brake, as shown in Fig. 8. Second, an icon for activation notification and the remaining time of braking intervention are displayed when the vehicle starts to brake, as shown in Fig. 9. During braking intervention, the length of the yellow side bars decreases according to the remaining time of proactive braking intervention. Finally, an icon for the complete notification is displayed when the vehicle completes the braking intervention, as shown in Fig. 10.
2.5. Improvement of Visual Content for Proactive Steering Intervention

Figure 11 shows a schematic of the timeframe of a proactive steering intervention with information sharing using previous visual contents, which are a simple mixture of the contents in the previous study\(^9\). Similar to the proactive braking intervention, 0.0 s indicates the time when the vehicle passed through the point just beside the parked car. In this proactive steering intervention, we assumed that the vehicle started steering 5.0 s before the vehicle completed the steering intervention. Regarding information sharing in proactive steering intervention in the previous study, we designed the following four types of visual contents as shown in Fig. 11.

- Notification of collision risk.
- Notification of safety confirmation.
- Notification of system activation, remaining time of intervention, and planning path.
- Complete notification of intervention.

Experiments in the previous study revealed the following problems regarding the existing visual contents.

- Providing various visual contents caused information overload for certain experimental participants due to the amount and layout of visual contents.
- The meaning of the symbol for complete notification of steering intervention was also difficult for certain experimental participants to understand.
- The stimulation of certain visual contents was so strong that the participants felt a disturbance.
Based on the abovementioned observations, we modified the visual contents of proactive steering intervention. Figure 12 shows a schematic of the timeframe of a proactive steering intervention with information sharing using modified visual contents. In contrast to the previous visual contents, we reduced the notification of system activation and remaining time, and the complete notification, adjusted the layout of the displayed visual contents, and weakened the stimulation of certain visual contents. Moreover, we added the advanced notification of steering intervention based on the observations in the previous study regarding the proactive braking intervention. As a result, we designed four types of visual contents in this study: notification of detected collision risk, notification of safety confirmation, advanced notification of activating the steering intervention, and planning path of steering intervention, as shown in Figs. 13, 14, 15, and 16 respectively. First, an icon to notify the driver of the detected collision risk is displayed 7 s before the vehicle starts to steer, as shown in Fig. 13. Second, an icon for safety confirmation is displayed 4 s before the vehicle starts to steer, as shown in Fig. 14. Third, an icon for advanced notification of steering intervention is displayed 2 s before the vehicle starts to steer, as shown in Fig. 15. Finally, a blue dotted line is displayed to notify the planned path of steering on the road in front of the vehicle when the vehicle starts to steer, as shown in Fig. 16.

The experimental method was designed to investigate the effectiveness of information sharing for elderly drivers. We conducted driving simulator experiments, and the experimental protocols were approved by the institutional review board for human studies of the School of Engineering at the University of Tokyo. Written informed consent was obtained from all participants.
3.1. Experimental Participants

In this study, we recruited the experimental participants from the participants in the previous experiments because some of them answered the negative evaluations for previous visual contents. As a result, 12 elderly drivers participated again in this study although remaining three participants could not participate. Their average age was 70.7 years old (SD = 3.1 years). They had a driving license for 47.9 years on average (SD = 6.3 years). Their average frequency of driving was 4.9 days per week.

3.2. Driving Simulator

Figure 17 shows an appearance of the driving simulator used in the experiments. This simulator possesses the following features.
- Three front screens that generate a field of view of approximately 120° from the position of the driver.
- Two small displays for right and room mirrors.
- Platform movable via a Stewart link.
- Steering wheel with a servomotor that reproduces reactive torque.
- Speaker systems that reproduce the sounds of surrounding simulated situations and of the vehicle's engine.

We set the motion platform to reproduce only the longitudinal and lateral accelerations to prevent motion sickness. The scale factor for each accelerator was set to 0.1 to reproduce only the initial motion cues of intervention.

3.3. Experimental Scenarios and Instructions

Before starting the evaluation, we explained the concepts and behaviors of both proactive intervention systems. Subsequently, we explained that the system displays varied information during the intervention. Regarding the experimental course, we explained the situations in detail. To investigate the effectiveness of the modified visual contents, we simulated two types of visual contents: the modified visual contents and a simple mixture of all visual contents that had been used in the experiments in the previous studies.

