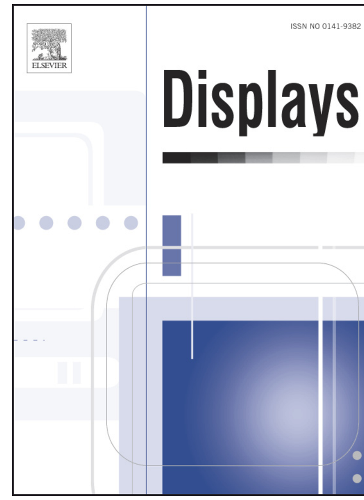

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PII: S0141-9382(14)00058-4
DOI: http://dx.doi.org/10.1016/j.displa.2014.08.001
Reference: DISPLA 1694

To appear in: *Displays*

Received Date: 6 December 2012
Revised Date: 11 August 2014
Accepted Date: 15 August 2014

Please cite this article as: Y-Y. Huang, M. Menozzi, Effects of discomfort glare on performance in attending peripheral visual information in displays, *Displays* (2014), doi: http://dx.doi.org/10.1016/j.displa.2014.08.001

Effects of discomfort glare on performance in attending peripheral visual information in displays

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Abstract

Large screens have become more popular in recent years. Because of the increasing size of displays, the amount of information presented in the peripheral visual field has gained importance in many tasks on visual display units. Users of displays are often exposed to some change or difference in luminance in or between different areas of a display, which in turn may produce a phenomenon known as discomfort glare. Discomfort glare is likely to affect cognitive performance. The performance in the visual periphery is more susceptible to disturbances as is the case for the performance in the central visual field.

This study explored the effects of discomfort glare on detecting and processing peripheral visual information in a complex visual task. The task consisted of comparing the orientation of arrows presented in the central visual field and at 18° in the periphery. The arrows were superimposed on a background video and presented by a projection system in virtual reality. 50% of the presentations were preceded by a mild glare scene with a luminance of 25 cd/m^2 flashed prior to the stimulus. Experimental results of 56 participants were analyzed using the theory of signal detection. A significant difference (two-tailed t-test $p = 0.01$) in detectability of stimuli ($d'_{glare} = 1.87$; $d'_{no\ glare} = 2.11$; $\Delta d' = 0.24$) was obtained when comparing the performance in the two situations of glare. Results show that discomfort glare impairs peripheral visual performance in attending stimuli in a virtual reality environment. We therefore propose to consider discomfort glare as a factor affecting performance in detecting peripheral visual information. Discomfort glare should be included as a quality criterion in rating visual information, as is done in present standards of displays and lighting.

Keywords

Large displays; Peripheral visual field; Peripheral vision; Discomfort glare; Visual attention; Complex visual information

1. Introduction

In our everyday life, many times we cannot overcome the difficulties caused by a sudden glare situation when performing visual tasks. Glare has been considered as an important factor affecting one's visual performance. In the following introduction section, we discuss the various forms of glare, i.e. disability glare, adaptation glare, and discomfort glare. For example, discomfort glare has been shown as the cause for some dropped performance. Such a fact then brings out the research question: what are the underlying causes/factors behind discomfort glare and how is the attention mechanism being affected? We further list some examples containing potential issues of discomfort glare exposure which might be seen in everyday display-media applications. In particular, we focus on the peripheral visual performance that has resulted from the popularity of large displays.

The more well-known "disability glare" [1] has been discussed and investigated frequently in many popular studies, such as examinations of safety-related research in car-driving [2, 3, 4, 5, 6] and the light-adaptation mechanism in physiology-concerning discipline [7, 8]. Disability glare disables the visual system to some extent and causes reduced visibility and contrast sensitivity. This disabling may be caused by light scattered in the eye physiologically. A common example occurs when one drives at night and an oncoming vehicle with very bright headlights is approaching. Another more well-known form of glare is "adaptation glare" [1], which occurs when the visual system is exposed to a sudden change in luminance. Because the visual system requires some time to adjust its sensitivity to altered level of light, adaptation glare causes a temporary impaired vision.

It is known that disability and adaptation glare could be severe risk factors in visual tasks. However, it is less commonly known that "discomfort glare" [1] might irritate one's vision, in addition to disability and adaptation glare [9]. Discomfort glare, a subjective sensation of discomfort, may occur when people do not necessarily notice any effect on their work performance [10], but people might complain about certain symptoms, such as eye discomfort, headache, etc., which reduces the efficiency and quality of the work. By means of an intervention study in Swedish mail-sorting facilities, Hemphälä and

Eklund [11] were able to show a significant reduction of eye discomfort after lighting conditions were improved and sources of discomfort glare were reduced. Based on the outcome of their study [11], the authors estimated that a total of 62000 hours of sorting time per year could be saved by applying the improvements of their intervention study in all Swedish mail-sorting facilities. In an office work environment, in particular with the usage of computer displays, the daylight through the windows and the lighting system indoors often cause the phenomenon of discomfort glare and have been considered a common problem [10, 12] in everyday life. For example, one may perceive lower luminance on the computer display where the main task is usually located, compared with the higher illuminated surrounding of the computer display [13]. Studies have been made to investigate the preference and postural symptoms of an office worker under different illuminating conditions for improving later lighting and office designs [10, 12, 13, 14]. Furthermore, suggestions have been made to evaluate a sufficient objective and quantifiable rating index/method linked to the subjective phenomena for better understanding and predicting potential discomfort glare problems which is still a challenge to be achieved [5, 10].

