

EyeChess: the tutoring game with visual attentive interface

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ABSTRACT

Advances in eye tracking have enabled the physically challenged people to type, draw, and control the environment with their eyes. However, entertainment applications for this user group are still few. The EyeChess project described in this paper is a PC-based tutorial to assist novices in playing chess endgames. The player always starts first and has to checkmate the Black King in three moves. First, to make a move the player selects a piece and then its destination square. To indicate that some squares could be activated, while other ones were forbidden for selection, color highlighting was applied. A square with a green highlight indicated a valid action, and the red color denoted invalid action. There were three options to make a selection: blinking, eye gesture (i.e., gazing at off-screen targets), and dwell time. If the player does not know how to solve the task, or s/he plays by making mistakes, the tutorial provides a hint. This shows up a blinking green highlight when the gaze points at the right square. Preliminary evaluation of the system revealed that dwell time was the preferred selection technique. The participants reported that the game was fun and easy to play using this method. Meanwhile, both the blinking and eye gesture methods were characterized as quite fatiguing. The tutorial was rated helpful in guiding the decision-making process and training the novice users in gaze interaction.

Author Keywords

Eye tracking, gaze-driven chess game, gaze-based interaction.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

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INTRODUCTION

With the great improvement of eye-tracking devices in accuracy and ease, the number of gaze-driven interfaces grows very fast [1, 2]. The gaze-based interaction requires from users to be able to control their gaze in a particular manner. Several methods exist to support user attempts to make an action or execute a command in such interfaces. The most common action is the object selection, which in mouse-based interfaces corresponds to the left mouse button click. The most known selection methods are 1) dwelling the gaze [3, 4], 2) intentional blink [5, 6] and 3) eye-gesture [7]. However, for novice users the intentional dwell, blink or gesture could be problematic because of the involuntary nature of eye movements: the eye is the tool to gather information, not to control anything.

Before participants took part in the eye-movement study, Gips et al. [8] trained them using games. The participants were ready for testing after they reached the desired level of success in the game-like target acquisition task. Other researchers supported this idea of using games as the gaze trainer [9, 10].

The games, however, could serve not only as the gaze training tool, but also for the testing interaction methods itself [11] and an evaluation of feedback of the controlling interface [12].

Another set of games have been developed to play employing the gaze as the control media without an intention to use them for training, but for leisure. The famous examples are "EyePainting" and "EyeVenture", developed by Gips et al. [8]. However, these games are not the first known games developed for playing through the manipulating by gaze over conventional graphical user interface (GUI). Nelson in 1992 [13] reported about successful and effective gaze appliance for ball controlling game. During next several years, a number of manufacturers have produced eye-tracking systems and distributed software packages with built-in gaze-driven games [14]. Due to a high cost, low accuracy and inconvenient way of the use of eye tracker systems those games did not become widespread. Nevertheless, the idea of using the gaze as one of the input tools (or/and in cooperation with hands, legs, head and voice) was heavily discussed among researchers and potentials users. An

example is the question raised in one of the games forum [15].

Since early 1970's, games have captured the attention of the researchers who pointed out that it might be useful in studying the processes of high mental activity in attaining the goal. Chase and Simod studied cognitive processes in chess [16]. This game perfectly suits for this kind of studies since it requires a lot of thinking and analysis. Not surprise, those studies were continued with development of more robust eye movements recording techniques and devices. Charness et al. in [17] have built the model of perception during chess game and evaluated a validity of the interface proposed through analysis of recorded eye movements. Not only chess but also other games were used in experimental studies of human behavior in diverse simulated conditions and with different tasks. Aschwanden and Stelovsky used the same methods for evaluation of the cognitive load while playing intellectual and cognitive games, when the subjects were asked to detect an object among others according to some specific parameters [18]. Hodgson et al. explored participant strategies while playing "Tower of London" game [19].