Figure 18 shows the overhead view of the entire experimental course for proactive braking intervention. This course contains four situations involving proactive braking intervention, as shown in Fig. 2. The experimental participants were instructed to drive the vehicle at 40.0 km/h. The proactive braking intervention started when the vehicle arrived at the position where the time to collision (TTC) to the unobservable crossing pedestrian was 5.0 s. The deceleration rate due to the proactive braking system was set to 1.0 m/s². For setting up the basis of evaluations and reducing the order effect, visual contents were not displayed in the 1st and 3rd situations, while they were displayed in the 2nd and 4th situations. In addition, evaluations were basically conducted based on the comparison with the condition without information sharing.

3.4. Evaluation Method

Similar to our previous studies, most behavioral data, such as reaction time and operation amount, were not quantitatively evaluated because driver operations were largely invalidated by switching the control during the interventions, as shown in Fig. 4. Thus, subjective evaluations served as our prime resource for analysis and discussion.

For the subjective evaluations, after completion of each trial performed on the driving simulator, the experimental participants filled out questionnaires to evaluate the intervention systems. Based on the results of our previous studies, we asked questions related to the following topics:
- Perception of the meaning of provided visual content: “Compared to the condition without information, to what degree did you better notice the following topics?”
  - For both proactive interventions
    - Reason of system activation
    - Surrounding risky traffic participants
    - Start timing of the system
    - Whether the systems are activated or not
End timing of the system  
- For proactive braking intervention  
- For proactive steering intervention  
  
- Activation of automated deceleration  
- Activation of automated steering  
- Planning path  
- Advanced safety confirmation  

- Perception of disturbance by information sharing: “Compared to the condition without information, to what degree did you feel that the system disturbed you while driving?”  
- Sense of trust in the system through information sharing: “Compared to the condition without information sharing, to what degree did you feel distrust in the automatic vehicle control system?”  
- Acceptability for proactive intervention systems without and with information sharing  
  
- For the condition without information sharing  
  “How much do you want to introduce the system into your own car?”  
  
- For the condition with information sharing  
  “On the condition that the information is always displayed, how much do you want to introduce the system into your own car?”  

Every questionnaire was in the form of a nine-grade answer sheet. Regarding the feeling of disturbance, the answers indicating the degrees of disturbance were as follows:  
- Grade 9: No disturbance  
- Grade 7: Negligible disturbance and no difficulty in driving  
- Grade 5: Slight disturbance, but no difficulty in driving.  
- Grade 3: Experienced disturbance that caused slight difficulty in driving  
- Grade 1: Experienced disturbance that caused substantial difficulty in driving  

Because the sensitivity of the evaluation results of each participant is different, the results of this evaluation do not have precise quantitative meaning. The important point is whether they felt difficulty in driving due to the provided visual contents. Thus, the important point is whether the evaluation results are less than grade 5.  

On the contrary, as for the other questionnaires, grades of answers indicate the degrees as follows:  
- Grade 9: Felt substantially  
- Grade 7: Felt moderately  
- Grade 5: Felt the same as if no information had been provided  
- Grade 3: Did not feel much  
- Grade 1: Did not feel at all  

Regarding the sense of trust, the evaluation grades were inversely used; Grade 9 indicates “Did not feel distrust at all”, and Grade 1 indicates “Felt distrust substantially.” The key point was whether each participant responded positively, neutrally, or negatively. Especially, we focused on whether the evaluation results were greater than, equal to, or less than Grade 5.  

4. Experimental Results  

4.1. Evaluation of Basic Characteristics of Modified Visual Contents  

4.1.1. Perception of the Meaning of Provided Visual Contents  

As discussed in the previous study\(^9\), individual characteristics regarding the perception of traffic environment affects the evaluation result of perception of the meaning of provided visual contents. Thus, in this study, we separately checked the evaluation results of each participant. Table 1 shows the evaluation results of perception of intended meaning for provided visual contents during proactive braking intervention. Larger values indicate better evaluations. Regarding the color of the cells in the tables including Table 1 and the following tables, cells colored in blue, green, and red indicate evaluations lower than, equal to, and higher than grade 5, respectively. Regarding proactive braking intervention, the modified visual contents received high evaluations although decreases of certain evaluation results are confirmed, as shown in Table 1. The important point is that the modification of visual contents in this study did not cause the system to be negatively evaluated.  

