No Next Box, No Experts: A Special Case of Epistemic Behavior in Extreme Tetris Expertise

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Abstract

How do extreme Tetris players observe, decide, and place Tetris blocks in less than one second? One explanation could be they engage in epistemic *sampling* by observing the identity of the upcoming Tetris block presented in the "Next Box" and then using this information to help place the current block and the unknown block after the next one. Epistemic action is not new to the study of Tetris and refers to performing actions in the world because they are too computationally difficult to perform solely in the head. However, this special case study of Tetris experts proposes that they engage in epistemic *sampling* or gathering knowledge from the world about the near future to help in decision making for the present and for the slightly-farther-than-near future. Epistemic action and epistemic sampling serve different functions in Tetris. Whereas the former is typically attributed to novices moving blocks around to envision different placement options before choosing the best one, the latter is for extreme experts to make block placements while ensuring they are always ready to score tetrises. This account is drawn from observing the remarkable outcome that *not one extreme expert at the Classic Tetris World Championship was able to score a single tetris when the Next Box was disabled*. Observations from this special, one-time, case study tournament are reported and compared to how these same experts performed during the tournament when the Next Box was used as normal. The considerable difference between their two performances provides a rare opportunity to shed insight on what contributes to extreme expert performance in the real world.

Keywords

epistemic, Tetris, planning, expertise, skill acquisition, epistemic sampling

"*Ideally, you're not just planning for the next piece, but for the third, fourth, fifth pieces and beyond.*"
Jonas Neubauer, 8-time Classic Tetris World Champion

Introduction

Epistemic action refers to using "the world" to complete certain cognitive tasks that are too overwhelming to do entirely in one's head. Each time you have used a GPS to get someplace or written a grocery list, you have used the world as an aide in your memory and cognition. Some 30 years ago, Kirsch and Maglio (1994; Maglio & Kirsch, 1992) used the Tetris game to study how seemingly useless actions performed in the world were actually goal-directed. Their research participants rotated and moved game blocks to help identify them or visualize their different orientations. According to Kirsch and Maglio (1994), "Rotations and translations occur in abundance, almost from the moment a zoid enters the Tetris screen. If players actually wait until they have formulated a plan before they act, the number of rotations should average to half the number of rotations that can be performed on the zoid before an orientation repeats" (p. 523). The authors thus distinguished between pragmatic action, intended to shorten the distance between current and desired goal states, and epistemic action, intended to uncover unknowns or to facilitate solving perceptual problems. According to Kirsch and Maglio (1994), epistemic actions serve one or more of the following functions: (1) reducing the memory involved in mental computation, (2) reducing the number of steps involved in mental computation, and (3) reducing the probability of error of mental computation. Later, I will return to consider these within the framework of extreme Tetris. For now, understand that epistemic action is used to work out problems by using the world like a virtual scratch pad before implementing a solution.

Presumably, the more familiar one becomes with a problem space, the less one is in need of external problem-solving aides. A college student, for example, would no longer need to perform long division on scratch paper to report that 105 divided by 10 is 10.5, whereas a fourth grader might. Destefano et al. (2011) showed this to be the case when they demonstrated that seemingly superfluous behaviors among those with greater-than-novice Tetris expertise were related to goal-switching and not to epistemic action. Though epistemic action is largely attributed to novice behavior, the current case study considers epistemic behavior at the extreme end of the Tetris skill spectrum by studying the behavior of players who compete annually in the Classic Tetris World Championship (CTWC). We can presume that epistemic action would not occur among CTWC players because they are so familiar with the game that most block patterns and configurations are known to them. Furthermore, CTWC players have about one-half to one-third of a second to place a block when the stack is midway high on the gameboard. We can therefore presume that epistemic action could not take place with such limited time. Though there is not sufficient time, that does not mean there isn't sufficient opportunity for *the information in the world to be sampled* to reduce uncertainty and help in decision making. Specifically, players are privy to the identity of the next game block that will spawn and are able to use this information to assist in deciding where to place both the current block and the block that will appear after the next one.

This proposition of epistemic sampling to explain aspects of extreme Tetris expertise was developed post hoc after observations made during field research. As such, this paper does not represent a formal study such as one conducted in the laboratory, with the sample size determined in advance, and incorporating thousands of observations. Indeed, Kirsch and Maglio's original observations of epistemic behavior in the Tetris game were also originally framed as a case study (Maglio & Kirsch, 1992). Following suit, it is my hope that my explanation for the differences in behavior in this inductive field study will spark a conversation about the nature of epistemic behavior in extreme expertise. This approach is advantageous as ecologically valid studies of extreme, real-world performance are rarely replicated in the laboratory. Insofar as this paper approaches the problem differently because it (1) inductively began with observations rather than being purely theoretically motivated from the start, and (2) was carried out in the real-world with no real controls in place, it still provides valuable insights into expertise, and it represents an exclusive, one-of-a-kind window into expertise that may never again be open.[1]

In this paper I propose a data-based hypothesis to explain one facet of extreme Tetris behavior: that is, the acquirable skill to decouple action from planning, weigh alternatives within constraints, and consider hypothetical alternatives to help make decisions, all while playing out the motor routines that result from those decisions being made. For the purposes of this paper, I am terming this *epistemic sampling*. This concept is important to the field of expertise because of the fragility of the homeostatic state extreme Tetris experts work to maintain. That is, expert players must constantly trade off the risk between topping out and losing too soon or missing an opportunity to score and falling behind their opponent, all while cleaning up any mistakes. They are managing all of this with just one piece of information: the upcoming block displayed in the Next Box. As a result, a hallmark of extreme Tetris is *situational awareness*.

