Quantitative Analysis Of Gaze Patterns Differences between Novice and Experts in Chess

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1 INTRODUCTION

One skill that is vital to a chess player is the ability to analyze the chessboard and recognize positions that are threatening or beneficial. This skill becomes increasingly important when the pieces are developed unconventionally. Typically, expert chess games will follow common patterns that begin with openings that have been studied by each player. Expert players study variations of openings to use against their opponents (Queen's Gambit, Sicilian Defense, Italian Game). Using these openings will position the pieces on the chessboard in a conventional way that is recognizable by expert players. Chase and Simon [1, 2] studied the ability of chess players to memorize and recreate the positions of pieces on a chessboard. The results showed that masters performed similarly to beginners when the positioning was random. However, master players placed more pieces correctly when the position was not random. The goal of this study is to explore the difference in the performance of expert and novice chess players when tasked with finding the best move for a given puzzle. In this study, the puzzles will be limited to ones that will have a definite best move. An example is a puzzle that will result in a one-move checkmate. The motivation for this study is to explore differences in the performance between expert and novice chess players that are not related to memorization. We hypothesize that not only will expert players select the best move more often, but will also select the best move more quickly than novices.

2 BACKGROUND

In gaining a deeper understanding into human cognition, perception, and visualization, many sources of literature revolve around the practice of chess. Due to the varying levels of complexity and magnitude associated with the game, chess player's serve as ideal participants due to their heightened abilities to analyze and interact with puzzles. As such, in tandem with observing differences between different skill sets of chess players through eye movements, two such hallmark studies that stand out, the first of which is one conducted by Heather Sheridan and Eyal M. Reingold [3]. Sheridan and Reingold's experiment dealt with analyzing complex visual patterns associated with eye movements measures such as "first fixation duration, first dwell duration." While this study provided key insights into expert vs novice chess players cognitive ability and reaction times, the results were limited to participants moving only one piece over several different trials, thus providing flat results based on one-dimensional variables. The second pair of the two hallmark studies was one conducted by Chase and Simon [1, 2]. As mentioned earlier, their studies revolved around chess experts ability to make the best move based on memory recognition. While memory is a key factor, we believe that it only serves as one of several facets by which human's abilities to perceive complex patterns and puzzles can be analyzed. As such, our experiment hopes to build upon these two benchmark studies, and dive deeper into analyzing participants eye movements and perception. We hope to achieve this by subjecting chess players of varied skills to multi-dimensional variables and randomized puzzles in an effort to extract more robust and quantifiable results.

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3 METHOD

3.1 Apparatus

Eye movements were measured with a pupil corneal reflection video based Gazepoint GP3 high performance remote eye-tracking device that utilized a 60Hz machine-vision camera at the heart of its imaging and processing system to provide a high spatial resolution. The device is detailed to be exceedingly precise, landing within 0.5-1 degree of visual angle accuracy as per manufacturer guarantee. Participants viewed the puzzles on a standard Dell 19" monitor while seated comfortably in a sturdy office chair. A iPad Pro 11-inch accompanied by an Apple Pencil was used to mark movements on the puzzle board to record participants (See Figure 1)

3.2 Stimulus

Each participants (white piece) evaluated the 5 puzzles (see Figure 1 for an illustration). While not as important, there are two shaded squares indicating the piece moved from what square. This piece is the most recent move made by the black piece (opponent). Each board were randomly generated and selected for the experiment. In other words, no board is constructed to be harder or easier than the other.

3.3 Participants

8 chess players (4 experts and 4 novices) were recruited from campus chess club at Clemson University, South Carolina. The novice participants had a chess rating between 800 and 1400. The expert participants had a chess rating above 1800. Chess ratings range from 0 to 3000+. The status of expert and novice is only relative to