Discomfort glare causes visual distraction; on the other hand, distraction has been suggested as a cause for discomfort glare [15]. Our cognitive mechanisms decide how to proceed with our visual attention when exposed to discomfort glare, which acts as a distracter. As a result, while causing visual discomfort, discomfort glare is distracting our visual system and sharing the perception resources, which affects our visual attention in the cognitive level.

Many times we are not well-prepared for the possible effects on our visual attention caused by a discomfort glare situation, which is happening even more frequently in our routine work environments. For example, when we work on our computers, a newly opened web-browser window might distract our visual attention for a short while. In the modern aviation environment, digitalized displays have been introduced and further provided the possibilities for acquiring various information. While switching between different information subcategories, the pilot might be disturbed by the changing frame on the screen. With certain visual disturbance in the aviation task, the pilot might change the overall control ability to detect some detailed information. A control-room administrator might have some difficulties in making decisions when encountering the reflection of a bright object on the screens. Moreover, in our leisure time entertainment, discomfort glare situations happen regularly as well. For example, we can easily find a bright scene from a video game such as applying a magic spell in an R.P.G. game, or a shining sky scene from a movie. This kind of discomfort glare usually stands at a low level luminance compared to light levels causing disability and adaptation glare, and this happens to us with various display media almost every day. As a result, it is important to know how a situation causing discomfort glare would distract our visual attention from the required visual information.

Wickens et al. [16, 17] have developed an attention model, which may help to understand effects of discomfort glare on visual performance. In Wickens's SEEV attention model, there are four elements which may alter the probability of attending visual information. The first element is the "Salience" of visual targets. Salience is stimulus-driven, and a bottom-up attention mechanism. Stronger physical properties of the target, e.g. higher contrast, larger size, etc. would increase the probability in attending the target. "Effort" is the second element that inhibits the movement of attention in certain conditions, such as scanning across longer distances between targets. "Expectancy," the third element, is linked to the likelihood of seeing an event, which is concept-driven and a top-down attention mechanism. Being a cognitive factor, observers may shift their attention to the location/moment when the expectancy is high. The last element, "Value," is also a top-down attention mechanism, which refers to the importance of a task. Observers may optimally allocate their attention based on the "Expectancy" and "Value" of an event.

The basic idea in Wickens's model is the limitation of resources which are available for information processing. Discomfort glare may bind resources, thereby reducing the amount of available resources for processing visual information. As a consequence, performance in processing relevant information may be reduced in the presence of discomfort glare. Binding of resources caused by discomfort glare may happen for various reasons. One possible cause is the overlaying effect which degrades the stimulus information. A mild glare scene may introduce the veiling effect, which influences the contrast of visual targets. In such a case, the glare disturbance might degrade the steady state visibility of visual information and make the target less salient to be detected. Another possible cause is the (temporal) covering effect which masks the stimulus information. Glare may temporarily mask the visual information and require a reprocessing period of the information after it becomes unmasked. Thus, the observer might require more effort in reconstructing the visual environment for the upcoming event. As in Wickens's SEEV model [16, 17], required effort contributes negatively to the probability for attending a target. A large variety of factors contributing to masking have been investigated in the past [18, 19]. As the masked visual information was usually of limited complexity, such as words [20] or simple objects, it is hard to use previous findings in order to predict effects of masking when using a complex display, which is usually presented in a simulator or in our daily lives.

The display in everyday life includes both relevant information and some information that is not used in a specific task and therefore is considered to be irrelevant. Irrelevant information acts as a distractor when performing a visual task. The process of neglecting irrelevant information while attending the relevant information may use resources as well, and consequently a complex display including irrelevant information lowers performance in attending the relevant information. As a result, it is important to investigate effects of discomfort glare while observing a complex display.

Nowadays, large-sized and wide-angle computer displays, LED/LCD-TV, and projection systems are accessible at work and at home. With the increasing usage of various displays which present visual information in a wide visual field in modern times, it may be necessary to rely on our peripheral vision much more than in the past. As a result, how visual tasks are performed when visual targets located in both central and peripheral visual fields has become an important issue. Normally, the tendency or habit is to focus on the visual information shown in the central visual field, especially when there is a heavy load in visual tasks. Thus, it might take more efforts from the attention mechanism to detect peripheral information under a complex visual task.

Moreover, the age factor might play a role in performing visual tasks affected by discomfort glare. With increasing veiling luminance in the elderly, it might be expected that there will be stronger effects in visual performance caused by discomfort glare for the elderly than the younger population.