Before looking more closely at my proposal that epistemic behaviors may also be as useful for understanding extreme Tetris play as they have been for understanding novice play, a brief introduction to the game is necessary, followed by a contrasting of key behaviors in novices and experts. I will then describe the components of situational awareness which make this skill so meaningful for extreme Tetris play. My observations made during this one-time special event are then presented. The work ends with a definition of epistemic sampling that puts these observations in context.

Introduction to Expert Tetris

Tetris is a block puzzle game in which players fit together Tetris blocks, also referred to as tetriminos, or tetrazoids, or zoids, and hereafter referred to as game blocks or simply blocks. Figure 1 illustrates the set of Tetris blocks and the controller used.

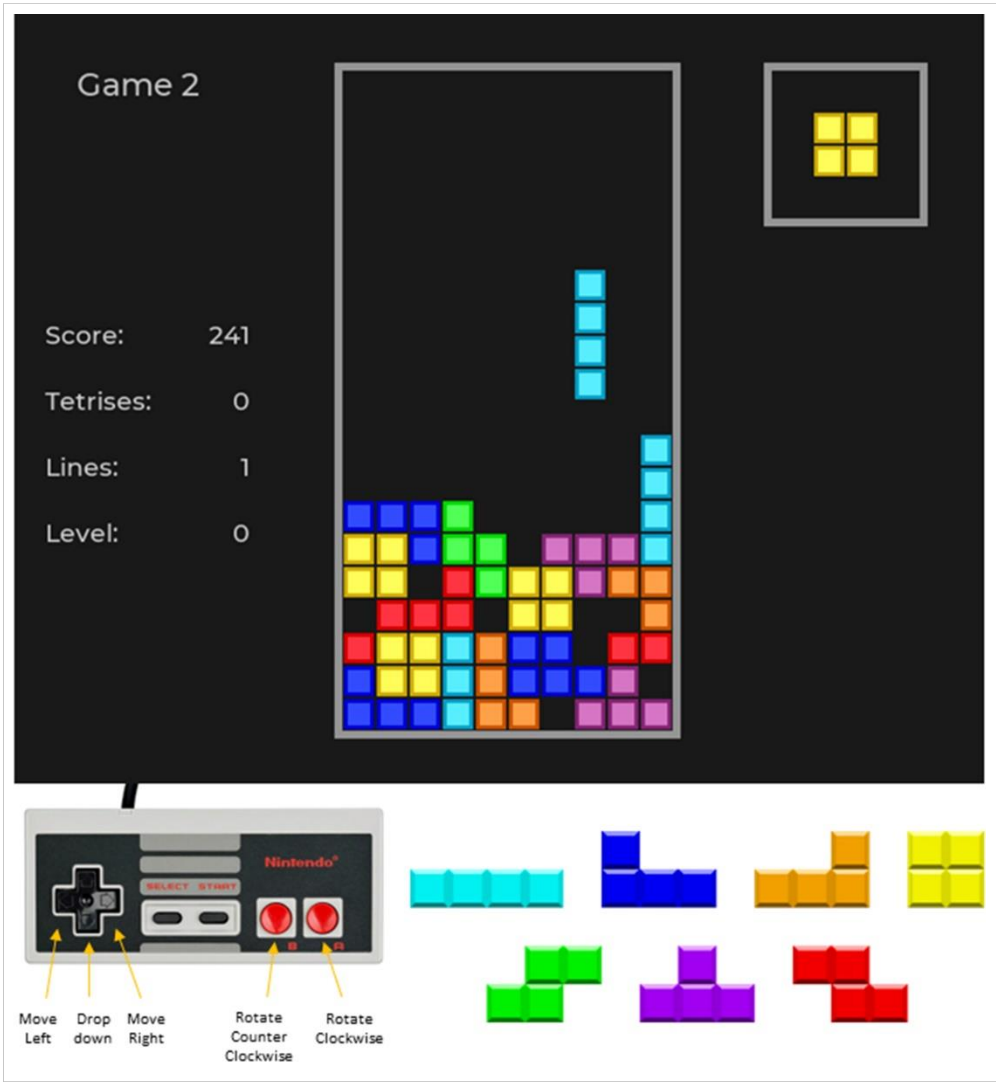

Figure 1. Set of Tetris blocks and the controller used.