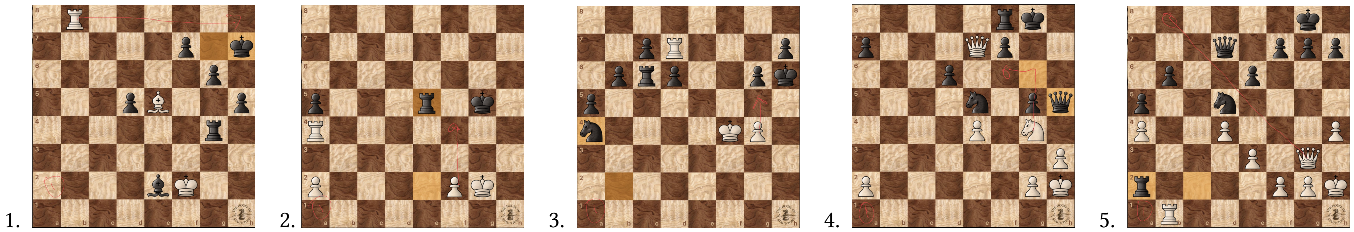

Figure 1: Expert Participant 1 - ***Images obtained from Pupil corneal reflection video based Gazepoint GP3 remote eye tracker***

the chess club in this establishment. The mean age was 25 years old in the expert group and 26 years in the novice group. There was four of male (unable to recruit any female experts) in the expert group and one male/three female in the novice group. All participants had normal or corrected-to-normal vision. Three participants wore glasses/contacts. Written informed consent was obtained, and the rights of the participants were protected.

3.4 Experimental Design

The experimental stimuli consisted of 5 different chessboards. Each puzzles were new games at different phases. Meaning that the previous stimuli decision were independent to the next and so on. Participants were allowed only one move per puzzle. The objective of this design was to examine the eye patterns that led to their "best move". Best move was described as what would help them best achieve the end goal (winning). In other words, a move that would put the opponent's King at check may not be the "best move" because the next round the King can simply move away. This evaluated the value factor of instant gratification. Because each games were independent and at random (for the participants) phase of the game, participants were given 2 minutes. This was enough time for participants to evaluate the current puzzle and then make their decision while still under a time constraint. The opponent was a Level 10 Computer, the maximum difficulty level for the AI (Artificial Intelligence). There was a combination of Minimax and Alpha-Beta pruning algorithm used by the Computer, with the level indicating the depth it would search. The higher value was the measurement used to determine the "best move".

3.5 Procedures

Prior to the experiment, the participants were asked what chess rating they were, using our pre-experiment questionnaire. They were instructed to evaluate the puzzle and play what they would consider to be the best move. They were briefed on what "best move" meant and the time constraint. At the start of each trial, the participants were required to calibrate the equipment to their fixation. Once calibrated, the participants were then instructed to fixate their gaze to the center of the screen before each puzzles were displayed. Participants were explained to treat this experiment as a slide show. First screen will be a blank black screen, and every other "slide" to prepare for next puzzle. When they were ready to see the starting/next puzzle, press space. Repeat process until last puzzle. A one minute timer would start once the new puzzle was displayed, and automatically moves on the to the next slide (black screen). Participants whom were unable to make a decision once screen transitioned, they were told to either make a quick guess or leave blank and moved forward with the trial. If a decision was made, participants press space to indicate to one of our experimenter they've made up their mind. The experimenter would then lay in front of the participant the same puzzle. They must immediate draw, in some shape or form, what piece moves where (see Figure 1). The participant id, puzzle number, time remaining, and value were recorded on a table for each trial and iteration. There were 8 trials with 40 total iterations for the experiment.

4 RESULT

Our main goal was to answer why expert chess players are able to play better chess compared to a novice chess player. To understand this, We will first compare the accuracy (correctness and time) between the expert group and novice group. Then we will examine further within the groups and compare the accuracy of individual participants. Lastly we will analyze the eye movement and compare it just the same as the accuracy analysis.

4.1 Group Accuracy

For the most part, the expert players performed as expected, with an overall *95* percent correctness level in solving the puzzles. Furthermore, all experts completed each puzzle well under the one minute time limit with an average completion time of *63.75* seconds from start to finish (*excluding introduction and preparation*). On the other hand, novice players incorrectly predicted the **best move** on more than half of their puzzles with only *40* percent correctness. In comparison, the novices averaged a much slower completion time of *191* seconds from start to finish. Two of our participants ran out of time on total of three puzzles. One participant was unable to mark a move on two of their puzzles. The other participant ran out of time as well, but still managed to mark the puzzle. As noted in **Procedures**, participants were informed they can leave puzzle unanswered if they ran out of time and did not have a best guess.

