Master's Thesis Proposal

Kevin O'Neill

Introduction

Flow is a state of intense concentration which is closely related to the concept of intrinsic motivation. Tasks which induce flow allow subjects to be more engrossed in the task, do the task longer without experiencing conscious fatigue, and be interested in continuing the task longer than they would for a non-flow-inducing task, due to the task being intrinsically motivating.

If tasks could be altered to be more flow-inducing, or if these flow-inducing properties could be transferred between tasks, performance could be improved in a variety of fields, especially those that require continuous attentional demands. For example, a fighter pilot in flow state would presumably have better concentration than one who is not, and thus would be better positioned to react to changing conditions or threats. Likewise, a supervisor of an assembly line who is in flow would likely perform better at monitoring the state of the system than one who is not in flow. If these flow states can be better induced, or transferred from flow-inducing tasks to target tasks, performance on these tasks or similar tasks could be improved, leading to positive outcomes like reduced operator error and increased attention.

The study of flow first arose through attempts to understand what made some activities autotelic, or intrinsically motivating, and others non-autotelic. Necessary characteristics of a task which would induce a flow state include a balance between perceived challenges and one's skills to deal with those challenges, as well as clear, proximal goals and immediate feedback about performance on the task (Nakamura & Csikszentmihalyi, 2009).

The subjective state of flow exhibits characteristics of intense concentration, a merging of action and awareness, a loss of reflective self-consciousness, a sense of being in control, a sense that time has passed faster than normal, and an experience of the activity as being intrinsically rewarding (Nakamura & Csikszentmihalyi, 2009).

Several ways of measuring flow have been established. A popular method is interview, where subjects are asked to qualitatively describe flow experiences (Jackson, 1995). Another method is questionnaire, which can offer a more quantitative measure of flow. Among the most well used are the Flow State Scale (FSS) and Dispositional Flow Scale (DFS) (Jackson & Marsh, 1996), and their updated versions, the FSS2 and DFS2 Jackson & Eklund, 2002, as well as short versions of the same scales (Jackson, Martin, & Eklund, 2008). The FSS and related versions measure the degree to which one experienced flow state in an activity, while the DFS measures how one's traits and personality predispose them to enter into flow states, something akin to Csikszentmihalyi's ideas of an autotelic personality (Nakamura & Csikszentmihalyi, 2009).

A third method, which is used for more cross-sectional analyses of flow phenomena, is known as the Experience Sampling Method (ESM). This method involves subjects being prompted at random times in their daily lives to record their subjective experience at that time with regards to flow (Csikszentmihalyi & Larson, 2014).

The literature makes a fairly clear distinction between flow and general positive affect. Flow involves and requires attention to and control over the task at hand. Passive but enjoyable actions, like watching television or viewing a sunset, can induce positive affect, but not flow. Studies like Keller and Bless (2008), and Keller, Bless, Blomann, and Kleinböhl (2011), showed a marked difference in both subjective reporting of flow and physiological markers between a condition of boredom and one of moderate challenge.

Other studies have been able to find differences in brain activity between low-effort and high-effort tasks. Plotnikov et al. (2012) have been able to train a machine learning algorithm to classify EEG data from subjects playing either a fast- or slow-paced version of the game *Tetris*, and achieved accuracy far above chance in assigning the data to the correct condition.

Some authors have characterized flow as an effortless activity. Westbrook and Braver (2015) cite flow as an example of a state which might demand cognitive control but not require cognitive effort. They describe cognitive effort as being closely linked to, but a separate construct from, attention, motivation, and difficulty. Attention is closely linked with flow state (Webster, Trevino, & Ryan, 1993), and one of the characteristics of flow state is that it is intrinsically motivating (Nakamura & Csikszentmihalyi, 2009).

Task difficulty is closely related to flow state as well. Arguably the most important precursor to flow is a balance between the challenge or difficulty of the task, and the skills that one has to meet that challenge. Earlier conceptions of challenge-skill balance described the match as a "flow channel" where flow would be induced if there was a match between skills and challenge, no matter how challenging the task was (Csikszentmihalyi, 1975), however later models specified flow as requiring a match between moderate to high challenge, and moderate to high skill at a task (Csikszentmihalyi, 1997). This was to account for activities which have little opportunity for action, such as watching television. These activities are characterized by low challenge and require little skill, but appear not to induce a flow state (Nakamura & Csikszentmihalyi, 2009).

Jackson (2000) links this sense of effortlessness with the "action-awareness merging" dimension of flow, where the actor feels a sense of oneness with their activity and ceases to notice themselves as being separate from their actions or experiences. It can often be felt as automaticity, and that no effort is required to perform these actions (p. 142).

Hockey (2013) raises the possibility that this perception of effortlessness as being a component of flow may stem from the fact that Csikszentmihalyi did not explicitly ask participants to rate the effortfulness of their experiences. He argues that it's possible that the subjects did not spontaneously describe their actions as effortful, but may have done so if they had been prompted (p. 130).

Even if the subjects did not consciously perceive their actions as effortful, they may still have been exercising cognitive effort. All of the traditional methods for measuring flow (interview, questionnaire, ESM) are subjective measures, and thus can only tell researchers what the subjects believed they experienced, not necessarily what they actually experienced.

A number of researchers have identified that there may be a disconnect between subjects' perceptions of their own abilities, and more objective measures of their skill in relation to the challenge of the task. Jackson, Ford, Kimiecik, and Marsh (1998), in studying flow among athletes, emphasized that they were measuring perceived sport ability and not actual sport ability, citing Csikszentmihalyi (1990), "it is not the skills we actually have that determine how we feel, but the ones we think we have," (p. 75).