These game blocks descend one at a time from the top of the game board. Each time a game block spawns, this is referred to as an episode. An episode is the duration of time for which one block is actively being placed by the player, and episodes end when the block lands and locks into place. Game blocks spawn in one of seven different shapes, made up of four block units, that approximate the letters O, I, S, Z, J, L, and T. Which block appears for each episode is determined by the game's random number generator, or RNG, in an unknowable sequence. I will return to the discussion of RNG later. Using a game controller, players move blocks laterally, rotate them left and right, and sometimes increase the rate of their descent. Once a solid row is formed across the game board without gaps, that row or line disappears and the stack of unfitted game blocks that have accumulated in the gameboard drops by one. The objective is to clear as many lines as possible with more points being awarded for multiple simultaneous line clears. As players clear more lines, the difficulty level increases, and the game blocks descend faster. The game ends when the stack of unfitted blocks reaches the top of the game board.

Speed and Strategy

What makes expert Tetris play so different from that of novices are the speed of play and the strategy used to clear lines, which combined lead to a major emphasis on situational awareness. It is this emphasis on situational awareness that leads to the dependency on the Next Box. Beginning with the speed difference, novices starting at level 0 will have sixteen full seconds to move and place a block before it reaches the bottom of the gameboard. By contrast, the players in championship matches have less than one second to place a game block, vastly limiting the number of movements that could be performed before it lands. Exacerbating these high speeds is a movement-limiting factor known as auto-repeat-rate (ARR). Briefly, digital devices with key inputs will often limit the rate at which characters and other inputs can be repeated. This is why pressing the '*d*' key once on your keyboard produces just one '*d*' even if you tap it for a bit longer than expected. In order for multiple '*d*s' to repeat across the screen you must press and hold for a second or two. This prevents errant keystrokes from yielding excess inputs. Within Tetris, however, this feature *delays* repeated sideways block movements. This further constrains movement options in the brief span of an episode and substantially increases the task's demands. I will return to the burden placed by ARR shortly.

Regarding the strategic differences, players may fit together game blocks to clear one, two, or three lines at a time. However, only the I block, also called the I-beam, can create a tetris[2], which is when four lines are cleared all at once. Most novice players rarely achieve a tetris, scoring at the most one or two per game. By contrast, experts work to score tetrises almost exclusively and in one game will often score 30 or more. They use this strategy because the game rewards players for executing the premium maneuver with as many as *7.5 times the number of points* than for clearing just one line. In addition, there is a set number of lines that are to be cleared before the game advances in difficulty and blocks descend faster[3]. Therefore, experts try as much as possible for the majority of their line clears to be included as part of tetrises, particularly when the speed is more manageable. Extreme players thus construct their gameboards by building up very high stacks of unfitted game blocks with 9 of the 10 gameboard columns filled. A 10th column remains open, usually on the far right and referred to as the well, in which the I-beam can be placed to simultaneously fit and clear four lines at once. Experts are purposely flirting with disaster by building high block stacks with little room for error. This returns us to the burden placed by the ARR limitation, since to overcome this experts must learn to master one of three heavily motor-intensive techniques. They are often pressing the directional pad to move the upcoming game block *before it even spawns* and continually run the risk of misdrops, including an I-beam accidentally landing on top before it enters the well. Figure 2 illustrates a typical gameboard for an expert.

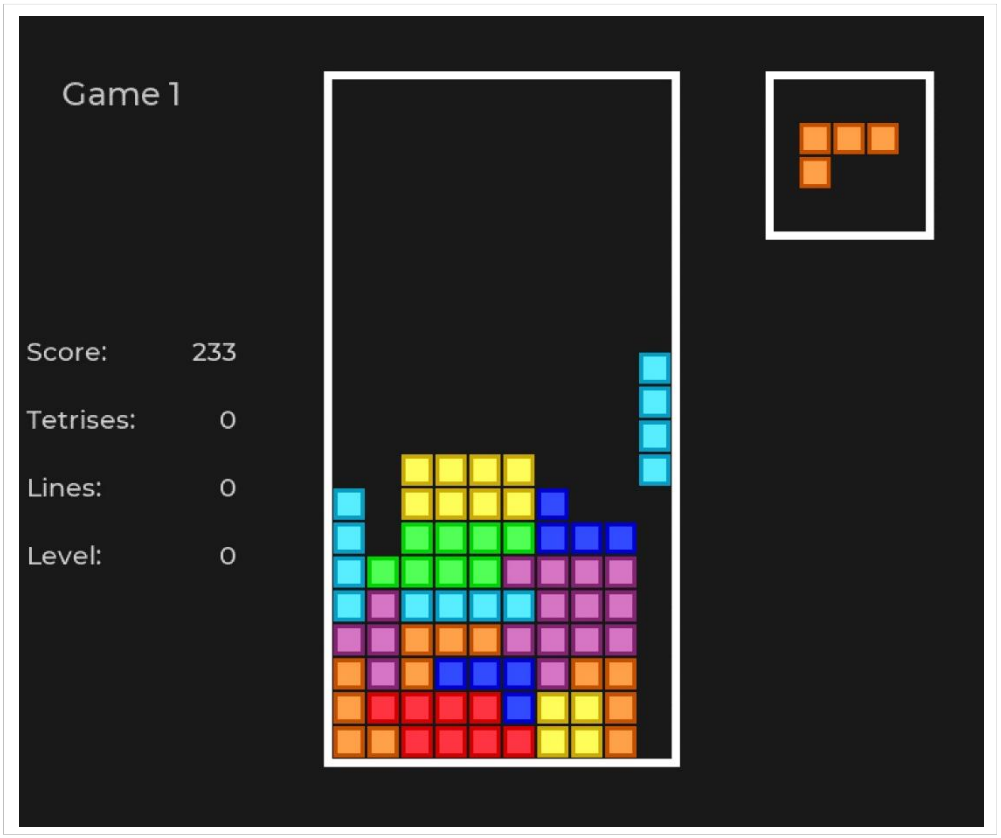

Figure 2. Typical gameboard for an expert.