4.2 Individual Accuracy

In terms of individual performance, only one expert made a mistake on one of their puzzles. Other than that one anomaly, expert players accuracy was fairly consistent with their run through. Expert players ran through the experiment with ease with little to no display of stress. The variance in novice players differed far greater than anticipated. Unlike the expert players, novice players lacked consistency in accuracy as well as time spent completing each puzzle. We looked at each puzzle and analyzed the chess piece and the placement.

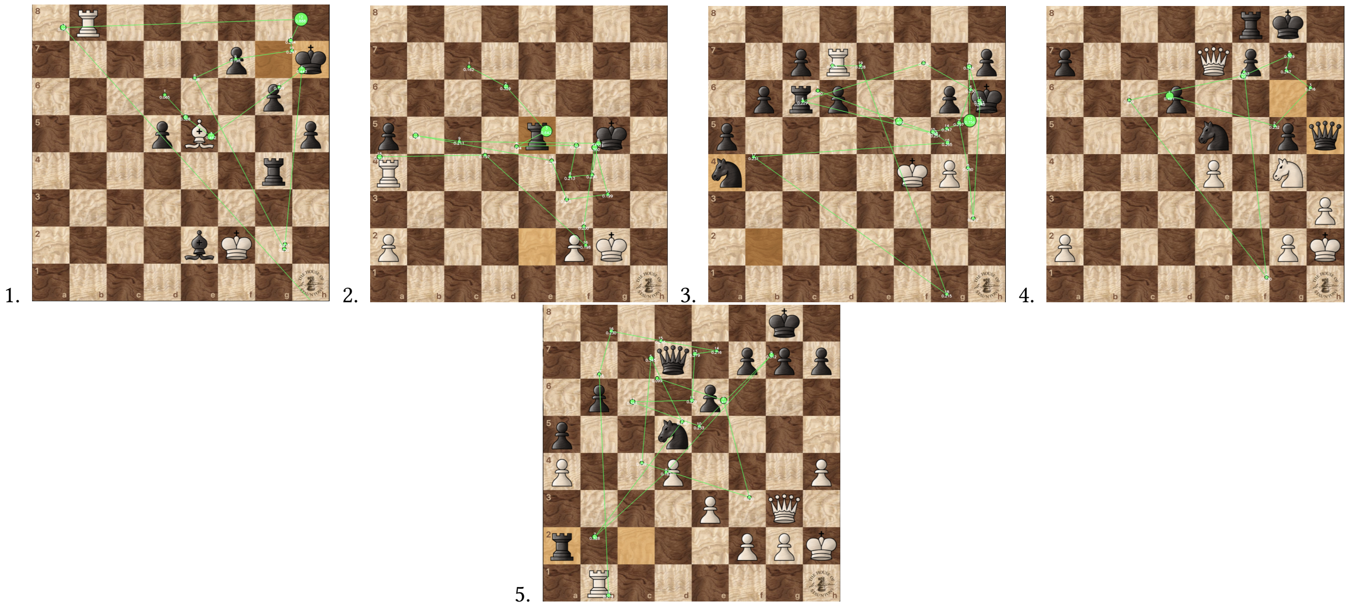

Figure 2: Expert Participant Gaze Patterns

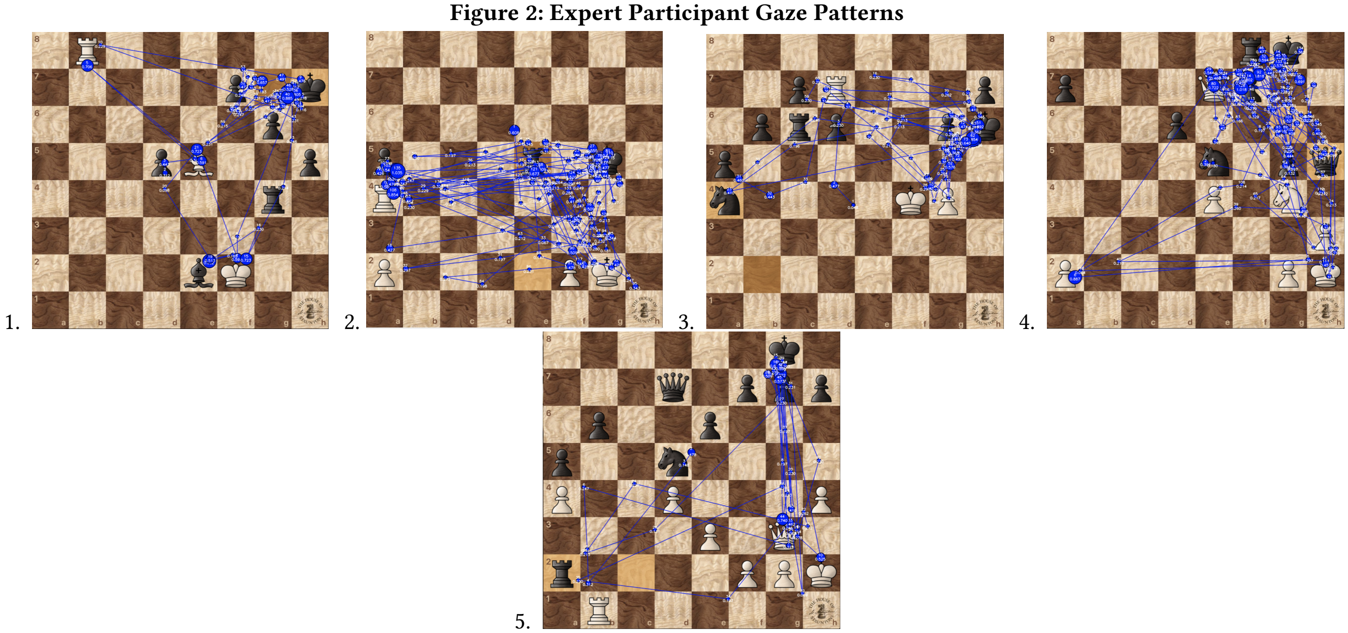

Figure 3: Novice Participant Gaze Patterns

Images obtained from Pupil corneal reflection video based Gazepoint GP3 remote eye tracker

4.2.1 ***Puzzle 1.*** One expert player made an incorrect move on this puzzle. The participant moved an incorrect piece, but coincidentally moved that piece to the correct square. Upon further analysis, even though this was not the best move, the position held value as the game would have progressed.Two of the four novice participants made an incorrect move on this puzzle. One participant moved the correct chess piece, but to the wrong position. The position was far from where the best move was. The move gave little to no advantage for the participant in completing the objective. The other participant picked the wrong piece but made a more logical movement. The selected piece, however, had no way of completing the objective given the range of movement it has. All participants finished within the time limit on this puzzle. However, the novice group overall average time was the highest on this puzzle than any other.

4.2.2 ***Puzzle 2.*** Three of the four novice participants made an incorrect move on this puzzle. One participant failed to make a move after the time ran out. The other two participants made similar type of error as Puzzle 1. This participant had picked the correct piece, but made the incorrect move. However, the movement was in the right direction and was only off by a square. The last participant picked the wrong piece, but made a very logical