**Table 1** Perception of intended meaning of visual contents during proactive braking intervention.  

| Intended meaning | Visual contents | Participants ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|------------------|----------------|----------------|---|---|---|---|---|---|---|---|---|----|----|----|
| Reason of system activation | Previous | | | | | | | | | | | | |
| | Modified | | | | | | | | | | | | |
| Surrounding risky traffic participants | Previous | | | | | | | | | | | | |
| | Modified | | | | | | | | | | | | |
| Start timing of the system | Previous | | | | | | | | | | | | |
| | Modified | | | | | | | | | | | | |
| Whether the system is activated or not | Previous | | | | | | | | | | | | |
| | Modified | | | | | | | | | | | | |
| End timing of the system | Previous | | | | | | | | | | | | |
| | Modified | | | | | | | | | | | | |
| Activation of automated deceleration | Previous | | | | | | | | | | | | |
| | Modified | | | | | | | | | | | | |

Table 2 shows the corresponding results for the proactive steering intervention. The modified visual contents improved certain evaluation results, especially that of participant 4. Based on the comments of participant 4, the moderate adjustments to visual stimulation and the modified layout of visual contents may have improved the evaluations. However, the evaluation of the planning path of steering intervention still remained negative. Participant 4 commented that he could not understand the meaning due to the rapid transition of visual content over time. Thus, we require improvement of implementation at this point. For other components of the system, we confirmed that the modification of visual contents did not decrease the evaluation results to the negative level.
4.1.2. Feeling of Disturbance

Table 3 shows the driver evaluation results for the feeling of disturbance caused by visual contents during proactive braking intervention. As shown in Table 3, although we confirmed negative evaluation of the simple mixture of previous contents, the modified visual contents improved those evaluations to at least medium evaluations, indicating that the system does not add difficulty to driving. Thus, we consider that the modifications in this study achieved the improvement.

Table 3 Disturbance of driving during proactive braking intervention.

| Intended meaning of visual contents | Participants ID |
|-------------------------------------|-----------------|
| Surrounded by risk of traffic accidents | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified                                  | Previous Contents |
| Modified                                  | Modified Contents |
| Planning path                            | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified                                  | Previous Contents |
| Modified                                  | Modified Contents |
| Participants ID                          | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified                                  | Previous Contents |
| Modified                                  | Modified Contents |

Table 4 shows the corresponding results for proactive steering intervention. Similar to the results of proactive braking intervention, we can confirm the improvement of all evaluation results to the higher level. Especially, regarding the evaluations results of participant 4, the modified visual contents significantly improved his evaluations. Thus, the modified visual contents partly solved the problem of information overload.

Table 4 Disturbance of driving during proactive steering intervention.

| Disturbance of the driving | Participants ID |
|---------------------------|-----------------|
| Planning path             | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified                                  | Previous Contents |
| Modified                                  | Modified Contents |
| Participants ID                          | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified                                  | Previous Contents |
| Modified                                  | Modified Contents |
| Participants ID                          | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified                                  | Previous Contents |
| Modified                                  | Modified Contents |

4.1.3. Feeling of Trust

Table 5 shows the results of the evaluation of feeling of trust for proactive braking intervention. Although the previous visual contents originally obtained satisfactory evaluation results, the modified visual contents improved certain evaluations of feeling of trust.

Table 5 Feeling of trust for proactive braking intervention.

| The degree of the trust | Participants ID |
|-------------------------|-----------------|
| Previous Contents       | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified Contents       | 1 2 3 4 5 6 7 8 9 10 11 12 |

4.2. Evaluation of Effectiveness to Improve Acceptability for Proactive Intervention Systems

Table 6 shows the corresponding results for proactive steering intervention. The modified visual contents resulted in the improvement of certain evaluation results without negatively affecting any evaluations. Regarding the results of participants 4 and 5, these improvements seem to be the secondary result of being free from information overload.

Table 6 Feeling of trust for proactive steering intervention.

| The degree of the trust | Participants ID |
|-------------------------|-----------------|
| Previous Contents       | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified Contents       | 1 2 3 4 5 6 7 8 9 10 11 12 |

Table 7 shows the results of the evaluations of acceptability of proactive braking intervention. The important point is that the target of this evaluation was not the acceptability of the visual content but the acceptability of the proactive intervention systems. Although acceptability of the proactive braking intervention system without information sharing was relatively satisfactory, the modified visual contents further improved the evaluations. Figure 19 shows a comparison of the results obtained with and without modified visual contents. As shown in Fig. 19, a significant difference under the 5% significance level was confirmed using the Wilcoxon signed-rank test. The Z value was 2.5584.

Table 7 Acceptability of proactive braking intervention.

| Acceptability | Participants ID |
|---------------|-----------------|
| No information | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Previous Contents  | 1 2 3 4 5 6 7 8 9 10 11 12 |
| Modified Contents  | 1 2 3 4 5 6 7 8 9 10 11 12 |

Fig. 19 Comparison of acceptability of proactive braking intervention.