Harris, Vine, and Wilson, (2017) specifically address this disconnect with respect to perceived vs. actual cognitive effort. They describe the common perception of effortlessness while in a flow state as being a consequence of one of two possibilities: either the task requires less effort when one is in a flow state, or that there emerges a dissociation between the one's own subjective experience and the actual amount of mental effort one uses. Harris et al. side on the latter possibility, citing a number of studies in which the "effortless" state of flow is experienced, but physiological measures still indicate that the subject is under a high workload. Many of these studies use heart rate variability (HRV) as a correlate of mental effort; low HRV has been associated with high mental effort (Hjortskov et al., 2004, Jorna, 1992).

Keller et al. (2011) found that challenge-skill balance, an important flow precursor, led to greater self-reported flow, but also lower HRV, suggesting high mental effort. Tozman, Magdas, MacDougall, and Vollmeyer (2015) similarly found that subjects presented with a challenge-skill balance task reported higher flow and lower HRV than those in a boredom condition, echoing the conclusions of Keller et al. (2011).

A limited amount of research has been done looking at flow performance in teams (Aubé, Brunelle, & Rousseau, 2014; Heyne, Pavlas, & Salas, 2011; Lazarovitz, 2004). Lazarovitz (2004) found that team flow in ice hockey athletes correlated with individual ratings of performance as well as actual performance. This implies that at least some variance in team performance might be explained by team flow. If so, teams which are more in flow, and in which team members help to contribute to each other's flow state, through things such as adequate communication or consistent behavior, would perform better at a task than teams composed of members which are not contributing to each other's flow state. Presumably, this kind of interaction could be present in a human-computer team as well, since the human's performance would still be affected by their own flow state. The literature seems to be sparse on analysis of flow state in human-machine teaming, but it seems to be an interesting avenue of research, and one which this project will hopefully address.

Flow in previous research has been a fairly nebulous term, and the bounds of the concept have not yet been fully worked out. In this document, we will be focusing on the dimensions of flow as used by Jackson and Marsh (1996), who base their Flow State Scale (and subsequent Dispositional Flow Scale; Jackson, Thomas, Marsh, & Smethurst, 2001) on the nine dimensions of flow identified by Csikszentmihalyi and Csikszentmihalyi (1988). These dimensions can be split up (as they are in Nakamura and Csikszentmihalyi, 2014) into three conditions for flow, and six characteristics of flow. The conditions identified as necessary for flow are a balance between the challenge of the task and the skills a subject has at that task, clear goals the subject can follow, and unambiguous feedback to allow the subject to determine how they are performing. The six characteristics of flow are a merging of action and awareness (described as a reduction in the awareness of self as separate from the activity at hand), concentration on the task, a sense of control over the task, a loss of self-consciousness (where actions taken feel instinctual instead of being deliberated upon by the self), the transformation of the experience of time (either feeling much slower or faster than normal), and an autotelic experience, where the experience of flow was intrinsically rewarding, and could be enjoyed for its own sake. Jackson and colleagues (1996, 2001, 2002) have created flow scales in which four questions pertain to each of the nine dimensions, leading to a total of 36 questions which measure the subject's perception of either the conditions or characteristics of flow.

In this document, we will primarily be operationalizing the construct of flow as its challenge-skill balance dimension. Thus we will consider a person to be in flow when the challenge of the task they are performing matches the skill they have to address that challenge. The following experiments all contain an "adaptive" condition, which has been crafted in a manner meant to maximize the balance between challenge and skill. These conditions are meant to keep the player in a state of high challenge, where their skill does not outstrip the challenge, which would lead to a state of boredom, and the challenge does not outpace their skill, which would overwhelm the player and lead to a state of stress.

In the following sections I will discuss the previous experiments which have been performed to look at the inducement and transfer of flow in attentional control tasks. These consist of the initial experiment, (Experiment 1), and the second experiment (Experiment 2), which addressed some limitations in the initial experiment, and is intended as a pilot test for the proposed experiment (the subject of this proposal).

Previous Experiments

Experiment 1

Our study into the flow state has focused on how it can be induced, and whether the flow state can be transferred from one task to another. Flow state seems to offer a number of positive benefits, namely that flow-inducing activities are intrinsically motivating and are subjectively perceived as being less cognitively demanding (Nakamura & Csikszentmihalyi, 2009). Being able to transfer these benefits to tasks which don't themselves induce flow could lead to improvements such as reduced operator fatigue and increased concentration. Many tasks which have high-stakes and require constant attention are not necessarily flow-inducing, and so the ability to transfer flow or its positive effects to such a task could improve performance and in some circumstances might save human lives.

Previous research has shown that flow state can be induced, and *Tetris* seems to be one of the more prevalent paradigms used to do so (Chanel & Rebetez 2008; Harmat et al. 2015; Keller