move, though still incorrect. The move put the opponents King into check, and given the range of movement the player's piece has, it theoretically would have been possible to take the King. Unfortunately, the player's move put that piece into a position of being taken in the next play. Expert group still performed well in time, whereas the novice group still fared high average completion time.

4.2.3 ***Puzzle 3.*** Two of the four novice participants made an incorrect move on this puzzle. One participant failed to make a move after the time ran out. The other participant made a move that had no strategic value. At this point, data started to show a pattern for time completion. Experts have kept a consistent completion time, with only a couple of outliers. Novices again decreased in overall completion time, though it was still high compare to the experts. This carried on through the rest of the puzzles. yo yo yo

4.2.4 ***Puzzle 4.*** Two of the four novice participants made an incorrect move on this puzzle. Both participants who got this puzzle incorrect, managed to made a very similar error. Both moved the same piece with the move resulting only a square away from each other. However close the result was, the implication on the next play resulted very differently. One had the advantage of getting a check on the King, but would be taken by the opponent next play. The other player took a safer approach, but the value quickly reduces as the game goes on.

4.2.5 ***Puzzle 5.*** Three of the four novice participants made an incorrect move on this puzzle. One participant ran out of time, but still marked their movement onto the puzzle. Similarly as above puzzles analyzed, the participants either moved the incorrect piece or incorrect movement.

One of the primary take away from analyzing our novice participants is noticing a lack of pattern. The variation of mistakes made per puzzle also reflects per participant. Not one participant made the same type of mistake all the time. Each participants were inconsistent in the degree of their mistakes, varying from moving the wrong piece, making the wrong move, moves with no value, or moves that seem logical (holds some value) but still incorrect.