With all mentioned above, games appear to be a powerful tool to use them in visual-attentive interfaces. They can serve for gaze training, to observe user behavior and doing an evaluation of the interaction methods efficiency at the same time. The chess seems to be one of the most suitable games for these purposes. In addition, the game can be developed as the tutor for novices. Sennersten [20] and Kucharczyk [21] investigated the usage of eye tracking in studying efficiency of tutoring games. The authors reported about the promising results in their research.

The goal of this project was to develop a PC-based tutorial to assist novices in playing chess endgames and to carry out a pilot evaluation of the efficiency of the proposed technique. It has been supposed that after the pilot testing the EyeChess software will be explored within framework of GOGAIN project [22]. The size of chessboard squares is similar to software buttons, which have been employed for text entry with the use of eye tracking systems having different resolution. Therefore such a game layout could be especially suitable to check whether the proposed grid cells are large enough to accommodate calibration drifts when different eye tracking systems are being used.

The paper comprises three parts. The first part contains the description of the EyeChess interface design. In the next part we describe a pilot study where the methods of the dynamics of a target selection and the user behavior during an eye-typing task have been investigated. In particular, we were primarily interested in estimating how long the gaze stayed on a key upon selection. The study could also help us to adjust the coefficients of the transfer function as well as the range of dwell time values best suited for the subjects. In the third part, the gameplay algorithm is discussed. Next, the results of pilot evaluation of the

EyeChess tutoring will be presented and discussed. In conclusion, we summarize the problems revealed and the benefits of the game as eye-tutorial.

EYECHESS INTERFACE DESIGN

The EyeChess software was designed as a plug-in to iComponent application [24]. Screenshot of the game EyeChess is shown in Figure 1. The main form occupies the full screen size.

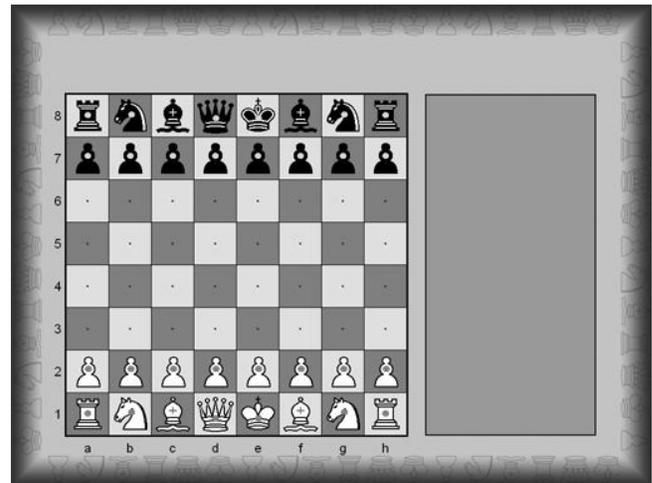


Figure 1. Screenshot of the game EyeChess. The pieces are in original starting positions.

The chessboard field has size of 512 by 512 pixels. It contains 64 squares, that is, each of squares has 64 by 64 pixels in size. Thirty-two standard chess pieces are displayed in original starting positions within the game field. Each piece and square has a dot, which serves as the anchor for the eye gaze. The right-side frame is "a bin" which contains the taken pieces. The field above the chessboard is used for providing instructions and other information.

After an eye-tracker starts gaze direction detection, the player is able to control the pieces. With the gaze movement upon the boards the squares are highlighted. The feedback appears as the pop-up border (Figure 2).

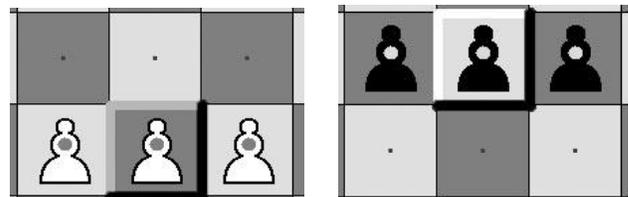


Figure 2. Highlighting and 3D effect to show an active position.

This visual feedback gives the clear hint of what a player is looking at. As shown in Figure 2, the highlighting color corresponds to the square color, that is, the lighter color and the darker one have been used.

