Gaze control ability of League of Legends players in various game situations: Perspectives from solo-ranked match

Inhyeok Jeong[1], Donghyun Kim[2], Naotsugu Kaneko[1] and Kimitaka Nakazawa[1]

[1] *The University of Tokyo, 3-8-1, Komaba, Meguro-ku, 153-8902 Tokyo, Japan*
[2] *MaxForm Corp., 242, Gonghang-daero, Gangseo-gu, 07805 Seoul, Republic of Korea*

Abstract

Previous research analyzes the superior gaze control ability of esports players in simple cognitive tasks or in full games. Therefore, it is necessary to understand the gaze control ability of esports players in various situations. We assumed that game situations that require multiple tasks had wider gaze distribution than other situations. Therefore, the current study aims to compare the gaze control ability between high- and middle-skilled "League of Legends (LoL)" players and among various game situations classified into four categories and in an unclassified situation (five in total). Eight high-skilled (top 10%) and eight middle-skilled (lower than the top 10%) LoL players were recruited for the experiment. They wore an eye tracker and were asked to play solo-rank matches in LoL games. We analyzed gaze distribution, Region of Interest (ROI), and fixation duration during the games. The results showed that high-skilled players had a wider gaze distribution and shorter fixation time regardless of the game scene than middle-skilled players. Furthermore, high-skilled players checked the ROI area more frequently than middle-skilled players, where they could see the overall flow and feedback of the game. Thus, focusing on the overall flow and feedback with wide gaze distribution is the source of high performance in LoL players. When the game situations required focusing on multiple stimulations simultaneously, wide gaze distribution was observed rather than in other situations, regardless of the skill level. Our results suggest that it is necessary to adopt the appropriate gaze control training for esports players based on the various situations in esports.

Keywords

Gaze control ability, League of Legends, solo-rank game, esports

1. Introduction

Esports consists of competitive video games with online and offline spectators [1]. With the development of the esports industry, research on esports has also increased in various fields. From the point of view of cognitive science, it is known that esports can help players gain faster reaction time and information processing skills [2, 3]. Moreover, esports experts have superior visual behavior (e.g., gaze movement) and attention skills (e.g., visual attention) [4, 5]. The gaze movement is a well-known factor for understanding the superior performance level in esports [6]. Among the many esports genres, the multiplayer online battle arena (MOBA) game is well known to require a high level of gaze control ability and cognitive functions [7,8]. In MOBA games, players team up with other teammates to fight against opponents with complex strategies [9]. The MOBA game generates various situations, such as one-on-one matches, team fighting, and communication with other players.

League of Legends (LoL) is one of the most famous esports belonging to the MOBA game, where players team up with 5 teammates to fight against opponents. To achieve high performance in LoL, wide gaze distribution and short fixation time are important for collecting more information during gameplay [10]. Moreover, in real-time strategy (RTS) games with a similar gaming interface to MOBA games, high-skilled RTS players had wider gaze distribution with fast gaze movement than low-skilled RTS game players [4]. Information and interfaces in MOBA and RTS games are widely distributed across the entire monitor. Therefore, fast and wide gaze movement allows high-skilled RTS and MOBA game players to collect more information faster than low-skilled game players during the gameplay [4,10]. To sum up the previous studies [4,10], it is uncontroversial that high-

8th International GamiFIN Conference 2024 (GamiFIN 2024), April 2-5, 2024, Ruka, Finland
hofwillson@gmail.com (A1, Inhyeok Jeong); devorca18@gmail.com (A2, Donghyun Kim); kaneko@idaten.c.u-tokyo.ac.jp (A3, Naotsugu Kaneko); nakazawa@idaten.c.u-tokyo.ac.jp (A4, Kimitaka Nakazawa)

0000-0002-1343-7442 (A1, Inhyeok Jeong); 0009-0001-9710-2542 (A2, Donghyun Kim); 0000-0002-1587-9287 (A3, Naotsugu Kaneko); 0000-0001-5483-8659 (A4, Kimitaka Nakazawa)

skilled MOBA and RTS game players have superior gaze control abilities.

However, LoL game players do not always have to pay attention to all the information from the entire monitor. In a game situation when players are engaged with multiple opponents, it is important to focus on a single piece of information. When strategizing the fight, it is important to pay attention to various information for an effective battle simultaneously. Each percentage of the situation was dynamically changed throughout the game. To sum up, situations that need to focus on multiple information and single information exist at the same time in a single LoL game match.

Even though various game situations exist in LoL, the criteria for dividing the game scene for scientific research in LoL is still lacking. Furthermore, given that different game situations exist in a single LoL game match, it is necessary to reveal the situation-based gaze control abilities of LoL players. In RTS games, gaze movement training based on the game situation has been suggested [4]. Therefore, revealing the situation-based gaze ability of skilled LoL players, one of the most famous MOBA genre esports might contribute to developing a new specific training method for LoL players.