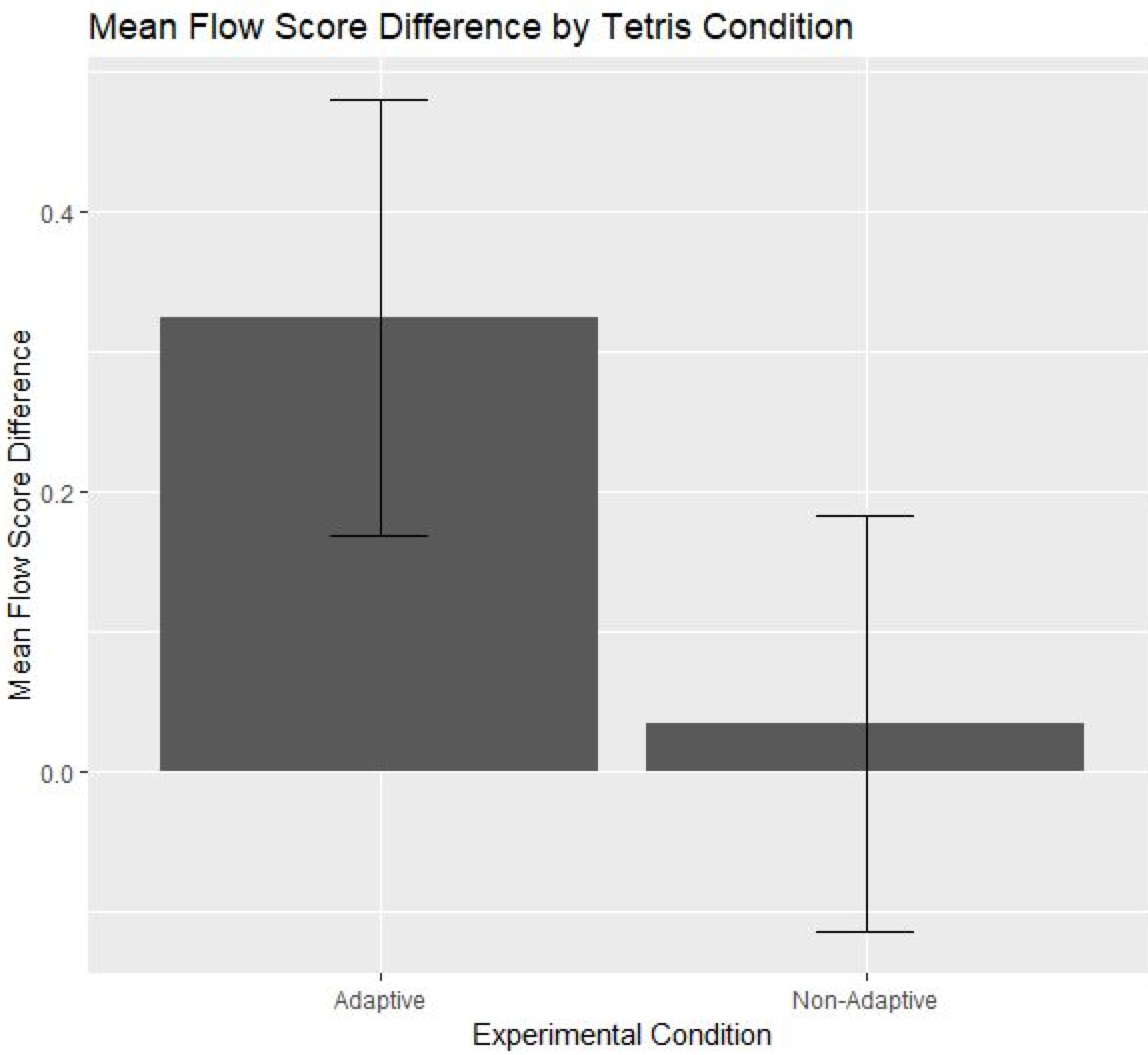
& Bless, 2008; Keller,Bless, Blomann & Kleinböhl, 2011; Plotnikov et al., 2012). Accordingly, in our experiment, we used a version of *Tetris* to manipulate the subjects' flow states.

Tetris seems to have many of the qualities necessary to induce a flow state. Primarily, it provides a balance between challenge and skill by starting out at a slow pace, and increasing in pace as the player clears lines. A more skilled player will clear lines more quickly than a less skilled player, so a more skilled player with find themselves at a higher piece fall rate, and thus a higher difficulty, more quickly than a novice player. In this way, *Tetris* ensures that the player is not in a state of boredom, where challenge is lower than skill. A game of *Tetris* will also quickly end once the player's skill is not sufficient to keep up with the challenge, as the pieces will pile up, the player will lose the game, and will be able to start a new game, reverting them to the initial difficulty level. This system keeps the player from being overwhelmed for a prolonged period by the challenge outpacing their skill. These aspects naturally cause the player to be at a balance of challenge and skill more often and not, which is why *Tetris* is an ideal starting point for flow research.