The player first has to select a piece. However, empty squares cannot be selected if there is no piece selected yet. If an attempt has been made to choose an empty square, the application plays the sound with slightly negative connotation. Chosen piece will be highlighted with the dark-yellow color, which is easily distinguishable on chessboard.

When the player gazes around within the board, other squares are highlighted according to the ability to move the piece on it (Figure 3). The allowed squares will be highlighted with the green color while forbidden positions will be highlighted with the red color.

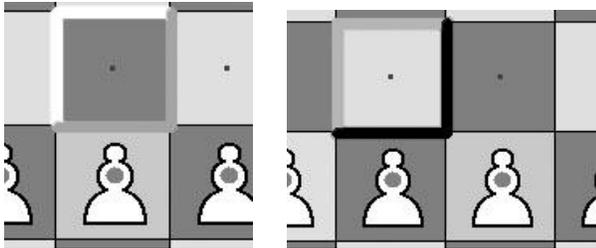


Figure 3. The allowable move (the left picture) and forbidden move (the right picture)

If the destination square was chosen (it appears with light-yellow background), the application performs the animated piece movement from the current position to the target one (Figure 4).



Figure 4. Animated movement of the piece.

If the player tries to move to the forbidden square highlighted with the red color, the application plays the same alert sound to inform that the move is not allowed. Such an attempt is not considered as the wrong move. The wrong move is the attempt to move any piece to the position with the green highlight, when the piece or the move destination does not correspond to the predefined pattern by the task scenario. In case of the attempt to make such a move the application plays the alert sound with very negative connotation. Thus, the tutorial prevents players from the wrong moves.

After two or more wrong attempts were made, the player may check whether the piece, s/he is moving, is the correct one. For this, s/he must look at other pieces one by one. The correct piece will have a blinking green highlighting. If s/he did not find a blinking piece, it means that the piece already selected is the correct one. If the player still has no idea what the correct move is for this piece, s/he can search for the square (empty or occupied by an opponent's piece) with a blinking green highlighting. If the selected piece was wrong and the player found the correct (i.e., blinking)

position, the target square looked at will not blink, unless another wrong move is made with the newly selected piece. The algorithm is presented in Figure 5.

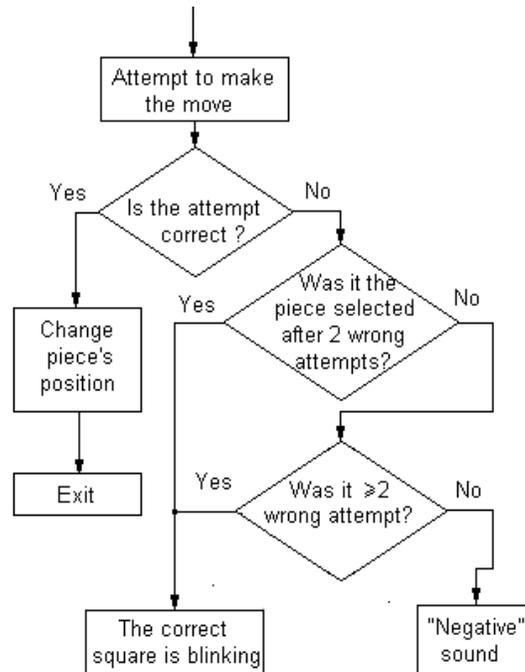


Figure 5. The gameplay algorithm to support the correct square recognition.

PILOT STUDY

Gaze-based selection methods

The EyeChess game requires a method to choose pieces. To find the best way of interaction, a pilot study was conducted. Three methods were implemented in the EyeChess software: selection by dwell, by blink and by gesture.

Employing the first method, players must to spot at a piece (square) for a certain time to select it. This is the most popular target selection method in gaze-controlling interfaces [3]. The dwell time is the crucial criterion. Since the nature of chess tasks supposes a lot of thinking to make a decision, the dwell time can be long enough to let players to consider the arrangement of chess pieces without unintentional selection, and not very long, since it is hard to keep the gaze stable for a long time. Based on an empirical estimation, the suitable dwell time is of about 1.8 seconds.