In the current study, we used solo rank games to categorize the game scene and evaluate the gaze control ability of LoL players. The rankings of participants directly change based on wins and losses matches in LoL solo rank games. This ranking system serves as an important motivational factor for esports players [11,12]. Thus, requiring participants to play a solo-ranked game is an effective approach to studying their ability in actual game situations. To sum up, using the solo rank game is suitable for investigating the gaze control ability of LoL players in various situations of actual LoL matches.

The purpose of the current study is to investigate the gaze control ability of skilled LoL players in challenging and motivating tasks adapted to various game situations using a solo rank game of LoL. The game scene was divided by the game situations in the solo rank game of LoL. According to previous research, esports players have a wide gaze distribution when performing multiple tasks simultaneously [4,10]. Therefore, we set the two hypotheses. H-1) Game situations that require multiple tasks have wider gaze distribution than not require multiple tasks. H-2) High-skilled players show wider gaze distribution than middle-skilled players in game situations that require them to perform multiple tasks simultaneously.

2. Methods

2.1. Participants

Eight high-skilled and eight middle-skilled LoL players were recruited for the experiment. The official rank of the high-skilled players was over than platinum rank (top 10%). Middle-skilled players were involved in bronze, silver, and gold tiers (lower than the top 10%). All participants self-reported that they had normal vision with no gaming disorder. Table 1 shows specific information about the participants. The experiment was approved by the Human Research Ethics Committee of The University of Tokyo (approval number: 872).

Table 1
Specific information about participants

Age	High-skilled: 22.7 ± 3.0 Middle-skilled: 22.7 ± 2.6
Education level	High school: 13 University: 3
Sex	Male: 16
LoL rank	Bronze tier: 2 Silver tier: 2 Gold tier: 4 Platinum tier: 3 Emerald tier: 1 Diamond tier: 4
Experience year	High-skilled: 9.2 ± 1.4 Middle-skilled: 4.3 ± 4.0

2.2. Equipment

The current study used a 27-inch 144 Hz refresh rate monitor for the experiment (ASUSTek Computer Inc., Taiwan) and an eye tracker (Pupil-core, Pupil-Lab, Haftungsbeschränkt, Berlin, Germany). Gaze movement was recorded using Pupil-Core, open-source software for Pupil-Core (Version 3.5.7). The eye tracker had one video camera (60 Hz, 1920 x 1080 px) and two eye cameras (200 Hz, 192 x 192 px) to record the experimental environment and gaze movement, respectively. The eye tracker had 0.06° accuracy with calibration and 0.02° precision. The eye tracker used the "dark pupil" detection method to analyze gaze movement. The "dark pupil" detection method detects the edge of the pupil for estimating the location of the gaze position. The eye tracker (pupil-core) had a maximum 40-millisecond delay in processing the gaze movement data (including pupil image transport, formatting, detecting, and showing the results) [13]. Four surface markers were attached to the corners of the monitor (Figure 1) to define the monitor screen and calibrate the gaze position. With calibration, the coordinates of the participant's gaze position were represented as a number between 0 and 1. The participants used their own mouse and keyboards for the experiment.

Figure 1: Surface markers and experimental environment. Each red box indicates the surface marker used for detecting the monitor screen and calibrating the gaze movement.

2.3. Experimental procedures

Before the experiment, participants wore the eye tracker and calibrated the gaze position using the Screen Marker Calibration method. The Screen Marker Calibration method calibrates the gaze position through five dots that appear on the screen (one center and four corners of the monitor) (Figure 2).

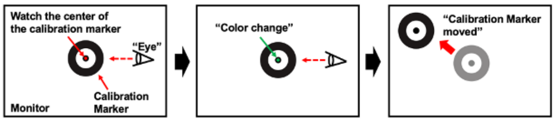

Figure 2: Overall flow of the "Screen-Marker Calibration" method.

When the calibration was finished, participants logged in to their own LoL account for a solo-rank match. Before starting the task, we set the distance between the monitor and the head position of the participants as 100 cm. After setting the head position, we requested the participants to keep their current head position as same as possible during the task. During the experiment, participants freely played the solo-rank match (called the Assignment). Solo-rank match was designed by the publisher of LoL (Riot Games, Inc., California, USA). During the solo-rank match, participants teamed up with four random players to play the match (one team with five members). When teaming up with four random players, it will be matched with players who have similar rankings to the participants by the AI matching system. Participants fought against the other opponent team players (not a bot) who had similar ranks to them.

When the match was finished, gaze movement was analyzed by open-source software for Pupil-Players (version 3.5.7). The overall flow of the experiment can be checked in Figure 3.

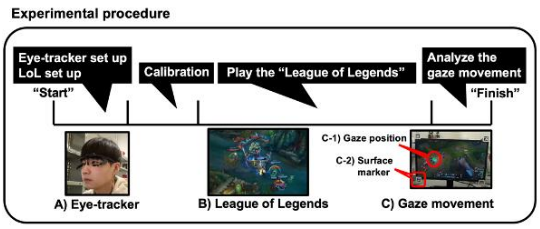

Figure 3: Overall flow of the experimental procedure.