In the present study, the effects of discomfort glare on visual performance in a complex and temporarily varying visual environment were investigated. In particular, since the peripheral visual field is of increasing interest for presenting information, the effects of discomfort glare when both the central and the peripheral vision are involved in a visual task were investigated. Effects were investigated using a projection display in a driving simulator task with participants of different ages. The working hypothesis is that if more binding attention resources are caused by the discomfort glare scenes, participants should be less focused on the detection task and less performed. In the experimental design, the "Salience" and "Value" elements in the SEEV attention model should remain the same since the task itself is not changed by the discomfort glare scene. Besides, it is assumed that the "Expectancy" should be increased since the glare scene might act as a hint of an upcoming detection task. On the other hand, the "Effort" should be increased by the glare masking disturbance and thus reduce the attention performance.

2. Methods

2.1 Participants

Fifty-six participants, 26 females and 30 males, participated in the experiment. Participants ranged in age from 24 to 64 years, with the mean age of 41.14 years and a median of 38 years. None of the participants reported any ocular diseases. All had normal or corrected-to-normal vision as determined by the vision examinations.

Participants wore their habitual optical correction for far vision during the experiment, if applied. The experiment consisted of one session of vision examination and one session of attention test in the driving simulator, for a total of 30 minutes, approximately. Participants were recruited from the ETH Zurich and the University of Zurich campuses and were rewarded a small gift after completing the experiment.

The present study has been approved by the Research Ethics Committee of ETH Zurich. All participants were given a full explanation about the experimental procedures orally and in a written form. A consent form was obtained with the right to withdraw from the study at any time without giving reasons and without any negative consequences.

2.2 Vision Examination

This research work has been motivated by interests in investigating potential effects on attention performance of glare disturbance for traffic applications. As a result, the Swiss regulation for regular driving licensing (non-professional, for driving license category A and B) were used as the vision examination criterion. That is, one must have a minimum visual acuity (decimal) at 0.6 in the best eye and 0.1 for the other eye. One can reach the acuity requirement with their habitual optical correction. One must have a minimum visual field of 140 ° horizontally and no double vision.

The Rodatest 302 vision screening device (Rodenstock, Germany) was used to examine the far visual acuity (G25 test for right/left/binocular vision) and the peripheral vision (GESICHTSFELD test for right/left peripheral visual fields at 35, 55, 70, and 85 degrees). Besides, the AR-1000 AUTO-REFRACTOMETER (Nidek, Japan) was used to check the refractive error for both eyes with habitual optical correction, if applied.

Finally, the LANG-STEREOTEST was used for disparities of 550”, 600”, and 1200” to check the stereoscopic vision.

All participants fulfilled the vision examination criterion as addressed.

2.3 Attention Test

The visual attention experiment was run in a driving simulator in virtual reality. In this test, participants were asked to detect a particular feature in projected test videos and to report detected features by pressing specified buttons on the steering wheel for their responses on a driver’s seat.

2.3.1 Instrumental set up

The test videos were displayed on a 3m by 3m white projection wall vertically by a projection system (BarcoSIM5plus, projector with SXGA resolution, aspect ratio of 4:3, and field of view (H x V) of 49.12° x 37.85°) at a distance of 3 meters to the observer. There was no auditory effect provided. Participants performed the visual tasks with the driver’s control interface (Logitech G25, steering wheel with buttons & position sensors and accelerator & brake pedal sensors). To report their answers for the given tasks, they pressed two corresponding buttons on the steering wheel. The driver’s control interface and the projection system were both connected to a control and record system (HP xw9400 workstation) which recorded the output signals of the driver’s control interface, i.e. the answers, by a LabVIEW program. Recorded data were sent to an output log file simultaneously for later uses.

2.3.2 Experimental design

The attention test was conducted in a driving simulator, and this attention test was a video-based task that contained a dynamic driving scenario as a video format but not interactive to the participants. In other words, participants performed the attention test passively by watching a driving scenario without the access/need to drive. During the task, participants were asked to keep their fixation on a fixation cross which was centrally superimposed on a video of a simulated driving scenario. Immediately after the fixation cross disappeared a central and a peripheral arrow appeared superimposed on the video. Participants performed a two-alternative forced choice (2AFC) task that required them to report whether the orientations of two horizontal arrows are the same or opposite by pressing two specified buttons on the steering wheel. Fig. 1 shows template scenes of the video-based tasks.

Before the main experiment, a two-minute training session was run in order to get participants acquainted with the task and the procedure. Participants were instructed to report their answers as quickly and accurately as possible. The detection trials, i.e. arrow sets, were shown pseudo-randomly throughout the test, and the time intervals between each trial were set to be 3 sec to 10 sec. The main experiment consisted of four blocks of a two-minute test video. In each block, there were 20 trials of the arrows sets. The two arrows, with the same geometry, were both shown in yellow color (RGB = 255/255/0) and with the luminance of 15 cd/m^2. The “central arrow” was presented centrally (0°) in the visual field and pointed either to the right direction or to the left direction. The “peripheral arrow” was presented at the same time at a periphery of 18° horizontally and located according to the direction the central arrow was pointing. The peripheral arrow also pointed either to the right direction or to the left direction. Both arrows subtended a horizontal angle of 140’ (minutes of arc). The two arrows were displayed simultaneously and were visible for the duration of 400 ms for the central arrow and 200 ms for the peripheral arrow. The peripheral arrow was presented shorter than the central arrow for preventing fixation on the peripheral arrow. Following a review reported by Becker [21], the latency for a saccade to a target located at 18° in the periphery is about 200 ms, and the duration of the saccade of an amplitude of 18° is about 52 ms. The duration settings were tested in a pilot experiment. Based on the experimental results of the pilot study, the final test was designed to be applicable yet not too easy for the general population.