4.3 Group Eye Movement Measures

Both experts and novices had consistent gazes within their respective group. It can be seen on Figure 4, 6 and Figure 5, 7 why experts had far lower average completion time than novices. Experts focal point was strictly on the objective, spending little time fixating on one point. Novices were more adventurous in learning the puzzle. However, even when they reached the same focal point as the experts, they were hesitant in deciding what was the best move. We can see from Figure 5, 7 the constant back and forth.

Figure 4: Expert Group Gaze Patterns - Puzzle 4

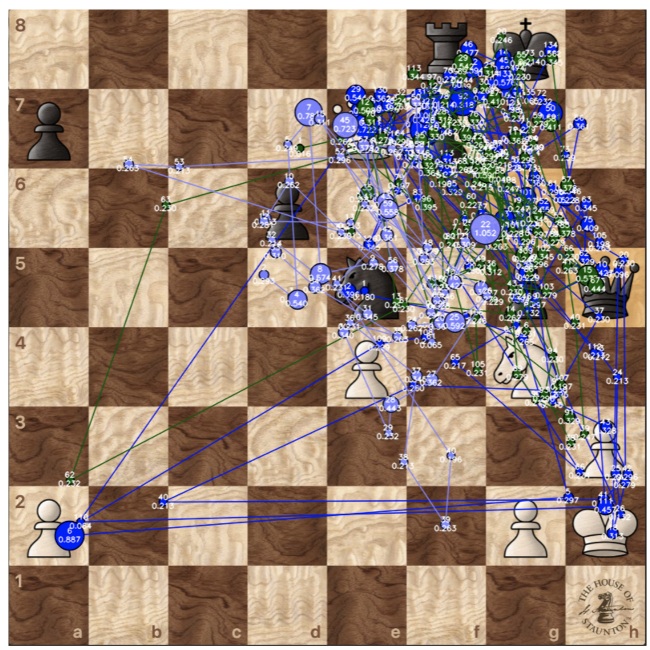

Figure 5: Novice Group Gaze Patterns - Puzzle 4
Images obtained from Pupil corneal reflection video based Gazepoint GP3 remote eye tracker

5 DISCUSSION / CONCLUSION

The culmination of this experiment provided us with several key outcomes in regards to saccadic eye movements between expert and novice chess players. Upon Gazepoint analysis of the chess boards, one apparent distinction that stood out between novices and experts was eye-movements focused on regional areas of the board amongst the latter group. In regards to experts as a holistic group, the eye-tracking experiment revealed that the scan-paths