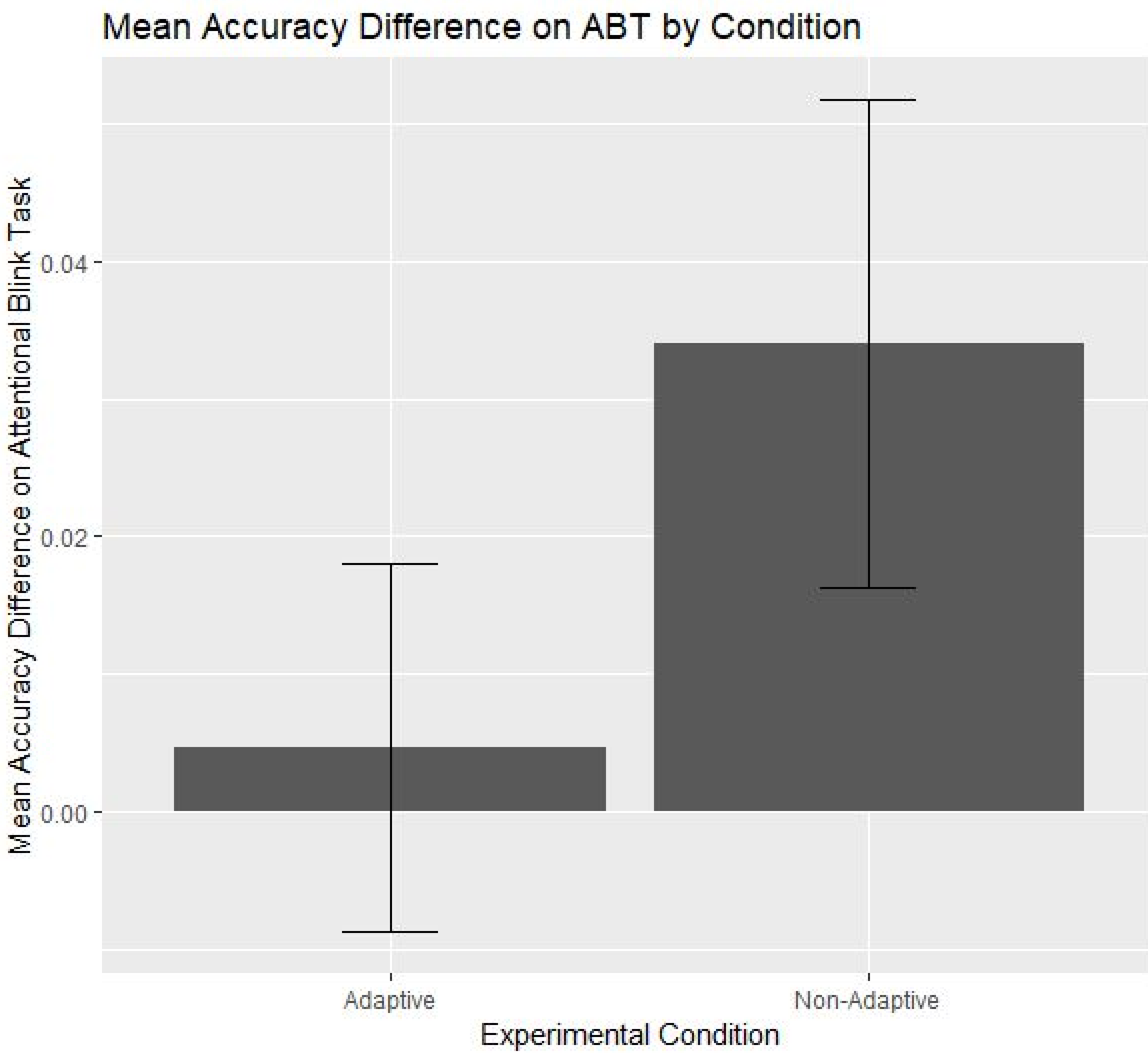
This version of *Tetris* has two conditions: a non-adaptive condition, which is unaltered from normal *Tetris* gameplay, and an adaptive condition, which has had two alterations made to better induce flow state. The first alteration is that subjects cannot get a game over which forces them to start a new game. When the accumulation (the pile of previously placed *Tetris* pieces while begins at the bottom of the game board) nears the top of the game board, the system will remove rows so that the accumulation is lower and the subjects will never lose the game. This system removes rows in order of the number of filled spaces in that row; rows that are mostly filled will be removed sooner than rows which are mostly empty. The second alteration is that subjects are able to control the speed the pieces fall at by pressing on a foot pedal, in a manner analogous to a car's accelerator. Thus, these alterations make the Tetris game adaptive, in the sense that the lower skill participants will be "helped" by the system and not be allowed to fail, while the higher skill participants could increase the speed to increase the challenge as they wish. These manipulations we apply to *Tetris* are intended to affect these characteristics of *Tetris* which are flow inducing. In the adaptive condition, they are intended to facilitate flow by facilitating challenge skill balance, while in the non-adaptive condition, they are intended to inhibit it in the same manner.

To test whether flow or any related effects are transferred from *Tetris* to another attentional control task, subjects do the Attentional Blink Task (ABT) (Taatgen, Juvina, Schippe, Borst & Martens, 2009) both before and after playing Tetris. If there was transfer of flow from Tetris to this task, then there should be a difference between performance on the first ABT and the second ABT. Additionally, we measured flow state before and after each task using the FSS2 and DFS2 (Jackson & Eklund, 2002).

We gathered data from 58 subjects, and discarded 6 subjects because of incomplete data or subjects not following instructions. Of the 52 analyzed, 18 were male and 34 were female, with age ($M=20.40$, $SD=2.97$). The likert-type flow report scales were normalized between 0 and 1, where 1 represents a subject fully in flow, and 0 represents a subject not at all in flow. Results were inconclusive; no significant difference was found between the flow/non-flow conditions in terms of difference in reported flow state, $t(50)=1.35$, $p=.18$, $d=0.374$ (see Figure 1).



Likewise, there was no significant difference in performance on the ABT for the flow/non-flow conditions, t(50)=-1.3361, p=.19, d=.371 (see Figure 2).



It seems probable that the conditions were not different enough to induce a significant effect. Only 4 subjects out of 27 in the adaptive condition actually pressed the foot-pedal for more than 500ms, and it seems likely that 20 minutes was not enough time for many of the subjects to reach a point in their game where the row removal system was necessary. Presumably, if these systems were never utilized, then the differences between the adaptive and non-adaptive conditions would be negligible, and a lack of any significance between them would be expected.

Experiment 2

The second experiment was designed to fix the above-mentioned problems with the first experiment. The mechanism to remove rows from the game board when the accumulation nears the top, which was present in the first experiment, has not been implemented in the second experiment. This was for several reasons. First, as mentioned above, it was noted that many players in the first experiment never reached the point where the accumulation was close enough to the top of the board that this mechanism was activated, and thus the accumulation could not have been a factor in any inducement of flow state they might experience, because it never occurred in their games.