----> *FIG1.jpg*

In 50% of the trials, further on referred to as the “glare condition”, a flash of a blank frame prior to the presentation of the arrow set was applied. The blank frame, which was shown in white color (RGB = 255/255/255) with a luminance of 25 cd/m^2, was visible for the duration of 200 ms and generated a transient mild glare scene. The sequence of trials with glare and without glare alternated pseudo-randomly. Each participant performed 40 trials with and 40 trials without applying glare stimuli. Fig. 2 shows the sequence of the trial. Before running the first block of the main experiment, a one-minute training session was applied to instruct participants how to perform the task. This could also help the experimenter to check if the participant has understood and performed the task correctly.

2.4 Data Analysis

From each participant, a total of 80 answers were received after running the four blocks of test videos. The theory of signal detection [22] was used to analyze the results. When one trial consisted of two arrows with the same orientations, this was defined as a signal. Depending on how participants detected the signals, they may generate “hits,” i.e. signals were detected, or “misses,” i.e. signals were not detected. In the no signal cases, i.e. the arrow set consisted of opposite orientations, participants may generate “correct rejections (CR)” or “false alarms (FA).” Total answers were collected and sorted into different data sets (e.g. glare condition) for further analysis. In particular, the detectability d’ was used to evaluate possible effects among various conditions.

----> FIG2.docx

3. Results

The results of the total 56 participants were evaluated. In the 40 trials with glare preceding the presentation of the two arrows, a mean correct rate, i.e. p(Hit) + p(CR), was 78.96% (SD = 11.72%). In the other 40 trials with no glare preceding the presentation of the two arrows, a mean correct rate was 80.68% (SD = 15.11%). Based on the theory of signal detection, the average detectability d’ were 1.87 (SD = 0.94) in glare condition and 2.11 (SD = 1.19) in no-glare condition. Fig. 3 illustrates the results with a box-plot. Participants performed significantly better in detectability when no glare was applied (two-tailed t-test, $t(55) = -2.614$, $p = 0.012$).

----> FIG3.jpg

In order to investigate the possible effect of the age factor, the total participants were divided into two age groups by a median split. AgeGroup A (24y to 36y) had 14 female and 14 male subjects with the mean age of 29.61 years and the median of 29 years. AgeGroup B (40y to 64y) had 12 female and 16 male subjects with the mean age of 52.68 years and the median of 53 years. The measured results of visual acuity as examined by the Rodatest 302 vision screener G25 test were shown in Tab. 1.

----> *TAB1.docx*

A 2x2 ANOVA was run considering the two-level within-subjects factor of glare condition (glare and no-glare) and the between-subjects factor of AgeGroup (AgeGroup A and AgeGroup B). Results showed a significant effect of glare condition ($F(1,1) = 6.793$, $p = 0.012$, Effect size $\eta^2 = 0.112$, Power = 0.726). A significant effect of AgeGroup ($F(1,1) = 9.014$, $p = 0.004$, Effect size $\eta^2 = 0.143$, Power = 0.839) was shown as well. There was no significant interaction between the glare condition and the AgeGroup ($p = 0.412$). Fig. 4 shows the mean detectability d' in different glare conditions of two age groups graphically. In AgeGroup A, mean d' were 2.21 (SD = 0.84) of the glare condition and 2.53 (SD = 0.91) of the no-glare condition. In AgeGroup B, mean d' were 1.53 (SD = 0.92) of glare condition and 1.69 (SD = 1.30) of the no-glare condition.

----> *FIG4.jpg*

4. Discussion

In this study, video-based visual tasks were applied to participants with various ages. Those tasks contained a video background with moving objects and visual targets located both in the central visual field and in the periphery. In other words, participants detected visual signals and made decisions based on their central vision and peripheral vision as well in a complex visual environment. Under different conditions, i.e. visual tasks with and without applying transient discomfort glare scenes, detectability d' was used to investigate the possible effects on our visual performance. The study has found that the detectability d' dropped in the discomfort glare condition among all participants.