Situational Awareness

It is well known that many tasks, once mastered, require little thought to perform. Think of all the times you may have driven home without remembering how you got there. Barring an emergency or other unusual event, people often behave on autopilot, robotically performing well ingrained actions. What makes Tetris different from other tasks is, once mastered, playing at the highest level still requires enormous attention. However, rather than still attending to the task minutiae, the player must graduate to use their attention for split-second decisions that determine success in the game. Players who have memorized all of the block orientations, mastered moving the blocks into place to score tetrises, and even mastered managing ARR may still zone out and play on autopilot. This is dangerous as RNG is unpredictable, and players must be prepared to deal with a bad sequence of game blocks. Remaining engaged and aware is key for more than short-term success. Figure 3 illustrates what is happening during the game and illustrates the importance of situational awareness. Whereas the components of building wells, clearing misdrops, and maintaining board height are all within the player's purview, i.e., they can control when and how to do so, RNG is completely out of the players control and completely unknown to the player, except for the identity of the block that will appear next. This highlights the importance of using the Next Box for decision making.

As illustrated by Figure 3, the extreme expert player is all-consumed with paying attention to what is happening despite the manual parts of the task being largely automated, if difficult. The player must be constantly maintaining a board height that is high enough for scoring tetrises, but not so high that it reaches the top and ends the game. The player must also recover from any mistakes they have made. The key component is "handling RNG" because Tetris uses a true random function so that each block is equally likely to appear on each episode. The player knows what block they are placing and what block will appear on the next episode, via the Next Box, but in the classic Tetris played at the yearly championship, beyond the next block it is unknowable. To put it succinctly, playing extreme Tetris is not like driving home from buying a gallon of milk; playing extreme Tetris is like driving at night, on the Autobahn, in the rain, at 200 kph. Every episode brings potential disaster and with mere milliseconds to respond, experts must rely on the only source of information they have about the upcoming sequence of game blocks: the Next Box.

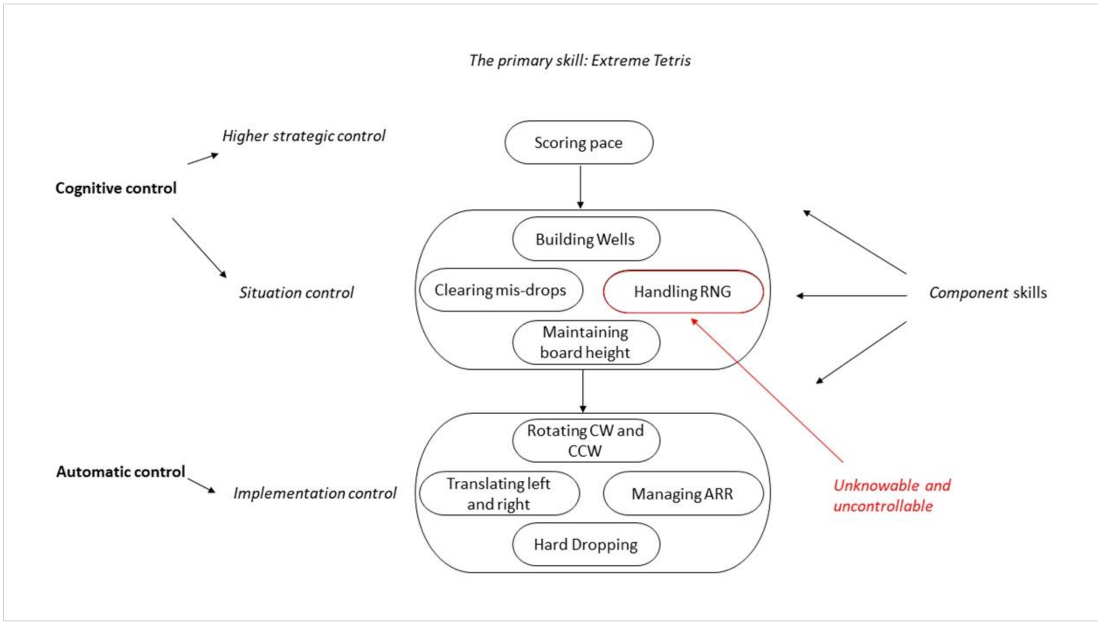

Figure 3. The primary skill: Extreme Tetris. Figure adapted from Christensen et al. (2016) with permission.