2.4. The Assignment

The game scene in the Assignment was divided into four categories (Moving, Fighting, Object, and Watching) and non-divided scene (ALL; total 5 game scenes). In esports, the game scene was classified based on the game situation that commonly appeared during the gameplay [14]. Thus, we categorized the game scenes that commonly appeared during the LoL single-rank matches as previous research. During the experiment, we record the feature of the Assignment as a video .mp4 file without including the gaze movement data. After the experiment, a video file of the Assignment was provided for an anonymous LoL player who judged and divided the game scenes. The game scene was classified by the top 1% of the ranked anonymous LoL players with more than 10 years of experience. In the Moving scene, the participant only moves their character in the game (Figure 4A). Participants could move their characters by using the mouse right-click. In the Fighting scene, the participant freely fought with enemy team players by combining the mouse left click and keyboard q, w, e, and r keys (Figure 4B). Four different types of fighting scenes were included in the Fighting scene (Figure 4B-1, 2, 3, and 4). In the Object scene (Figure 4C), participants fought with six types of objects that were operated by a computer AI system (Tower, Nexus, Dragon, Inhibitor, Rift Herald, and Baron). Participants can obtain items and buffs that are important in the game by defeating the six types of objects. Participants could destroy the objects by using the mouse left click and keyboard q, w, e, r keys. The Watching scene included the action of watching another player play to check the overall flow of the match by using the keyboard's left, right, up, and down keys or mouse right-click (Figure 4D). Finally, the ALL scene was defined as a game scene that was non-classified. The Assignment was finished when the participants won or lost.

After the Assignment was finished, two parameters were calculated to evaluate the performance level. The first is the Kill/Death/Assistant ratio (KDA) used to evaluate the performance level of each participant. KDA was calculated as following equation (1).

$$\frac{eliminate\ the\ enemy\ +\ assistant}{eliminated\ by\ enemy} \qquad (1)$$

The second is "Total Damage to Champions" used to evaluate the Assignment performance. "Total Damage to Champions" represents the amount of direct damage to the opponent team characters.

2.5. Gaze movement acquisition

At the end of the Assignment, gaze distribution, Region of Interest (ROI), and fixation duration were calculated for each of the five scenes (Moving, Fighting, Object, Watching, and ALL scene). According to the manufacturer, it is recommended to only use data with a confidence level of 80% [13]. The confidence level was used as the accuracy of the gaze movement data. The confidence level was calculated by the accuracy of the pupil detected through the eye camera. A total of 7.18% of the gaze movement data (have lower accuracy than 80%) were excluded from the evaluation. In gaze distribution, the standard deviation of horizontal and vertical gaze was calculated respectively. The coordination of gaze position was normalized by the monitor size and represented as a number between 0 to 1. We set the five following ROIs: Chatting, Skill, KDA, Mini-map, and Game scene areas (Figure 5). Participants could view the chat in the Chatting area (Figure 5A). In the Skill area, participants could see the remaining time of skill, purchased items, virtual commodity, and level of skills (Figure 5B). The KDA area showed how many enemies a participant had taken down and helped other teammates (Figure 5C). In the Mini-map area, participants could see the entire flow of the game (Figure 5D). The Game scene area represents the main screen where the Assignment was performed (Figure 5E). The percentage of gaze position located in each ROI was calculated. Fixation was defined when the gaze position was fixed more than 100ms and the maximum pupil dispersion was less than 1.5 degrees.

Figure 4: Feature of the Assignment game scene. Each picture indicates the scene of the Assignment. A) Moving scene. The Moving scene includes the simple movement of the participant's character. B) Fighting scene. B-1,2,3,4 indicates the sub-category of the Fighting scene. The Fighting scene includes the battle of the participant character. C) Object scene. The Object scene includes when a participant hits the objects. D) Watching scene. The Watching scene includes when the participants watch the other players play.

Figure 5: Each position of ROI. Each red box indicates the ROI of the game. A) Chatting area, B) Skill area, C) KDA area, D) Mini-map area, E) Game scene area.

2.6. Statistical analysis

All statistical analyses were performed by the RStudio version 4.3.1 (R Studio, Boston, MA, USA). After the experiment, a power analysis was conducted to estimate the number of participants was appropriate (G*Power version 3.1.9). Three parameters were used to estimate the power of the sample size. Horizontal gaze distribution in the Moving scene and the Watching scene, ROI percentage between high- and middle-skill in the Mini-map area, and fixation duration between high- and middle-skill were used for power analysis. The effect size was calculated according to Cohen's method [15]. The specific results of the power analysis can be checked in Table 2.