Second, some players nearer the more skilled end of expertise in Tetris can reach the higher levels of Tetris within the time period. What level of Tetris is being played directly maps the speed that the pieces fall at, and when the pieces fall too quickly, the player does not have enough time to move them from the center position they are dropped from, leading to a tall narrow tower of pieces forming in the center of the game board. When this tower reaches the top of the game board, the row removal mechanism will remove the most filled rows first, which means that the accumulation the player has been working on will be mostly or entirely removed by the time the game speed is reduced to a level the player can manage once again. This would leave those players with a single narrow tower of pieces in the center of the board, requiring players to fill it in on the left and the right to get back to a normal manageable game board. This seemed to be non-conducive to flow, as the player is quickly thrust into a separate situation from the one they have been working on.

Thirdly, the piece-choice mechanism was likely a more productive avenue to pursue than the row-removal mechanism with regards to inducing flow state, since it more directly addresses the challenge-skill balance aspect central to flow. Because of these reasons, the row-removal mechanism has not been re-implemented in this iteration of the experiment.

An additional change was the method of altering difficulty for the subject. Instead of giving subjects the option of using the speed of the falling pieces to affect the task difficulty, the second experiment uses an algorithm that gives the subject Tetris pieces based on what would be better or worst for a given game state. We believe that this method of manipulating game difficulty allows us to manipulate challenge-skill balance much more precisely than was possible in the previous experiment, and is present whether or not the subject consciously decides to make use of it.

A corollary of this is that, the preview box, which normally shows the next piece to be given, has been removed in the experimental tasks, since in those tasks the game hasn't determined which zoid will be given next until the player has placed the zoid in the current round.

To allow for easier implementation of this alteration of the piece-choice mechanism, the project was transitioned over to the *Meta-T* framework, a *Tetris* analog designed and optimized for behavioral science research (Lindstedt & Gray, 2015). This implementation has been designed to allow a great deal of control over game parameters, and gives richer log data than our previous implementation. This framework has also been used in a number of other experiments into expertise and cognitive-motor skills within the *Tetris* paradigm (Pilegard, & Mayer, 2018; Sibert 2015; Sibert, Gray, & Lindstedt, 2015; Sibert, Gray, & Lindstedt, 2017;

Thompson, McColeman, Stepanova, & Blair, 2017), and our experiment will be building upon this work.

This modification involved sorting between all of the possible Tetris pieces, called *zoids*, to evaluate their usefulness for a particular board state. There are 7 unique zoids (see Figure 3), and for any given board configuration, it is possible to order them from "best" to "worst" based on a number of features of the game board. These features include things such as maximum height of the accumulation (the pile of zoids at the bottom of the game board), number of wells (holes in the accumulation which are open at the top), and number of pits (holes in the accumulation which are not open at the top). (For a more complete list, see Thiery and Scherrer, 2009). Higher or lower values among these features are considered better or worse for performance; for example, a good AI will minimize the maximum height, since the higher the accumulation is, the closer the AI is to losing the game. Likewise, numbers of pits and wells are to also be minimized, since pits and wells make it more difficult to clear rows.

Use of feature sets is a standard practice in AI approaches to Tetris (Fahey, 2003; Thiery & Scherrer, 2009; Sibert, Gray, & Lindstedt, 2015), and *Meta-T* has the ability to output and log these features, as well as an AI system which can determine a feature-based score for every possible placement for a given zoid and board configuration.

The modifications to the existing *Meta-T* framework consists of a subsystem which uses this AI to generate the potential feature score for each of the possible orientations and placements of each zoid, returning the maximum feature score for a possible placement, indicating the "goodness" of the most ideal placement of that zoid. In this manner, each zoid can be rated as being more or less ideal for the player to be given, and the system can choose to give better or worse zoids in order to manipulate game difficulty.

There are three difficulty conditions being used in this experiment, a “best” condition, a “worst” condition, and an adaptive condition. In the “best” condition, each zoid being given would be, when placed in the most ideal spot, the most ideal for the given accumulation, and presumably would lead to a player doing better at the game because of this. In the “worst” condition, each zoid being given, when placed in the most ideal spot for that zoid to be placed on that particular game board, is the least ideal for the given game board, and presumably would lead to the player doing worse at the game because of this.

In the adaptive condition, the piece being given scales from best to worst based on the maximum height of the accumulation (that is, the height of the highest block in the accumulation). When the accumulation is empty, or its maximum height is very near the bottom, the worst pieces are given,because the player is probably doing well and should be given more challenge. When the maximum height of the accumulation is near the top, the best pieces are given, because the player is doing poorly and could use some assistance. When the accumulation is between these maximum and minimum values, the “goodness” of the zoid given is linearly proportional to the height of the accumulation, binned into one of seven categories, one for each of the seven possible zoids.