Observations

At the 2018 Classic Tetris World Championship tournament, organizers sponsored an *ad hoc* competition wherein players could compete against one another in Tetris with the Next Box disabled. The competition format was identical to the regular CTWC tournament (i.e., match play), except that the Next Box was disabled, and ended with the two best "No Next Box" players competing against one another. After witnessing the event in person, I conducted video analysis of both the main tournament event and the No Next Box event that took place that year using publicly available videos posted online. A total of 16 players, each of whom also participated in the main event, participated in the No Next Box tournament which was held the day before the main event. Event sponsors used two side consoles and CRT terminals reserved for tournament matches that would take place the next day but would not be displayed on the main stage because of space constraints. Of the 16 players who participated in the No Next Box side event, 11 of these players had also posted scores during qualifying rounds high enough to participate in the main tournament event. For these 11 players, I compared No Next Box and regular Tetris tournament performance. For each player who participated in both the main tournament and the No Next Box event I calculated average and high scores, average and most number of lines cleared, and average and most number of tetrises scored. This was aggregated across all games and across all matches for both tournaments.

Results

The difference in player ability between the regular and No Next Box tournaments is striking. Incredibly, these extreme experts cleared *just 8 lines* on average, and attained *just*

1% of their normal points. I conducted series of paired *t* tests comparing the regular and the No Next Box tournaments for the High and Average Scores and Most lines and Average lines cleared, all $t > 4.5$, all $p < 0.001$. Table 1 and Figures 4, 5, and 6 depict the results.

Table 1. High and average scores and most and average number of lines cleared for each of the 11 players included in the analysis in both the regular CTWC and the “No Next Box” Tournaments.

		CTWC Tournament				No Next Box Tournament			
Player	CTWC Qualifying Seed	High Score	Avg Score	Most Lines Cleared	Avg Lines Cleared	High Score	Avg Score	Most Lines Cleared	Avg Lines Cleared
1	1	914,880	558,115	230	152	30800	14190	36	16
2	5	932,480	626,848	230	166	27360	13871	29	16
3	6	833,680	602,060	230	171	6460	3876	8	5
4	7	752,875	566,698	214	172	4940	2787	6	4
5	8	736,943	612,804	231	199	17105	6237	22	8
6	10	648,820	517,339	187	153	7220	3728	9	5
7	12	516,500	477,180	206	195	3420	1900	4	2
8	18	643,840	493,965	212	166	4180	3990	5	5
9	22	418,840	247,951	164	111	7980	5016	10	6
10	25	582,420	351,329	130	88	23592	11125	29	14
11	40	108,680	64,790	54	36	7980	4307	10	5
Average		**644,542**	**465,371**	**190**	**146**	**12,822**	**6457**	**15**	**8**

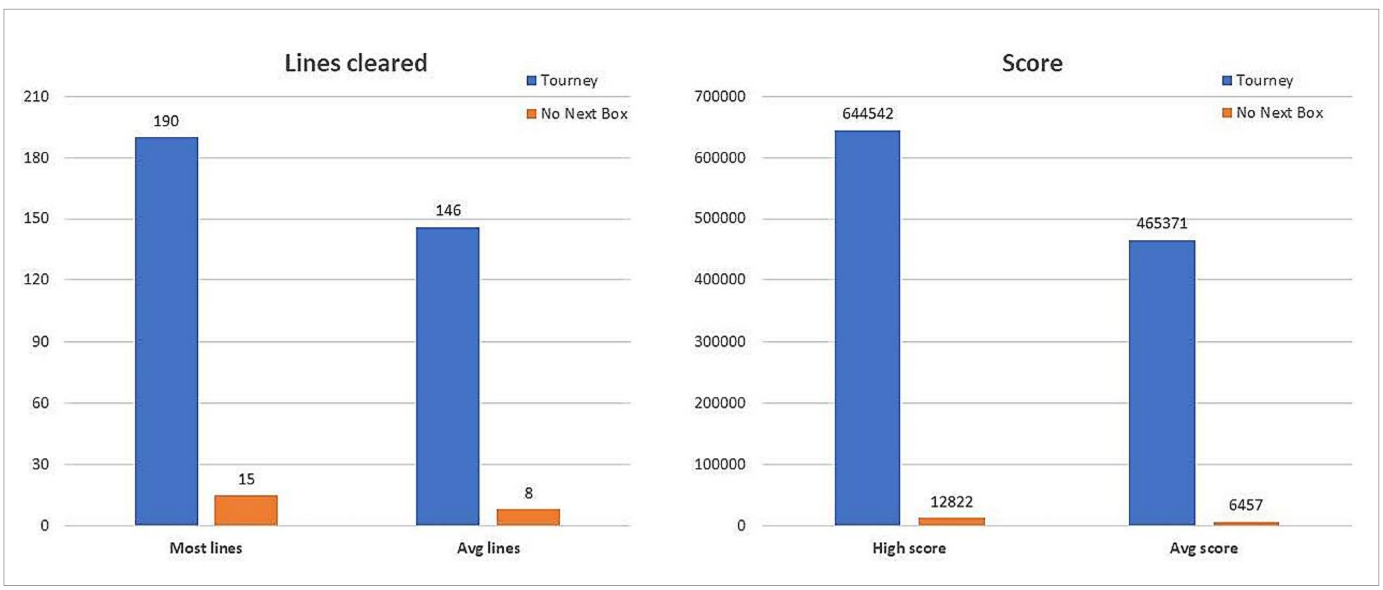

Figure 4. Lines cleared and Score in the main and No Next Box tournaments.