An important question to answer is how far the recorded drop in performance might have been related to a loss of sensitivity caused by the varying level of light adaptation of the eye. Various studies have reported an increase in luminance threshold for detecting a visual target when the surround or the background of the target is briefly increased in luminance. Bichao et al. [23] investigated luminance threshold for detecting a disc subtending 11.4' and presented for 15 ms in duration either in the fovea or at an excentricity of 2.8°. Compared to the dark adapted eye, luminance threshold in Biacho's experiment and for the foveal presented stimulus raised from about 3 cd/m^2 for the dark adapted eye to about 4.4 cd/m^2 when a glare of 17.5 cd/m^2 surrounding the stimulus was applied. In the case where a surrounding glare of 70 cd/m^2 was applied, luminance threshold shifted to higher values depending on the asynchronicity between the onset of the glare and the onset of the stimulus. Presenting the stimulus 15 ms after glare onset raised the threshold to 10 cd/m^2, whereas presenting the stimulus 500 ms after glare onset caused the threshold to increase to 5 cd/m^2. In average, the effects were stronger (about 30%, compare fig. 11 in [23]) in the periphery. As also noted by Crawford [24], luminance threshold peaked at about the time of the onset of the glare and then decreased with time. When the glare was switched off, threshold luminance peaked again; however, the peak at switch-off time of the glare was considerably lower than the peak at the onset of the glare. The peak in luminance threshold at switch-off time disappeared for a glare of approximately less than 100 cd/m^2. As can be learned from Crawford, threshold drops fast after switching off the glare, so that for low glare level conditions (about 100 cd/m^2 in [24]), sensitivity reaches almost the sensitivity at dark adaptation level within around 100 ms. Compared to this study's settings, Bichao's results for the 500 ms stimulus onset asynchronicity with a glare of 70 cd/m^2 caused a luminance threshold of about 5.6 cd/m^2 (and about a 30% higher one in the periphery), can be used as a worst case estimation of the effect of transient adaptation on visual performance. Although this study would have simultaneously surrounded the yellow target (15 cd/m^2) by the white frame (25 cd/m^2) in the experiment, the arrow would still have been visible. Moreover, since the luminance threshold rapidly drops further after the switch off, visibility of the arrow in our experiment is additionally improved as compared to Bichao's experiment. It is therefore that the effects of transient adaptation would have affected visual performance in this experiment.

Significant effect on d' caused by discomfort glare was shown in all ages. This study found that discomfort glare affected our visual performance in a complex visual task with the displayed media causing visual attention impairment in periphery. Discomfort glare might distract one's visual attention system, causing one to be unable to focus on the visual information continuously. This finding could be a major concern in our daily life. The glare scene applied in this study is generated by a blank frame in a projected medium to the observer, which represents a similar situation one might encounter when acquiring information from a display. Employing Wickens's SEEV model [16, 17], the

"Salience" parameter should not be affected since the mild glare scene applied in the test is neither enhancing nor diminishing the salience of the arrow sets to be detected. As well as for the "Value" parameter, one would not expect any difference between the glare and no-glare conditions. In the experimental setup employed in this study, it is quite likely that participants would expect an upcoming event (to detect the orientations of the arrow set) when a glare scene appears as a hint. Thus, they should have higher "Expectancy" under glare conditions, i.e. the probability of attending the task should be increased. At the same time, the mild glare masking interrupted the driving scene before the detection task. The glare scene distracted participants and required some extra "Effort" to recall their visual memories to perform the visual task continuously. i.e. reduced visual attention could be expected. From the result found in this study, it may be assumed that the influence on “Effort” is larger than on “Expectancy” caused by discomfort glare in the experimental set up. Moreover, if the experimental set up employed in this study was such as not to generate an increased expectancy, the effect of discomfort glare on visual performance would have turned out even stronger.

In addition to the SEEV attention model, it is important to discuss how the spatial attention may allocate/distribute differently in the two glare conditions in this study. In the glare condition, the visual information was temporarily masked by the mild glare scene, and thus it is necessary to re-build the visual field after the glare stimulus. The arrow sets for the detection task were presented right after the glare presentation. As the driving scenario was applied in the test, as well as the experiment was carried out in a driving simulator, participants may adopt their routine driving habits/strategies while performing the test. That is, when an experienced driver needs to cope with increased mental load, it would be a more cleaver and effective strategy in putting the focus on the most important and informative area of the visual field, i.e. the road ahead, which is located in the central visual field. This may cause the "tunnel vision" effect, which is in line with this study's experimental results. In the glare condition, there was significantly reduced performance in detecting the arrow sets. This finding may be due to the discarded peripheral visual information or the shifted-focuses on central vision. In accordance with previous studies [25, 26], marked reduction of the visual inspection window was shown under conditions of mental workload, associated with the limited attentional resources. As a result, under the load of glare disturbance and re-building visual environment, it is likely the participants have decreased breadth of visual scanning (inspection window, visual field) in performing such tasks requiring attending visual targets located in both the central and peripheral visual fields.

Regarding the age factor, the detectability decreased in both the glare and the no-glare conditions as the age increased, i.e. in general elder people might need more time for processing visual information than younger people. However, there is no correlation between the age factor and the drop of d', which means discomfort glare results in same effects in all ages. There seems to be no influence of the veiling luminance.

In present standards and specifications, some guides, restrictions, or design requirements should be considered for a disability glare situation, i.e. nature sun light. However, a mild glare situation, and in general discomfort glare, should be considered as a criterion in present standards of displays, lighting, etc. as well.