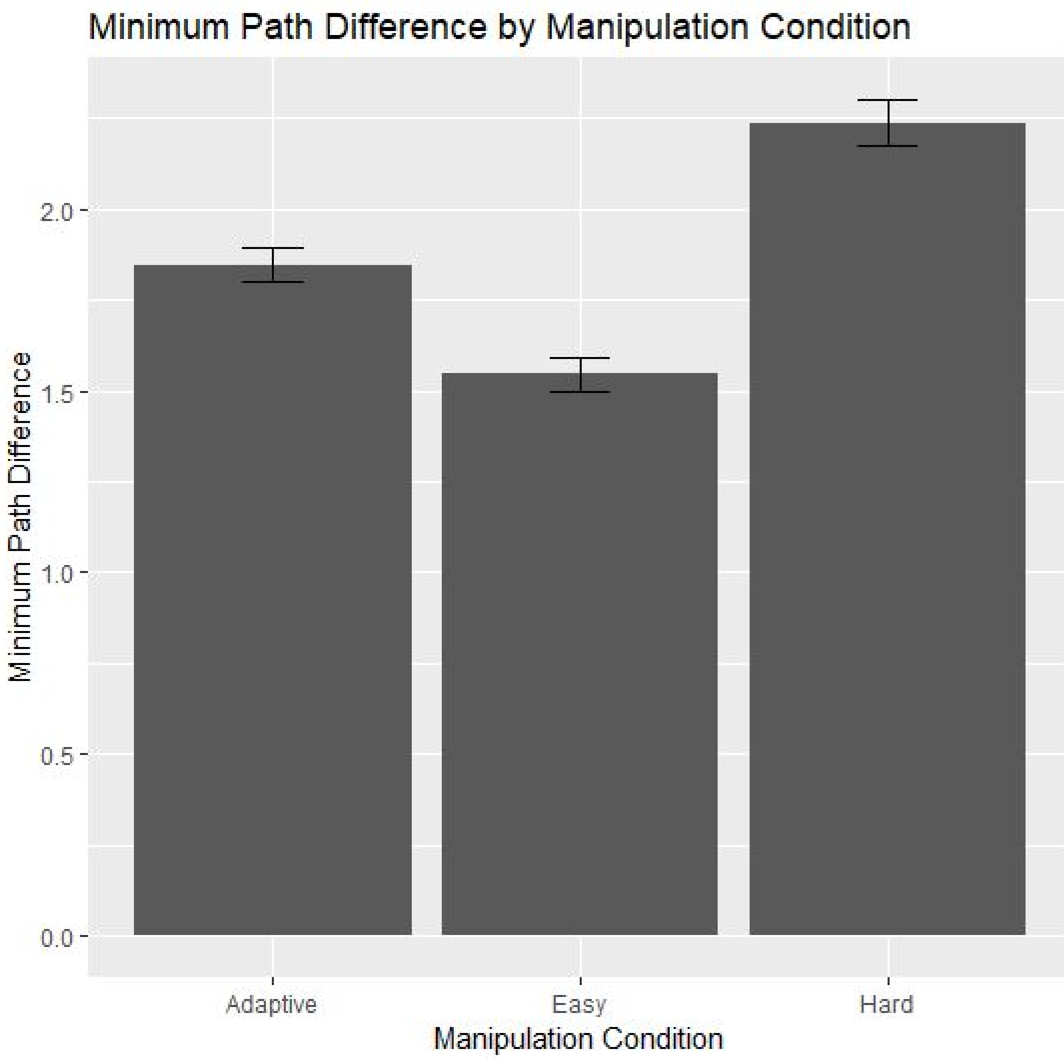
Analysis of Conditions

While “adaptive” is descriptive of the actual functioning of the game in the condition, “easy” and “hard” are relative terms, and it is not necessarily assured that the manipulations which are assumed to correspond to decreased and increased difficulty actually do. To verify if this is actually the case, I ran several ANOVA's on different metrics of performance within the manipulation conditions. The three metrics of performance used were minimum path difference, initial latency, and feature score difference.

Minimum path difference

Minimum path difference is the number of unnecessary translations and rotations performed in placing a piece in a particular placement. It is computed by taking the actual number of translations and rotations performed by the player, and subtracting the minimum necessary translations and rotations to move the piece into the proper location and orientation for its final placement. This is indicative of performance because a player who is performing better will likely have a better idea of where they want to place a piece, and will generally move the piece to that point in a more straightforward manner. On the other hand, a player who is performing poorly will be less sure about where they want to place a piece, and may move and rotate the piece in ways not necessary to reach the eventual placement, either in aborted attempts to place the piece in a different position than the final position, or as a manner of spatial manipulation to aid in their determination of where the piece might fit. Cooper (1975) showed that the rotation of 2d shapes from an initial orientation is proportional to the time required to make a determination about whether its form matches another form. Given this, it seems reasonable that subjects, when given the ability to affect the rotation and translation of the object, would manipulate it in the world space as opposed to in the mental space, both to lessen mental processing load and decrease mental processing time, an important factor in a time-sensitive game such as Tetris. We would expect a player playing an easier version of Tetris would have a lower minimum path difference than a player playing a harder version, as they would make fewer unnecessary moves.

I conducted a one-way between subjects ANOVA and determined there was a significant effect of the manipulation of the Tetris task (i.e. easy, hard, adaptive) on performance on the minimum path difference metric, $F(2,9576)=39.17$, $p<.05$, $\eta^2=.0081$. A follow-up Tukey's HSD test determined that all conditions were significantly different from each other, with $p<.05$, and that the scores appear in the order expected, with "Easy" having the lowest minimum path difference, "Hard" having the highest minimum path difference, and Adaptive having a minimum path difference found between the two.