Using the second method, it is supposed that the players have to blink while gazing at the square to select it. Nevertheless, this method is not much popular, some researchers believe it may be usable in interaction with computer [30, 31], some of them even reported about successful appliance of blink for this purposes [34]. To avoid selection because of unintentional blinks, the selection algorithm accepts blink with the duration 350-

1000 ms only. Shorter blinks can be accidental, and the longer are hard to keep [26, 27, 28].

The selection by gesture requires off-screen target that the player must quickly look at to select the square they just left. This method has been applied in some studies as well [5, 30, 32, 33]. The off-targets are placed in four corners of PC monitor. The selection gesture can be produced by the next way: the player finds the square to select, moves his/her gaze upon one of the off-screen targets and quickly (at most 1 second) backs to the same square or near to it. The fixation occurs at the 3 degrees distance at most from the previous fixation on the screen. These gestures were selected according to advices of Ravysse et al. in [25].

Both eye-gestures and blinks have no “Midas-touch” problem as the dwell time has. However, these methods require unnatural eye behavior and may be inconvenient for some reasons. To check the possibility to use different techniques for target selection in game script, the pilot study was conducted.

Participants

Three un-paid volunteers (2 males, 1 female) participated in the preliminary testing. All of them were students at the University of Tampere. One of them wore glasses and two subjects had prior experience with eye tracking technique.

Equipment

The test was conducted on a Pentium III 733 MHz PC with a 17-inch LCD monitor with a resolution of 1024 x 768. A remote eye tracking system iViewX from SensoMotoric Instruments served as the input device.

Procedure

The subjects were asked to move any 10 pieces which they would like to the positions allowed as quickly as possible regardless to errors by using each gaze-based selection method. The completion time was measured and after the test all the subjects were asked to comment their preferences regarding each gaze-based selection method.

Results and Discussion

The first selection method (by dwell) took 3.3 s in average to make a selection; the second method (by blink) took 2.5 s and the last one (by gesture) took 2.8 s. The fastest way appears to be the selection by blink, and the slowest selections were made through dwell. But the subjective opinions reported were sorted in the opposite way: the selection by dwell was recognized as the most convenient technique for target selection, and other 2 methods were recognized as “equally unsuitable/bad”. These results coincide with conclusion made by other researchers [28, 29].

The target selection through dwell time was chosen for the interaction in the EyeChess game. The 1.8 seconds dwell time was recognized as the close to the most suitable for such a case.

THE EFFICIENCY OF THE EYECHESSTUTORIAL

Participants

Four un-paid volunteers (1 male and 3 females) who did not take part in the pilot testing participated in the evaluation of the efficiency of the EyeChess tutorial. All of them were students at the University of Tampere. All of them had a normal vision. Two of them had prior experience with eye tracking technique and two subjects have never used eye-based input technique. All the participants had only a very little or no experience in chess game. However, all of the subjects knew how the pieces move.

Equipment

The experiment was conducted on a Pentium IV 3.06 GHz PC with a 19-inch LCD monitor with a resolution of 1024 x 768. A remote eye tracking system Tobii 1750 from Tobii Technologies served as the input device.

Procedure

The subjects were provided with basic guidelines in a written form about piece selection, piece movement, feedbacks and hint supported by EyeChess software. Then supervisor instructed them to solve endgames in 3 moves in all tasks. The supervisor explained that they have to play “whites” and computer plays with blacks pieces; thus, the player should perform the first move. After eye tracker calibration was completed, the subjects were asked to train in the use game interface while solving two tasks.

In total, the players solved 20 tasks without any break between. At completion the task players were congratulated by sound of applause.

RESULTS AND DISCUSSION

The average solving time was of about 71.4 second ($\sigma=19.3$) in total. However, of about 78% of this time (56 s) the players spent to find the first correct move. The second and third moves took of about 9.6 s and 5.8 s respectively (Figure 6).