Therefore, in this work, the first aim/attempt was to investigate as well as to demonstrate the potential effects of discomfort glare on attention performance. One major consideration of this study is to show that even in the everyday display-medium environment, one might have significant attention impairment caused by the visual discomfort and disturbance involving a mild glare masking feature. For the display designers, to the key point is to avoid the chance in producing the discomfort glare to the users, but how? From the physical (hardware) point of view, one might choose a less-reflective screen surface design to prevent reflection on the display which causes the discomfort glare masking phenomenon, e.g. applying the anti-glare display material. Another option would be to integrate a camera sensory system to real-time analyze the surrounding environment in order to adjust the display luminance, color components, etc. for reducing the influence or chance of discomfort glare. Such features and/or considerations should always combine with the software and interface designs. Designers should take all visual information presented at the same time in the display into consideration. It is intuitive that unnecessary or complex visual information should be avoided, and designers should try to preserve the central visual field for the most important/relevant information. Furthermore, designers should keep in mind how our attention resources might be altered/allocated under certain conditions. For instance, when the distracting factor cannot be avoided, designers may try to increase the chance for the observer to attend the relevant visual targets by enhancing the (color) contrast, enlarging the size, etc.

As a first yet successful step, this study was able to find the reduced attention performance caused by discomfort glare. In the next steps, further studies may develop this approach into broader and deeper aspects in order to better understand and evaluate the linking factors between discomfort glare and visual information processing mechanisms. For example, to better employ the SEEV attention model and to better clarify the parameters changes and weightings, itmay be necessary to design a similar detection task as presented in this study, but including/introducing more stimuli types (e.g. varying salience levels in terms of contrast, color, size, etc.).

5. Conclusions

In a projection environment, participants performed attention tasks that contained complex visual information and that required them to detect visual targets that relied on both the central vision and the peripheral vision. Results showed reduced visual performance in all ages when transient discomfort glare was presented. Discomfort glare reduces performance in detecting or processing peripheral information and therefore should be avoided.

When exposed to a sudden discomfort glare situation that acts as a distracter, one's limited resource for processing visual information is shared. As a result, it is quite likely one may miss some important visual information in such a case. This might result in crucial issues when one is performing visual inspections of switching information for safety and quality control at airports or power plants, or for examination in hospitals or factories, etc. Also, with the development of electronic paper technologies, there are more and more e-paper devices introduced in daily life. Users of such e-Ink displays might be disturbed by the refreshing moment, i.e. displayed information being switched. Where to present and how to arrange various visual information on a display is therefore an important issue. For example, it is necessary to avoid any distracting factor while performing a critical visual task, and the most important information should be displayed in the central visual field.

Finally, the experimental outcome demonstrates that display systems, as used in virtual reality settings, offer the possibility to conduct experiments about effects of glare on human performance even though the luminance level of such display systems is far lower than the luminance level of real glare source.

Acknowledgments

This work was supported in part by the Swiss federal road administration ASTRA (Project No. FGU2010/003). The authors thank the volunteers for participating in the pilot test as well as Esther Baumer-Bergande for her great help in advising and running the vision examination.

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Figure 1. Scenes template of the task. Upper left: the fixation cross when no arrows were shown; upper right: the mild glare scene generated by a blank frame; lower left: same orientations of one arrow set; lower right: different orientations of one arrow set.

Figure 2. The stimuli sequence of the trials. The time interval between trials varies pseudo-randomly.

Figure 3. Box-plot diagram presenting the distribution of detectability d' in the glare condition and the no-glare condition of the total 56 participants.

Table 1. Median visual acuity in AgeGroup A (24y to 36y, N = 28) and AgeGroup B (40y to 64y, N = 28).

Figure 4. Graphical representation of the mean detectability d' of AgeGroup A (24y to 36y) and AgeGroup B (40y to 64y) under different glare conditions.

	Median visual acuity for far vision (decimal acuity)		
	Better eye	The other eye	Binocular
AgeGroup A	1.25	1.0	1.25
AgeGroup B	1.0	0.8	1.25