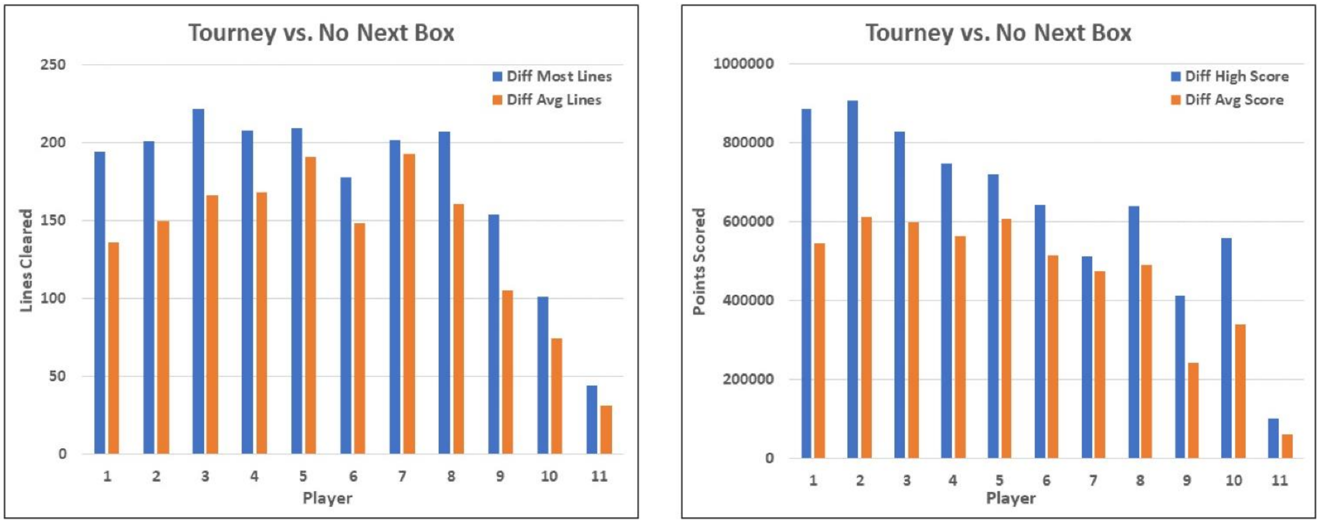

Figure 5. Difference between most and average lines cleared and high and average scores in the main and No Next Box tournaments.

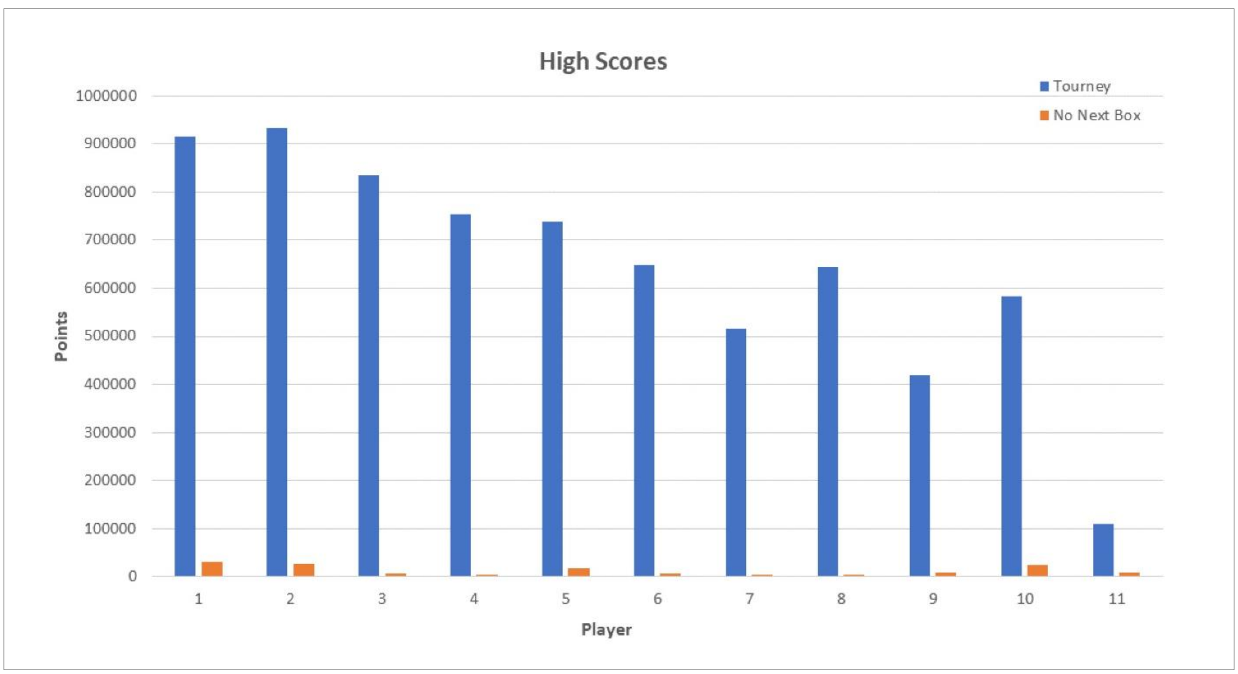

Figure 6. A comparison of high scores in the main and No Next Box tournaments.