Table 2

Results about power analysis. A) Horizontal gaze distribution between the Moving scene and the Fighting scene. B) ROI percentage between high- and middle-skill in the Mini-map area. C) Fixation duration between high- and middle-skill.

Parameter	P value	F value	Cohen's d	Actual power
A)	.01	5.68	1.61	0.83
B)	> .001	23.23	1.08	0.50
C)	.007	7.63	0.41	0.42

According to Levene's test and Shapiro-Wilk test, all datasets did not follow the normality and homogeneity. Therefore, the Wilcoxon rank-sum test was performed to determine the difference in performance levels (KDA and "Total Damage to Champions) and experienced years between the groups (high- and middle-skilled players). Gaze movements (horizontal gaze distribution, vertical gaze distribution, ROI, and fixation duration) were analyzed by two-way analysis of variance (ANOVA) with aligned rank transform (ART), non-parametric statistical methods [16], for two skill levels (high-skilled, middle-skilled) and five scenes (Moving, Fighting, Object, Watching, ALL scenes). When a main effect was observed in scenes, a contrast test was performed for multiple comparisons. When a significant interaction between skill level and scenes was observed, the contrast test was performed as the post-hoc test. P values were adjusted by using the Holm-Bonferroni correction method. Partial η^2 indicated effect size for the ANOVA. All levels of statistical significance were set at $p < .05$.

3. Results

3.1. Scene classification result

There was no significant difference between high- and middle-skilled players in Assignment playtime (high-skilled: 1790 sec. ± 328 sec., middle-skilled: 1479.4 sec. ± 626 sec.; Wilcoxon rank-sum test, W = 17, p = .42). A total of 1214 scenes were classified from all participant's game scenes (Moving: 358, Fighting: 419, Object: 265, Watching: 172). There was no significant main effect observed in skill level (F = 0.08, p = .77, Partial η^2 = .008). The main effect was detected in the scene (F = 3.54, p = .02, Partial η^2 = .31). According to the contrast test, the Watching scene had a smaller number than the Fighting scene (p = .03). However, there was no significant difference in other scene compare results (Moving-Fighting: p = .97; Moving-

Object: p = .22; Moving-Watching: p = .09; Object-Fighting: p = .10; Watching-Object: p = .96). There was no interaction effect detected between skill level and scene (F = 0.49, p = .73, Partial η^2 = .01).

3.2. Performance level

The high-skilled players had a longer LoL experience than the middle-skilled players (Wilcoxon rank-sum test, W = 53.5, p = .02). Figure 6 indicates the performance level of each group. The high-skilled players had a significantly higher KDA than the middle-skilled players (Wilcoxon rank-sum test, W = 52, p = .04). Moreover, the high-skilled players had better "Total Damage to Champions" scores on average (high-skilled players: 21567 ± 5328.6, middle-skilled players: 14338.8 ± 14320.2, respectively). However, there was no significant difference in "Total Damage to Champions" scores between the high- and middle-skilled players (W = 48, p = .10).

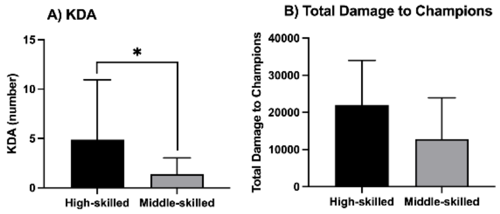

Figure 6: Performance level of high- and middle-skilled players. A: KDA of high- and middle-skilled players. The bars indicate the average of KDA. The whiskers represent the standard deviation of the bar plots. B: average "Total Damage to Champions" of high- and middle-skilled players. The box plots indicate the average of the "Total Damage to Champions". Whisker shows the standard deviation of the bot plot. A significant level was $^{*}p < .05$.

3.3. Gaze distribution

Figure 7 shows the statistical analysis results in gaze distribution. In horizontal gaze distributions, significant main effects in skill level and scene were observed (skill level: F = 5.68, p = .01, partial η^2 = .07, scene: F = 8.56, p < .001, Partial η^2 = .32). Contrast test found that Moving scene had wide gaze distribution than Fighting scene and Object scene (both p < . 001). The Fighting scene had a narrower gaze distribution than the Watching scene and ALL scene (p = .002 and p = .01, respectively). Finally, the Object scene had a narrower gaze distribution than the Watching scene and ALL scene (p = .005 and p = .02, respectively). There was no significant interaction effect detected (F = 0.27, p = .89, Partial η^2 = .01). In vertical gaze distribution, there were no significant main effects and interaction (skill level, F = 0.97, p = .32, partial η^2 = .01; scene, F = 2.26, p = .07, partial η^2 = .11; interaction, F = 0.11, p = .97, Partial η^2 = .007).