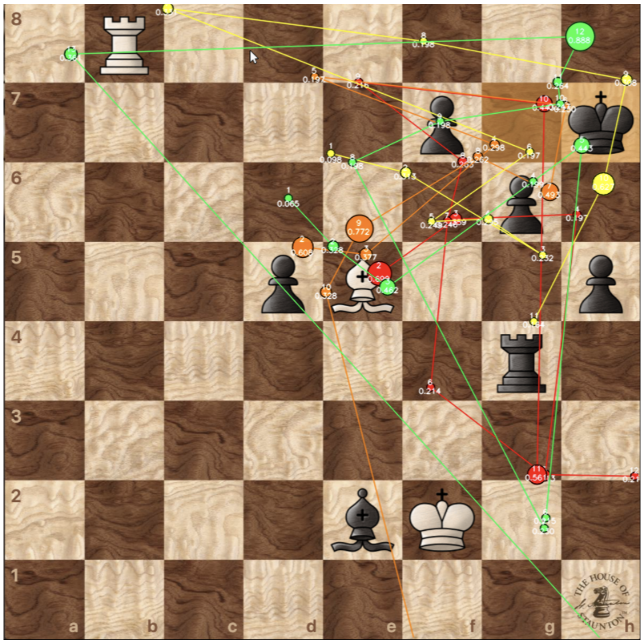

Figure 6: Expert Group Gaze Patterns - Puzzle 1

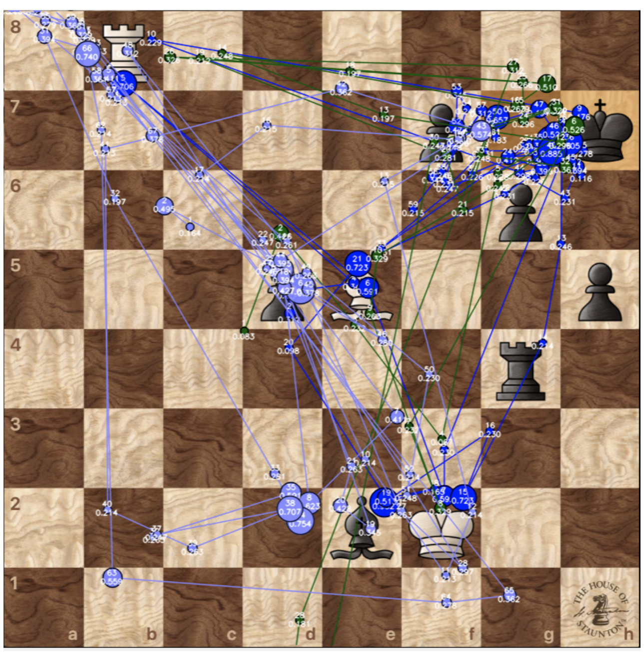

Figure 7: Novice Group Gaze Patterns - Puzzle 1
Images obtained from Pupil Corneal Reflection Video based Gazepoint GP3 Remote Eye Tracker

of all 4 experts were nearly identical in that their eyes fixated on similar regions of the board over all iterations. Experts saccadic movements were heavily focused on areas near the chess piece that would end up being pivotal in making the best move. All other irrelevant pieces and non-pivotal quadrants of the board were often ignored after the first overview scan. This indicates that experts were able to quickly zone in and identify the correct piece that would make the "best" move. On the other hand, the saccades of novices were far more diverse and exhaustive in comparison. As depicted in Figure 3, we noticed that novices scanned the entire board looking at non-relevant areas trying to follow each individual chess piece's range of movement regardless of whether or not that piece was actually essential in making the "best move." Often times, novices fixated on the same areas and pieces multiple times illustrating their indecisiveness - a feature that was clearly absent in the fixations of experts who knew exactly where to look and what move to make. This outcome is buttressed and quantifiable by the amount of time that the experts took, which was just over 60 seconds to complete all 5 puzzles. In comparison, novices finished all 5 boards in nearly triple the time, taking on average 191 seconds for completion. Within the experts as a group, we realized that while all participants tended to be more concise and decisive within their eye-movements, there was still a little spread in where they looked within the relevant regions of the board. From Figures 4 and 6, we can see that while all the experts looked in the same region near where the best move was made, the difference lies in the extremities of their eye movements. For example, expert participant 4, outlined by the green line, looked at regions near the bottom end of the puzzle. Similarly, expert participant number 1, depicted by the red line, also had a comparable scan path to participant 4; however, this was different from the peripheral gaze of participants 2 and 3. Upon further analysis of participants 1 and 4, we gleaned that not only did they have the highest ELO ratings amongst all expert participants but that they also verbalized their moves using algebraic notation, such as "Rook to H8." As such, the letters and numbers of algebraic notation are listed on the bottom and left boundaries of the board, which helps explain why experts 1 and 4 looked near those areas. In comparison, the pattern that stood out between all novice participants was their tendency to look at irrelevant pieces and regions of the puzzle. As can be seen from Figures 2 and 7, novice participant 5 shifted their gazed over almost every piece in all 5 puzzles. Similar patterns are seen with the other 3 novices. Unlike the experts who gravitated their gaze over certain pieces in the same order as other experts, we noticed that novices tended to look over all regions of the boards in random order. This seems to suggest that experts thought of possible outcomes in a similar fashion that might stem from their years of experience of playing chess and are able to recognize similar board positions from the past. These findings have been supported through similar research conducted by Chase and Simon [1, 2] who found that expert chess players encode chess configurations that they've seen over years of experience into memory and are able to recognize similar chess formations and apply past solutions to solve current problems.

In retrospect, the findings of this experiment aligned with our hypothesis. Not only did expert participants pick the "best move" more often, as witnessed by a 95 percent accuracy rate, but they also finished the puzzles in a third of the time it took for the novices. These outcomes and the analysis behind it is stanchioned by relevant literature on the topic and can be used by future researchers to delve into subject matter concerning eye movements and cognitive processes.

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