Why This is Epistemic Behavior

Simply because extreme experts are not making extraneous piece movements, nor are they probably goal switching, that does not mean that they are not *using the world* to help in decision making. Using the Tetris Next Box window can be considered epistemic behavior because one is using the world to ease the mental burden of making decisions with unknowable information. Below I address whether this behavior fits with the epistemic behavior in Tetris originally proposed by Kirsch and Maglio (1994) some three decades ago.

Definition of Epistemic Action

Kirsch and Maglio (1994) identified three components of epistemic action:

1. reducing the memory involved in mental computation, that is, space complexity;
2. reducing the number of steps involved in mental computation, that is, time complexity;
3. reducing the probability of error of mental computation, that is, unreliability.

First, expert Tetris players are not reducing their memory involved in determining the sequence of blocks presented in successive episodes. One cannot reduce the memory of events that have yet to happen. Also, they have already memorized the different block orientations, whereas novices have not, explaining why novices will rotate blocks to help in visualization. However, expert players *are* attempting to reduce the space complexity *by increasing the option space* for subsequent game blocks. Specifically, a player might place a block in a place that fits well for that block in particular but does not leave a space for the upcoming block. A hole might be created as the player was then forced to put the upcoming block in an ill-fitting location. However, the player could place the block in a space that enables the upcoming block to be easily placed as well. Extreme experts, who are fully engaged in situational awareness of the task, are trying to place the current block *so that the next one and the following one also have good-fitting locations*. The player is thus increasing the option space and giving themselves as many alternatives as possible for future block placements. They are thus addressing the future (physical) space complexity of potentially having to place blocks into ill-fitting locations.

Second, extreme Tetris expert players are also addressing time complexity because of the pace at which blocks are descending. There is insufficient time to decide where a block will be placed and to execute the physical action to make it so, all within one episode. By looking at the next block the player can decide where it will be placed in relation to the current block and also consider how it will allow for the block thereafter. In some cases, small, quick adjustments can be made when the Next Box indicates a particular upcoming game block. The extreme Tetris expert can thus *amortize* playing out the motor movement to place the block in the intended location while simultaneously deciding on the placement of the upcoming block. Indeed, without the ability to do both things at once it seems unlikely there would be enough time within the same episode to make a decision and then place a block according to that decision. This is precisely why the Next Box may be so crucial.

Third, epistemic action reduces the probability of error. Insofar as players are attempting to avoid leaving gaps that will prevent tetrises from being scored; planning for the upcoming block enables the player to create as gap-free stack as possible. This diminishes the unreliability of one being prepared to consistently score tetrises. By these definitions, the player is engaging in epistemic behavior when they use the Next Box to plan for the upcoming and future blocks. The difference, however, is that no *action* is being performed. The player is “using the world” in the sense that information is there that can help them that does not exist in the head. However, this same world is not being used as a doodle pad but as a resource.

In addition, this behavior is also epistemic in that is goal-directed. Traditionally, the purpose of epistemic action in Tetris has been to aid in decision making by testing behavior in the world in a temporary manner with no lasting effect. That is, moving pieces around to envision where they might go before eventually placing them costs nothing in the grand scheme of a game played at level 0, in which pieces descend very slowly. Therefore, the player has a free period in which to test things out before making a decision. The gameboard is like a scratch pad. For expert players, however, decision making is being augmented by reducing uncertainty about future events

Finally, this behavior can be considered epistemic in that the purpose is offloading part of the decision making. One purpose of epistemic action is to use the world as a virtual scratch pad to help one organize their thoughts and decision making with the goal of offloading some of the working memory requirements associated with decision making. In Kirsch and Maglio (1994), for example, novice players could not envision all possible block placements and permutations and so would experiment *in situ* by rotating and moving blocks as they descended in order to envision different outcomes. Experienced Tetris players have memorized the different piece orientations and already know many of the different possible placements. They can therefore make decisions about where to place blocks more quickly and at higher speeds. However, rather than treating each episode as an isolated event, and dealing with only the tetris block at hand, experienced players recognize the flow of events and that as each block spawns it can be placed together with the upcoming block, joined to the existing stack, or the upcoming block can be joined with whatever block will come after. The purpose for advanced players, therefore, is not to deal with how to place the piece given the current board state, as it is for novices, but instead how to place the piece for the future board states given the possible sequence of pieces.