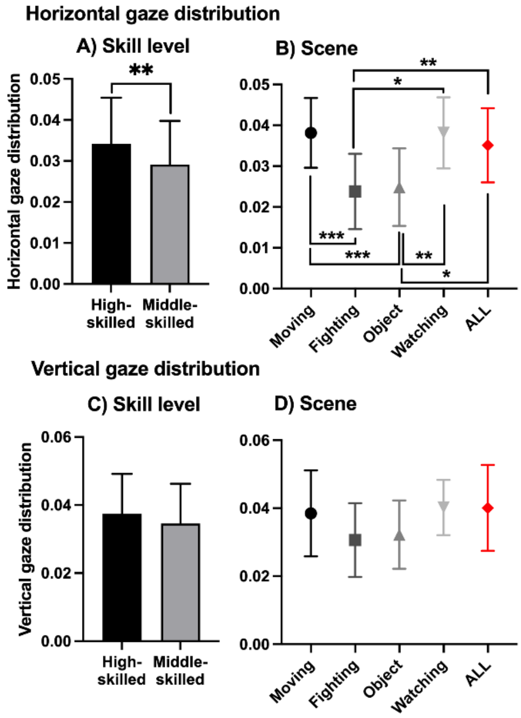

Figure 7: Horizontal and vertical gaze distribution. A, C: Difference between high- and middle-skilled players in horizontal and vertical gaze distribution. The box plot indicates the average of high- and middle-skilled players. Whisker shows the standard deviation of the average. B, D: Difference of horizontal and vertical gaze distribution in each scene. The dots indicate the average of each data. Whiskers show the standard deviation of each data. A significant level was $^{*}p < .05$, $^{**}p < .01$, and $^{***}p < .001$.

3.4. ROIs

Figure 8 represents the percentage of gaze movement in each ROI. Two-way ANOVA with ART revealed no significant main effects (skill level: F = 0.20, p = .65, Partial η^2 = .006; scene: F = 1.94, p = .11, Partial η^2 = .08) and interaction (F = 0.29, p = .88, Partial η^2 = .03) in the Chatting area. In the Skill area, no significant main effect (skill level: F = 0.11, p = .73, Partial η^2 = .03; scene: F = 0.18, p = .94, Partial η^2 = .01) and interaction (F = 0.17, p = .95, Partial η^2 = .004) was detected. In the KDA area, no significant main effect (skill level: F = 0.06, p = .79, Partial η^2 = .001; scene: F = 0.30, p = .87, Partial η^2 = .04) and interaction (F = 0.20, p = .93, Partial η^2 = .04) was observed. In the Mini-map area, the main effect was detected between high- and middle-skilled players (F = 23.23, p < .001, Partial η^2 = .23), but not in scene (F = 0.40, p = .80, Partial η^2 = .01). No interaction was detected in Mini-map area (F = 1.11, p = .35, Partial η^2 = .02). There was no main effect (skill level: F = 0.44, p = .50, Partial η^2 = .01; scene: F = 0.33, p = .85, Partial η^2 = .003) and interaction (F = 0.29, p = .87, Partial η^2 = .004) in the Game scene area.

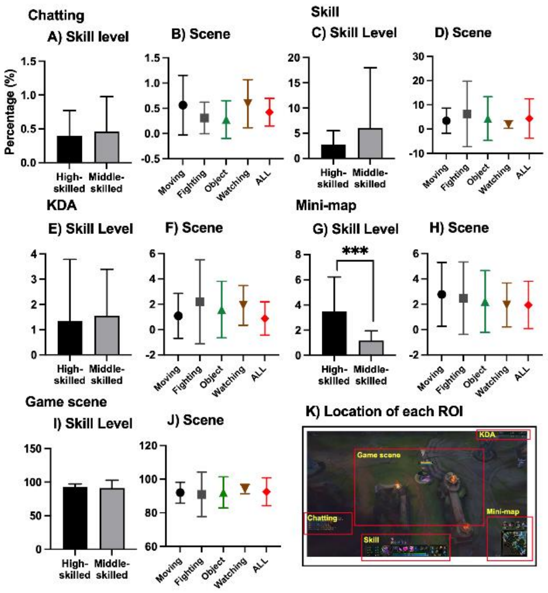

Figure 8: Percentage of gaze position in each ROI. A, C, E, G, I: Box plots indicate the average percentage of ROI. Whiskers indicate the standard deviation of each boxplot. B, D, F, H, J: The dots indicate the average of each data. K: location of each ROI. Whiskers indicate the standard deviation of each boxplot. A significant level was $^{***}p < .001$.

3.5. Fixation duration

Figure 9 represents the duration of gaze fixation in each scene. Two-way ANOVA with ART found that the main effect between high- and middle-skilled players ($F = 7.63$, $p = .007$, Partial $\eta^2 = .04$). There was no main effect of the scene ($F = 0.44$, $p = .77$, Partial $\eta^2 = .002$) and interaction ($F = 0.06$, $p = .99$, Partial $\eta^2 = .002$).