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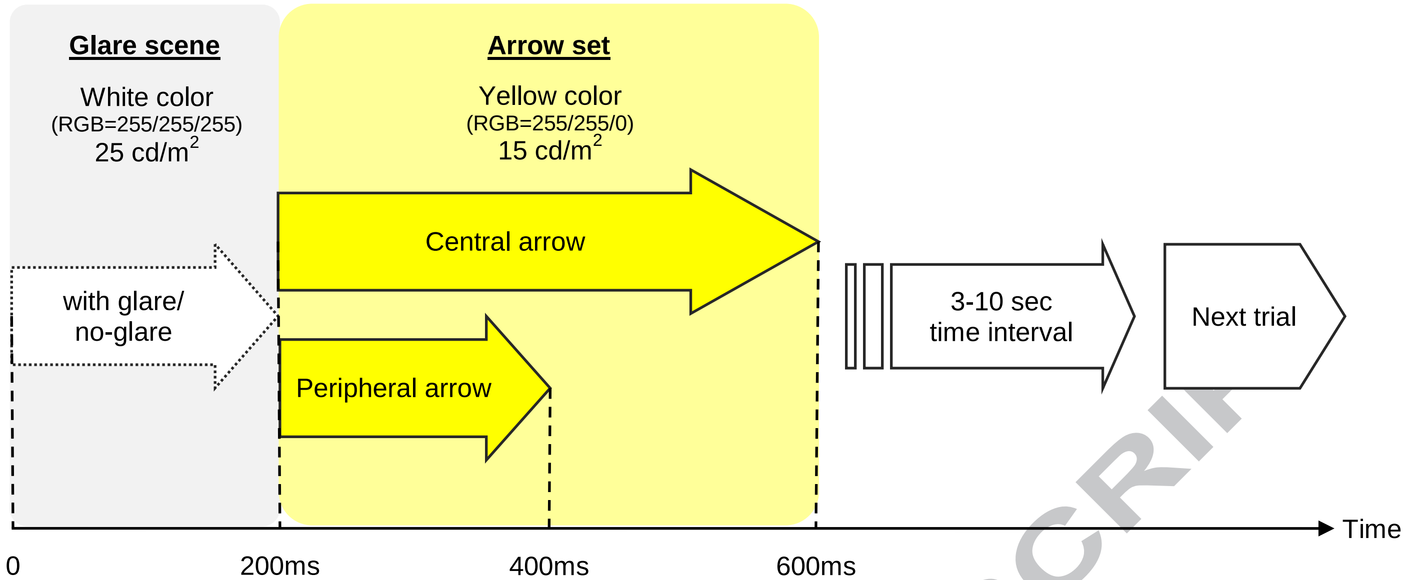
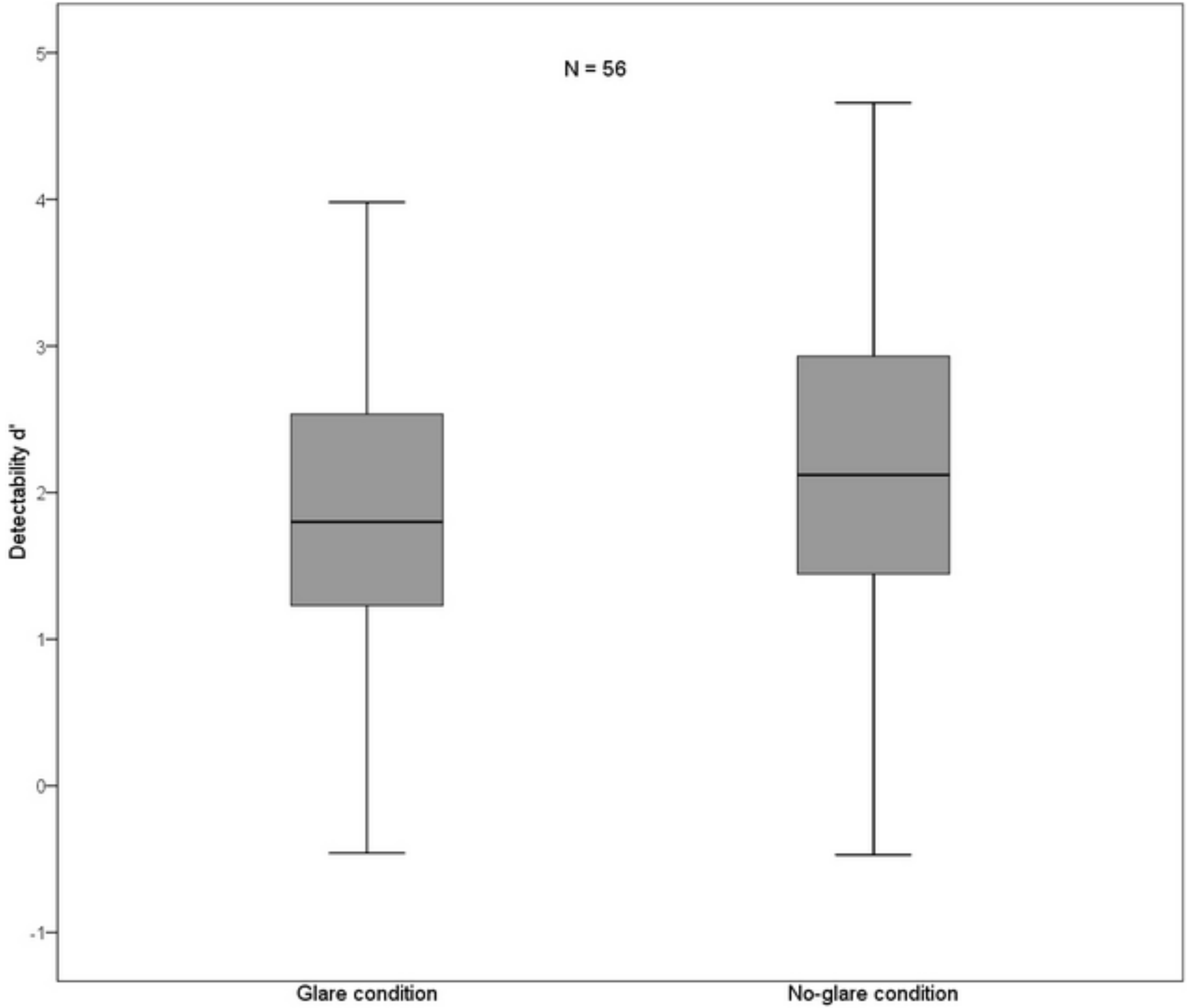
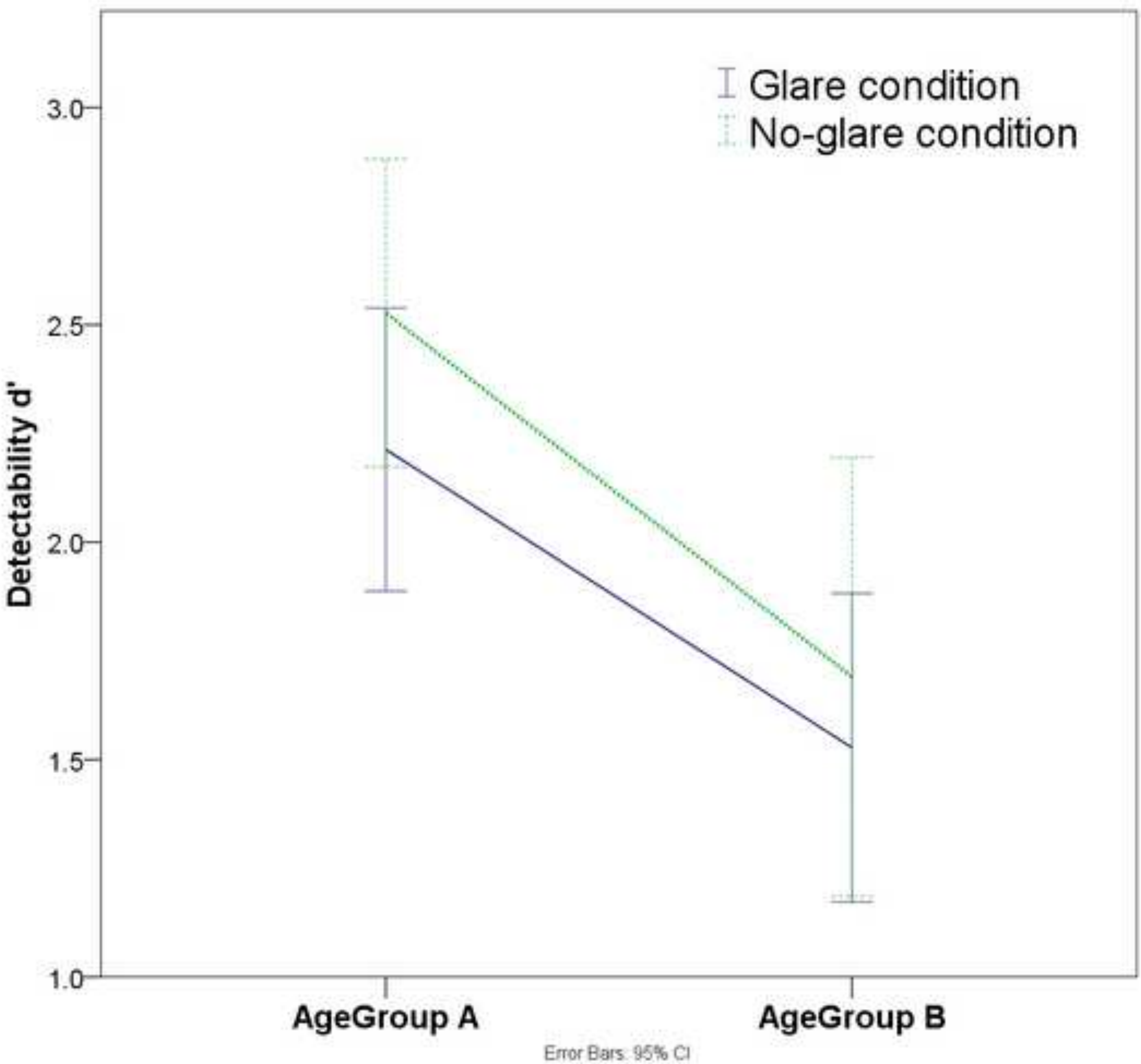
Ergonomics of Information Medias


Glare scene
White color
(RGB=255/255/255)
25 cd/m2
Arrow set
Yellow color
(RGB=255/255/0)
15 cd/m2
Central arrow
with glare/
no-glare
Peripheral arrow
3-10 sec
time interval
Next trial
Time
0
200ms
400ms
600ms


N = 56
Detectability d'
5
4
3
2
1
0
-1
Glare condition
No-glare condition


Glare condition
No-glare condition
3.0
2.5
2.0
1.5
1.0
Detectability d'
AgeGroup A
AgeGroup B
Error Bars: 95% CI

Highlights

- Glare experiments are achievable for evaluating visual attention in display media.
- Discomfort glare results in reduced visual performance in all ages.
- Discomfort glare reduces performance in detecting peripheral information.
- Discomfort glare, as a distracter, shares the resource for processing information.
- To consider discomfort glare as a serious issue in a complex visual environment.