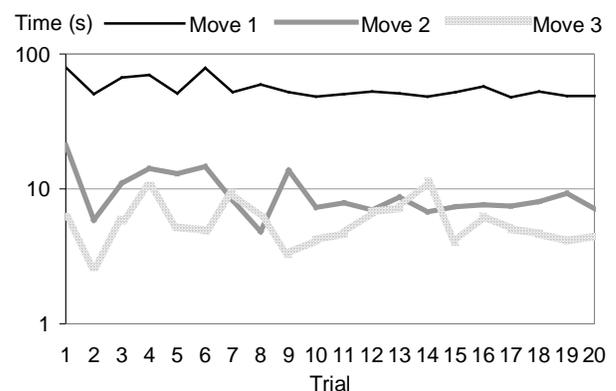


Figure 6. The task completion time in the game progress.

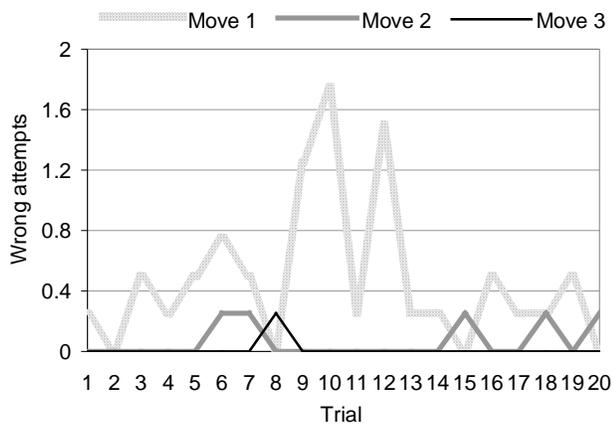


Figure 7. The wrong attempts committed in the game progress.

Of about 18% of all attempts to move were wrong ($\sigma = 6\%$). As it was expected, the greatest part of them (34%) was collected while players were trying to make the first move. While making the second and third moves, only 6% and 1% of the attempts have been recognized as wrong (Figure 7).

In almost every tenth task (9%) the players attempted to make a wrong move, at least 2 times. In such a case all of them found the hint (blinking square). Nobody made 2 or more wrong attempts after the first correct move was found.

While making an attempt to move, the piece was not the correct one in 8% of all attempts ($\sigma = 4\%$), and the attempts to move a piece at the first time in 21% were incorrect because of this reason. The next moves led to the wrong choice of the piece as less as 1% of attempts. However, the players often selected a wrong piece (23% in overall), and then changed their mind and did not move it. It has been observed in 58% cases before they made the first correct move. Then, such a gameplay behavior has been occurred rarely – in 5% and 6% before the second and third moves accordingly. It seems that after the first move was performed, the player did mistakes or selected wrong pieces only because of the calibration drift.

It seems that the players were stressed during the first 7 tasks. They tried to analyze the given task carefully and this resulted to a long thinking. Then they relaxed and this led to more errors (trials 9-13 in Figure 7). At the end all players solved tasks faster than at the beginning. The wrong attempts after the first successful move have been occurred rarely.

CONCLUSION

The EyeChess software was developed and tested in a pilot research. The gaze-based tutorial is intended to assist novices in playing chess endgames. When the player does not know how to solve the task, or s/he plays by making mistakes, the tutorial provides a hint. This shows up a blinking green highlight when the gaze points at the right square.

The pilot study revealed that dwell time was the preferred selection technique than blinking and eye gestures (i.e., gazing at off-screen targets). The study in the efficiency of the EyeChess revealed that the software tutorial was helpful in guiding the decision-making process. However, the tasks were too easy and the EyeChess tutoring support was rarely used.

The average completion time per trial at the end was noticeably shorter than at the beginning. However, both groups of the players showed the same progress. Thus, no significant improvements in the gaze interaction were found.

Overall, the game is eye tracker-friendly and easy to play, as the pieces and squares on the chessboard are large enough to accommodate calibration drifts with different systems used.

FUTURE WORK

The project will be continued to support both novices and experts. The author plans also to extend the game to a full-range game with an opponent: a computer or another player over the net.

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