Table 8 shows the corresponding results for proactive steering intervention. The results for the system without visual contents contain several negative evaluations. The modified visual contents...
contents improved the evaluation results to the positive level. Figure 20 shows a comparison of the results obtained with and without the modified visual contents. As shown in Fig. 20, a significant difference under the 5% significance level was confirmed using the Wilcoxon signed-rank test. The Z value was 2.5488.

Table 8 Acceptability of proactive steering intervention.

| Participants ID | Acceptability |
|-----------------|---------------|
| 1               | 2             | 3              | 4              | 5              | 6              | 7              | 8              | 9              | 10             | 11             | 12             |
| No information  | 3             | 5              | 3              | 4              | 9              | 8              | 5              | 9              | 4              | 9              | 8              |
| Previous Contents | 5             | 9              | 4              | 3              | 7              | 9              | 9              | 7              | 8              | 9              | 7              |
| Modified Contents | 6             | 9              | 6              | 8              | 9              | 9              | 9              | 9              | 9              | 8              | 9              |

Fig. 20 Comparison of acceptability of proactive steering intervention.

4.3. Discussions

To utilize the findings in our previous studies and this study, we summarize the results from the viewpoints of situation awareness (SA)(12). In contrast to the existing studies that discussed the driver assistance systems for manual driving, this study focused on the partially automated driving that the authority of driving was switched to the intelligent vehicle during the intervention, as shown in Fig. 4. On this point, we think that designing the visual contents with considering, at least, levels 1 and 2 of SA was important. First, in our previous studies(8)(9), we selected the necessary visual contents for elderly drivers to comprehend the driving situation and the system’s plan to avoid the potentially risky situation. This was the design of visual contents with regard to the level 2 of SA. Then, in this study, we modified the stimulation of visual contents for elderly drivers to easily perceive the visual contents provided by the system. This was the design of visual contents with regard to the level 1 of SA. As for the intervention system that invalidates the driver’s operation, we think that designing from viewpoints of levels 1 and 2 of SA is the minimum requirement for the elderly drivers. However, as for the shared control that will be discussed in future, level 3 of SA, which is related to the projection of future status, will be an important factor because the driver needs to behave adequately. Thus, based on the findings of our studies, further investigation is necessary.

In addition, for preventing information overload of elderly drivers, how to manage the visual contents when the multiple risks occur is one of remaining challenges. For example, the situation that requires both braking intervention and steering intervention is typical one. Because the acceptability of the proactive braking intervention system without information sharing was relatively satisfactory as shown in Table 7, we think that reducing the visual contents with regard to the braking intervention is better solution for avoiding information overload than reducing the visual contents with regard to the steering intervention. Confirmation of this policy through the experiments is another future work.

5. Conclusions

To improve the acceptability of the proactive intervention systems, we focused on information sharing. Based on the experimental results of our previous studies, we modified the visual contents for two types of proactive intervention systems: proactive braking intervention and proactive steering intervention. Subsequently, we conducted driving simulator experiments to investigate the effectiveness of the modified visual contents. Although our observations were limited to the conditions of the experiments, we obtained the following conclusions.

- The modified visual contents basically maintain or improve the evaluation results of conveying the intended meanings, reducing the disturbance, and improving feelings of trust.
- The modified visual contents improved the acceptability of the elderly drivers for the proactive intervention systems.

Because the number of the participants were limited, the generality of the abovementioned conclusions were also limited to a certain degree. However, we thought that the approach for the problems regarding information overload of elderly drivers who were weak in perception of traffic environments would be helpful for the following trials in this research field.

However, further investigation is needed. Because there was a few negative evaluations for the modified visual content regarding the planning path during proactive steering intervention, further modification is one of future works. One idea for this remaining challenge is to slow the provision speed of visual contents.

Additionally, in this study, we assumed that the automated vehicle performs perfectly in relatively simple situations. However, automated vehicles sometimes fail to behave adequately in the real world. Similarly, the prediction of the surrounding traffic situation for proactive vehicle controls does not always obtain correct answers due to the complexity of actual situations. Thus, we require investigation regarding the conditions under which false alarms occur.

Although this study assumed intervention systems that used control switching, our final goal is to realize intervention systems that use shared control. In contrast to switching control, as the drivers are required to drive the vehicle appropriately to a certain degree, they should acquire the information more actively. Therefore, we intend to investigate the characteristics of active information sharing based on the results of this relatively passive information sharing.

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