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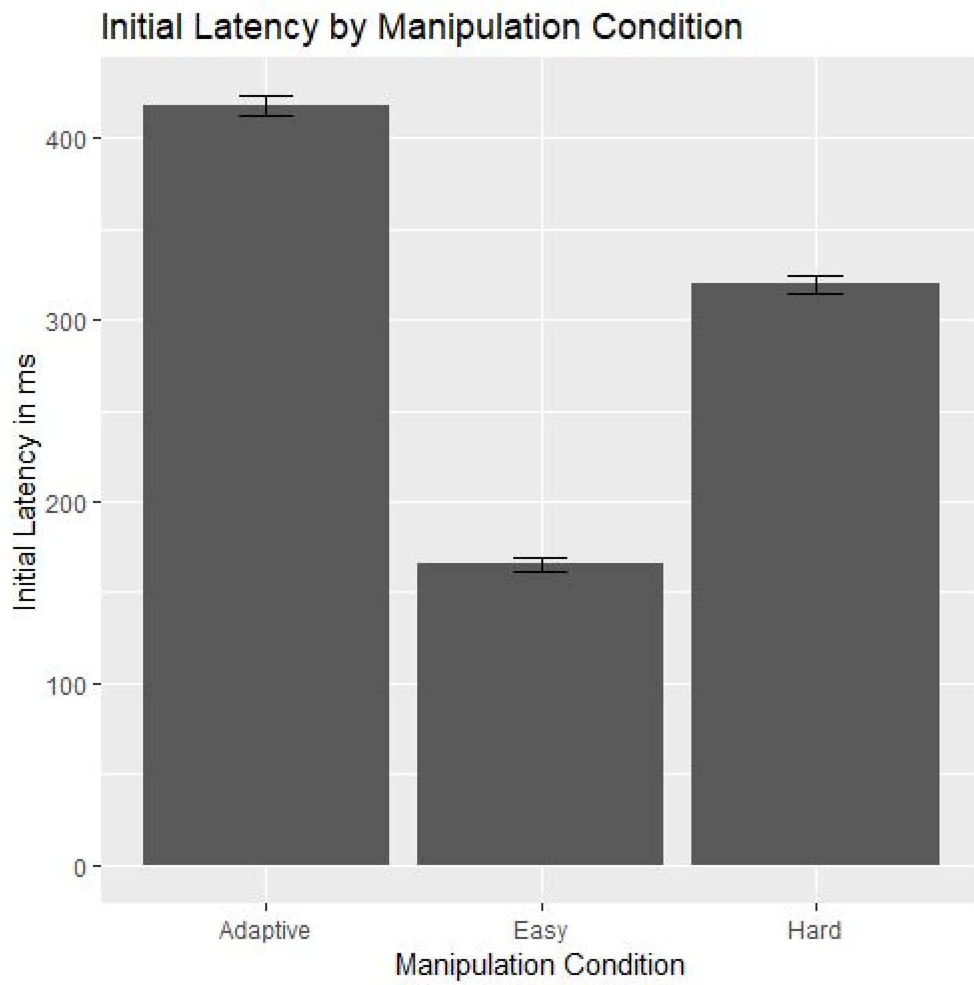
Initial latency

Initial latency is the second metric of performance examined, and is defined as the time (in ms) between initial presentation of a Tetris piece and when the subject first presses a button to begin manipulating the piece. A subject who is under higher mental workload would likely be unable to respond to the presentation of a new zoid as quickly as a subject who is under lower mental workload. This measure can be thought of as analogous to a reaction time measure. We would expect subjects playing an easier version of Tetris to have a lower initial latency than subjects who are playing a harder version of Tetris.

I conducted a one-way between subjects ANOVA and found a significant effect of experimental manipulation (easy, hard, or adaptive) of the Tetris task on the initial latency metric, $F(2,9576)=631.5$, $p<.05$, $\eta^2=0.12$. A follow-up Tukey's HSD found that all conditions were significantly different from each other. The "Easy" condition had the lowest initial latency, and the "Hard condition had a higher initial latency than the easy condition. However the adaptive condition had an initial latency significantly higher than both the "easy" and "hard" conditions. Its possible this due to the changing conditions of the Adaptive task, which means players may find it more difficult to generate strategies to place the pieces, since a strategy which is valid when the accumulation is low, and therefore pieces are likely more difficult to place, may not be valid when the accumulation is high, and the pieces would probably be easier to place.