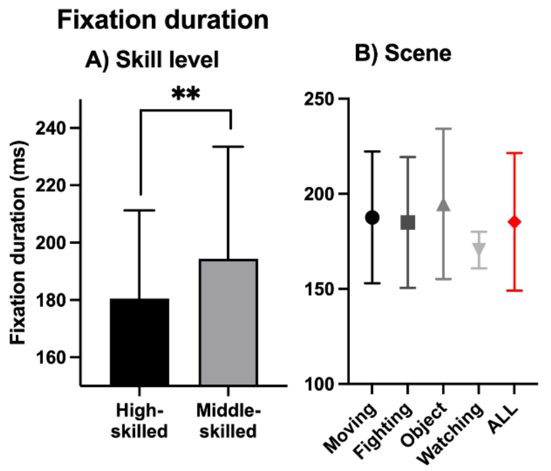

Figure 9: Fixation duration of each scene. A: average fixation duration between high- and middle-skilled players. The bar plot shows the average fixation duration in each scene. Whisker indicates the standard deviation of each bar plot. B: average fixation duration between each Scene. The dots indicate the average of each data. Whisker indicates the standard deviation of each bar plot. A significant level was $^{**}p < .01$.

4. Discussion

In the current study, we investigated the differences between high- and middle-skilled players' gaze movements depending on the situation. The Assignment of the current study (solo-rank game) had participants fight against opponent players in a motivated situation (affecting the participant's official ranking). Moreover, participants fought against the human opponent players. The motivated situation and human opponent players allow the experiment to reveal the source of the high performance of LoL players in actual game situations. In terms of performance level (KDA and Total Damage to Champions), the high-skilled players had significantly higher performance levels (KDA) than the middle-skilled players (Figure 6A). Moreover, the high-skilled players had more experienced years than the middle-skilled players. This result indicates that each group (high- and middle-skilled players) was clearly divided, and high-skilled players had higher performance levels than middle-skilled players. However, there was no significant difference observed in Total Damage to Champions between the groups. Total Damage to Champions is affected by not only the individual performance but also the items and positions that participants used. For example, if participants select the item and position to help the teammate rather than directly fight with enemy players, Total Damage to Champions is naturally decreased.

According to the scene classification result (Result 3.1.), there was no significant difference in the number of each scene between high- and middle-skilled players. In addition, the number of the Fighting scene was greater than the Watching scene. Thus, analyzing the characteristics of the gaze movement as a whole game without categorizing the situation is likely to bias the overall results due to factors related to the specific situations.

According to the results about horizontal and vertical gaze distribution, the high-skilled players had a horizontally wider gaze distribution than the middle-skilled players (Figure 7A). It is well known that dividing the gaze movement into horizontal and vertical directions was common practice in esports studies [4,8,10]. Moreover, previous research points out that gaze distribution and performance level in esports have significant correlations [17]. Thus, analyzing the gaze movement of esports players by dividing the gaze distribution helps to understand the superior gaze control ability of LoL players. Since the monitor is a long object in the horizontal direction, no significant difference between high- and middle-skilled players was caused by the physically short length in the vertical direction. Moreover, the high-skilled players had a shorter fixation duration than the middle-skilled players (Figure 9A). These results are consistent with previous studies that have shown that skilled LoL and real-time strategy (RTS) game players had wider gaze distributions and short fixation times [4,10].

Horizontally wide gaze distributions might be caused by the superior visual processing skills of high-skilled LoL players. Generally, the wide gaze distribution is beneficial for collecting information from a wide area in cognitive tasks and esports [4,10,17,18]. Since the user interface and information in LoL are widely spread on the monitor, it is essential to check the entire screen for the information that LoL players need. Obtaining information not only from a wide area but also quickly is important for achieving high visual processing skills. For example, short fixation time with high task accuracy in cognitive tasks represents high visual processing skills [19]. In fixation duration, high-skilled LoL players had a shorter fixation duration than middle-skilled LoL players regardless of the game scene. This indicates that getting information quickly, regardless of the game situation, might be a superior characteristic of high-skilled LoL players. To sum up, short fixation time and horizontally wide gaze distribution indicate that high-skilled LoL players had superior visual processing skills than middle-skilled players.

Surprisingly, horizontal gaze distribution changed significantly depending on the game situation regardless of the skill level (Figure 7B; H-2). However, there was no significant difference between high- and middle-skilled LoL player's gaze movements in specific scenes (H-1). The results related to H-1 show that LoL players should be able to control their gaze movements for specific situations, regardless of their skill level. The Moving scene had a wider horizontal gaze distribution than the Fighting and Object scene. Participants must move their characters after understanding the overall flow to win the game. To process the visual stimulation, it is necessary to visually check the target first [20]. Thus, it is beneficial for winning the game to distribute the gaze movement and gathers a broader range of information than in the Fighting and Object scene through the wide gaze movement. Fighting scenes and Object scenes have a narrower distribution of gaze than Watching and ALL scenes since more information is concentrated in the center of the monitor. Furthermore, the gaze control ability observed throughout the game (ALL scene) is not the same as that in the Fighting scene. Previous research suggests training to widen the gaze distribution simply since skilled esports players have a wider gaze distribution during games [4]. However, according to the result of the current study, it is necessary to conduct situation-based gaze control training in LoL players regardless of their skill level.