Definition of Epistemic Sampling

The concept of epistemic sampling is related to but differs from the concept of "*epistemic planning*" in artificial intelligence which refers to artificial agents recognizing a difference between their current and desired states of knowledge and then making plans for how to achieve the desired knowledge (Bolander, 2017). This comparison is appropriate as the definition describes the problem faced by the extreme Tetris player. In essence the player is constantly asking this question with every block that spawns: "*Given what I know about the episode coming next, how should I place the current block for the largest possible option space for the next block and the block that will appear after that?*" In Tetris, players understand that some unseen sequence of game blocks will fall. Yet they must still make decisions with the goal to achieve or maintain a state of tetris-readiness.

One difference between human and machine agents could be that the goal of the individual expert is to have as many options as possible for placement of upcoming blocks, knowing that until the game is over there is no way to know actually what blocks will appear. The individual expert's purpose is to be poised to handle any and every eventuality. In contrast, an artificial agent could obtain the desired state of knowledge and all of the intermediate states in between, depending on the problem constraints. Epistemic planning for the machine agent might be able to eliminate all uncertainties. However, a human expert Tetris player is dealing with a known uncertainty that can only be reduced but not eliminated. The goal is not to eliminate uncertainty but to maintain readiness.

Epistemic sampling is also different than epistemic action. Whereas epistemic action involves changing events in the world to help make decisions in the head, epistemic sampling involves *consulting* the world *before* performing an action when there is uncertainty. There is a distinction between changing things in the world to help make a decision and sampling the world to help make a decision. Sampling the world to engage in decision making is epistemic in that the decision could not have been made as accurately with only information in the head. In contrast, acting in the world for epistemic reasons is physically creating temporary states in order to help envision the optimal end result. For example, suppose you brought home a new piece of artwork and are deciding where it is to be placed. You might imagine where it should go based on the color of the walls and other décor. However, that will eventually extend from imagining to actually trying it out in different spaces in your home. There are far too many variables in properly conveying artwork for that to be an activity that takes place solely in the head. This is epistemic *action*. Consider as well that you bought that piece of art ahead of a dinner party for which you are also cooking a large meal. You may follow a recipe for the main dish but the "fistfuls of ingredients" you use to make the recipe your own must be judged *during the flow* as you are cooking. As the recipe is simmering you wonder if you have added enough salt. You probably already know how much salt you put in, but such creations are never exactly the same each time and the subjective experience of taste is often judged best in relation to the other ingredients in the recipe. Therefore, you dip in a spoon and taste it to decide if you will add more salt. This is epistemic *sampling*; you are deciding whether to add more salt by consulting the recipe's current flavor.

Conclusions

Epistemic action is using the world to help in decision making that is too complex to use just the head. In novice Tetris play, this refers to rotating and translating game blocks in ways that appear useless and does not shorten the distance between the current and desired states. However, such behavior is highly useful for novices because it helps them visualize the different block orientations and placement options. The present work argues that extreme expert Tetris play also involves epistemic behavior but includes sampling information in the world rather than acting to reduce uncertainty about upcoming events. I argue that without this behavior extreme Tetris expertise as we know it does not exist. This case study was a one-time opportunity to look at how, once removed, one facet of play crippled the normally remarkable playing ability of the best in the world. Indeed, one of the eleven participants included in the analysis actually won the championship that year. Though he performed better than most other pros in the No Next Box tournament, neither he nor anyone else who participated was *able to score even a single tetris*.

Epistemic sampling is likely a part of extreme ability in other domains. One might envision a Formula 1 driver with some knowledge of the track having to make split-second judgments based on seeing whether the track is wet or on the current behavior of the other drivers. A professional bowler might recognize that the wax placed on the lane at the beginning of a tournament has nearly worn off by the end, affecting the spin rate of his ball. The No Next Box tournament held a few years ago at the CTWC was a one-time opportunity for the curtain to be opened and the world to see what environmental attributes are scaffolding extreme play. It's worth noting that aside from the one-time event in 2018, a handful of players have independently worked to score as many points as possible while playing without using the Next Box and also made these videos available publicly. They have found that success comes largely from starting on a lower level than is typical for extreme experts, e.g., level 8 or 9, and the current record is 477,000 points set in July 2020, which is still a far cry from what extreme Tetris experts are capable of when the Next Box is in play. It seems that knowing what block will appear next is not merely nice to have but is a must for playing at the speeds that champions maintain. Future work might bring expert players into the laboratory and experiment with different playing speeds and styles and without the Next Box to determine the limits of performance with this knowledge in place. Epistemic sampling is not yet part of the standard lingo in human expertise, but perhaps it should be to describe how the world can help experts too.

Endnotes

1. The No Next Box side event Tournament took place for the first time at the CTWC in 2018 and has not taken place since.
2. The reader should note that when the word Tetris, with the first letter capitalized, is used, I am referring to the proper name of the game. When the lowercase "t" is used, as in "tetris," I am referring to the in-game maneuver of clearing four lines at once.
3. At level 18, players clear 130 lines for which game blocks descend at a rate of one per second. After that, block speed descent increases by 50%, with the transition to level 19, for which game blocks descend at a rate of one per 0.667 seconds.

Author's Declarations

The author declares that there are no personal or financial conflicts of interest regarding the research in this article.

The author declares that the research reported in this article was conducted in accordance with the Ethical Principles of the *Journal of Expertise.*

The author declares that the dataset is not publicly available but can be provided upon request.

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