In the ROI percentage of gaze position, high-skilled players had a higher ROI percentage in the Mini-map area than middle-skilled players for two reasons (Figure 8G). First, the game interface is designed to share the information in the Mini-map area. For example, participants were able to give feedback on dangers (e.g., enemy is coming) with icons in the Mini-map area. Second, the overall flow of the Assignment was represented in the Mini-map area. Understanding the overall flow of the game and cooperating with teammates are key factors to winning. According to previous research about RTS game players, high-skilled RTS game players frequently check the overall flow of the games than low-skilled players [4]. RTS game and LoL had similar user interfaces (e.g., the mini-map was represented in the right corner of the monitor). Thus, focusing the gaze position on the information about feedback and the overall flow might be important factors in achieving the high performance of the high-skilled players in LoL.

However, there was no significant difference in the ROI percentage of Skill and KDA area between high- and middle-skilled LoL players (Figure 8C and E). There is a possibility that both high- and middle-skilled players had superior visuo-spatial ability. The visuospatial ability is the capacity to memorize and understand visual-spatial objects correctly [21]. Both information in the Skill area and KDA area were related to the visual and spatial elements. In the Skill area, participants could check the left time of the skills. In the KDA area, participants could see the information about time and KDA. Previous research points out that long-term esports training can improve visuospatial ability [22]. In the current research, all participants had enough LoL experience (experienced years; high-skilled: 9.2 years, middle-skilled: 4.3 years). Thus, it might be able to estimate the information without seeing the Skill and KDA area with high visuospatial ability. Thus, each participant had enough experience to guess what was being displayed without looking directly at the information on the Skill and KDA area.

In the Chatting area, there was no significant difference between high- and middle-skilled players detected in ROI percentage. The reason is as follows: Both high- and middle-skilled players did not prefer to use the Chatting area because typing the chatting takes a long time to communicate with other players. It is important to reduce wasting time to react fast during the game. Therefore, there is a possibility that participants spent less time communicating with other players by using the feedback icons rather than typing a chatting.

The Game scene area is the main area where the game is played. Therefore, the Game scene area had a high importance in both high- and middle-skilled players. High importance might be effect to no significant difference in the Game scene area was observed between high- and middle-skilled players.

5. Limitation

In the current study, we only experimented with eight high-skilled and eight middle-skilled LoL players (small sample size). Thus, some parameters have low power which is related to sample size (see Table 2). It is important to be cautious about applying the obtained results to all LoL players. In future research, conducting the experiment with a large sample size is necessary. To induce the actual solo-rank gameplay situations, we did not strictly control the trial of each scene. Thus, there is a possibility that some scenes might have more or fewer gaze points and affect the gaze movement-related data. Moreover, we did not strictly control the head movement. Therefore, we cannot exclude the possibility that head movement affected the gaze movement data.

6. Conclusion

The current study analyzed the gaze control ability of esports players in various and motivated situations. High-skilled LoL players were advantageous to collect the information from a wide area through a wider gaze distribution and a shorter gaze fixation time than middle-skilled players regardless of the game situation. Since overall flow and communication information had an essential role in achieving high performance, high-skilled players saw the area displaying overall flow and communication information than middle-skilled players. Surprisingly, the gaze control abilities showed significant differences between full games and specific situations, regardless of skill level. Specifically, gaze distribution was wider in game situations, which require focusing on multiple pieces of information simultaneously, than in other situations. Therefore, esports research should investigate the gaze control ability of esports players in separate game situations might shed light on the development of the training method in esports.

Acknowledgments

We appreciate Minjun Kim for providing information on LoL-related knowledge. The current research was supported by the Tateisi Science and Technology Foundation (grant number: 2237004), Meiji Yasuda Life Foundation of Health and Welfare.

References

[1] V. H. S. E. Robertson, "eSports and Digital Ecosystems: An Antitrust Perspective," *J. Eur. Compet. Law Pract.*, vol. 12, no. 8, pp. 591–592, Oct. 2021, doi: 10.1093/jeclap/lpab040.

[2] J. G. Reitman, M. J. Anderson-Coto, M. Wu, J. S. Lee, and C. Steinkuehler, "Esports Research: A Literature Review," *Games Cult.*, vol. 15, no. 1, pp. 32–50, 2020, doi: 10.1177/1555412019840892.

[3] M. W. G. Dye, C. S. Green, and D. Bavelier, "Increasing Speed of Processing With Action Video Games," *Curr. Dir. Psychol. Sci.*, vol. 18, no. 6, pp. 321–326, Dec. 2009, doi: 10.1111/j.1467-8721.2009.01660.x.

[4] J. Inhyeok, K. Nakagawa, R. Osu, and K. Kanosue, "Difference in gaze control ability between low and high skill players of a real-time strategy game in esports," *PLOS ONE*. pp. 1–17, 2022, doi: 10.1371/journal.pone.0265526.

[5] W. R. Boot, A. F. Kramer, D. J. Simons, M. Fabiani, and G. Gratton, "The effects of video game playing on attention, memory, and executive control," *Acta Psychol. (Amst).*, vol. 129, no. 3, pp. 387–398, 2008, doi: 10.1016/j.actpsy.2008.09.005.

[6] A. Klostermann, C. Vater, R. Kredel, and E.-J. Hossner, "Perception and Action in Sports. On the Functionality of Foveal and Peripheral Vision," *Front. Sport. Act. Living*, vol. 1, 2020, doi: 10.3389/fspor.2019.00066.

[7] X. Li, L. Huang, B. Li, H. Wang, and C. Han, "Time for a true display of skill: Top players in League of Legends have better executive control," *Acta Psychol. (Amst).*, vol. 204, p. 103007, 2020, doi: https://doi.org/10.1016/j.actpsy.2020.103007.

[8] F. Ryousuke, and H. Goichi, "Gaze and Electroencephalography (EEG) Parameters in Esports: Examinations Considering Genres and Skill Levels", 2023 International Workshop on Smart Info-Media Systems in Asia (SISA 2023), Aug.31-Sep.1.

[9] M. Mora-Cantallops and M.-Á. Sicilia, "MOBA games: A literature review," *Entertain. Comput.*, vol. 26, pp. 128–138, 2018, doi: https://doi.org/10.1016/j.entcom.2018.02.005.

[10] I. Jeong, K. Kudo, N. Kaneko, and K. Nakazawa, "Esports experts have a wide gaze distribution and short gaze fixation duration: A focus on League of Legends players," *PLoS One*, vol. 19, no. 1, p. e0288770, Jan. 2024, [Online], doi: https://doi.org/10.1371/journal.pone.0288770.

[11] D. Railsback and N. Caporusso, "Investigating the Human Factors in eSports Performance BT - Advances in Human Factors in Wearable Technologies and Game Design," 2019, pp. 325–334.

[12] F. Brühlmann, P. Baumgartner, G. Wallner, and S. Kriglstein, "Motivational Profiling of League of Legends Players," vol. 11, no. July, pp. 1–18, 2020, doi: 10.3389/fpsyg.2020.01307.

[13] M. Kassner , W. Patera , A. Bulling , "Pupil: An Open Source Platform for Pervasive Eye Tracking and Mobile Gaze-Based Interaction", *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*: Adjunct Publication, 2014, 1151-1160, doi: https://doi.org/10.1145/2638728.2641695.

[14] Y. Maeda, "Scene Classification in FPS Game Videos Based on Acoustic Information." 2023 IEEE Conference of Games, 2023, ISBN: 9798350322774

[15] J. Cohen, Statistical Power Analysis for the Behavioral Sciences. 2013.

[16] J. O. Wobbrock, L. Findlater, D. Gergle, and J. J. Higgins, "The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011, pp. 143–146, doi: 10.1145/1978942.1978963.

[17] I. Jeong, T. Nobuto, N. Kaneko, T. Kato, and K. Nakazawa, "Investigating the gaze control ability of VALORANT players using a Python based tool," *arXiv Prepr.,* doi: https://doi.org/10.48550/arXiv2310.15542, 2023.

[18] M. Sanz-matesanz, G. M. Gea-garcía, and L. M. Martínez-aranda, "Computers in Human Behavior Physical and psychological factors related to player ' s health and performance in esports : A scoping review," *Comput. Human Behav.*, vol. 143, no. August 2022, p. 107698, 2023, doi: 10.1016/j.chb.2023.107698.

[19] S. Pannasch, J. Schulz, and B. M. Velichkovsky, "On the control of visual fixation durations in free viewing of complex images," *Attention, Perception, Psychophys.*, vol. 73, no. 4, pp. 1120–1132, 2011, doi: 10.3758/s13414-011-0090-1.

[20] B. D. Cameron and J. López-Moliner, "Target modality affects visually guided online control of reaching," *Vision Res.*, vol. 110, pp. 233–243, 2015, doi: https://doi.org/10.1016/j.visres.2014.06.010.

[21] F. Irani, "Visual-Spatial Ability BT - Encyclopedia of Clinical Neuropsychology," J. S. Kreutzer, J. DeLuca, and B. Caplan, Eds. New York, NY: Springer New York, 2011, pp. 2652–2654.
[22] L. Milani, S. Grumi, and P. Di Blasio, "Positive Effects of Videogame Use on Visuospatial Competencies: The Impact of Visualization Style in Preadolescents and Adolescents," *Front. Psychol.*, vol. 10, 2019, doi: 10.3389/fpsyg.2019.01226.