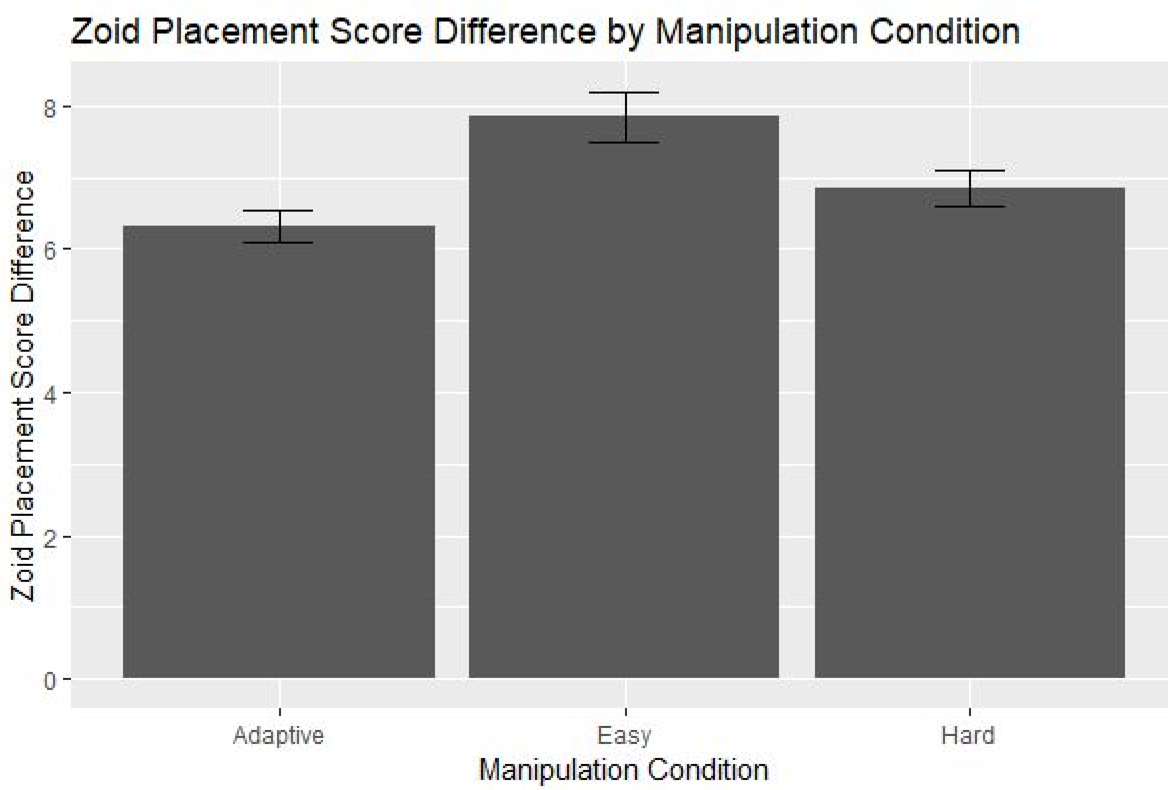
Feature score difference

Feature score difference is the difference in weighted feature scores for the post-placement accumulations of the player's Tetris piece placement, and the placement of a zoid recommended by Meta-T's AI capabilities, in this case using the Dellacherie controller (Fahey 2003). This AI generates a weighted feature sum (as described above) for each possible placement, and then picks the placement which has the greatest score. If we take a difference score between the AI's placement score and the player's placement score, we get an indication of how well the player is playing compared to the difficulty of the current accumulation, which would be indicated by the magnitude of the AI move's feature score.

Lower numbers on this feature score difference measure indicate the player chose a "better" placement as evaluated by the AI. A score difference of zero would mean that the player either chose the same spot, or a spot with an equivalent feature score, meaning a spot which is just as good (as evaluated by the Dellacherie controller) as the one chosen by the AI. A negative score difference indicates that the player found a better placement of the piece than the AI did, which is possible because the AI only considers positions which can be reached solely by dropping a piece in a particular orientation from the top of the game board. Positions which require the player to slide a piece underneath a portion of the accumulation are not considered by this algorithm, in part because of the larger computational overhead required to evaluate all possible paths to a given placement on top of simply evaluating all orientations from the top of the board. However, even though it is possible for the player to score higher than the AI (and does occur in a minority of cases), the feature score difference measure is still indicative of the player's placement ability relative to the placement difficulty of a particular accumulation, and is still informative.

We would expect that a player in an easier Tetris condition would get lower scores on this metric than a player in a harder Tetris condition, as players with more available cognitive resources will be able to evaluate more possible placements, and will be more likely to choose a better placement, as opposed to one with fewer available cognitive resources, who would be more likely to satisfice when confronted with the constraints of the task.

I performed a one-way between subjects ANOVA and found a significant effect of the experimental manipulation on the Tetris task (either easy, hard, or adaptive conditions) on the feature score difference metric, $F(2,9576)=7.89$, $p<.05$, $\eta^2=.0016$. A Tukey's HSD follow-up test found significant differences between easy and adaptive, and easy and hard, not between hard and adaptive. It also found that easy had higher average feature score differences than hard, as expected, but that adaptive had lower feature score differences than easy and hard (although, as mentioned above, not significantly lower than the hard condition).



It is important to note that each of the above is only a part of the whole story. Each measure is an indicator of overall performance, but does not describe the entirety of performance. The main measure we use as a more descriptive measure of performance is the game score, which is logical to use because it is also what the players themselves will use to determine their performance. As can be seen in the results concerning hypothesis 2 below, overall score in the three conditions, relative to individual performance on the baseline tetris task, behaves as expected, with players scoring relatively highest on the easy condition, followed by the adaptive condition, followed by the hard condition.

Experimental Design

This interaction between the subject and the piece-choice system can be conceived of as an instance of human-machine teaming, with the system being an AI agent. Both the player and the agent have an influence over the performance of the game; the player has control over where the pieces are placed on the game board, and the agent has control over what pieces will be given to the player based on its evaluation of the game board. It stands to reason that there are actions which the agent may make which improve or worsen the player's performance in Tetris, and that those actions which keep the player in flow (which are present in the adaptive condition) will lead to better performance than those which do not (in the easy or hard condition). This interaction can then be characterized as an instance of team flow, where the actions of the AI agent can have an effect on the flow of the player, and that cooperative interaction between the AI and the player will lead to better performance than an antagonistic interaction.

The experiment lasts three hours over two sessions. In the first session, subjects take the DFS, to get a measure of their trait flow, and then do a baseline *Meta-T* task for 50 minutes. This task gives subjects a random zoid each time, and is closer to the *Tetris* games some players might be familiar with than the experimental tasks are. The purpose of this task is to familiarize the subjects with the game and leave enough time for any practice effects to occur, as well as to gather data for the post-experimental task to be compared against.

When gaining expertise in a task, people will go through periods of learning, which will increase performance to a task. Eventually they will reach a point where their performance plateaus, and further performance improvements will not occur unless they alter their strategy, allowing them to transcend the ceiling imposed by their previous strategy (Ericsson, 2009; Gray & Lindstedt, 2017). Ideally, the first *Meta-T* task will give the players long enough time to reach a plateau, which would reduce the amount of learning effects across the experimental task and into the final *Meta-T* post task, hopefully diminishing its influence as a confound.

In the second session, subjects will do the experimental *Meta-T* task for one hour, in which they have been randomly assigned to either the "best" condition, the "worst" condition, or the adaptive condition. Following this task, they will take the FSS, to gain a measure of their state flow immediately following the experimental task. After this experimental task, they then play a second unaltered *Meta-T* game for 50 minutes, to determine if there is any transfer of flow from the experimental task, differing based on the different experimental conditions.

Performance on each Tetris task is evaluated using a "criterion score." This is a measure intended to remove some of the variation in Tetris score caused by the semi-random nature of gameplay. Sometimes players will get a disadvantageous sequence of zoids, which could cause them to have poor performance in a single game, which wouldn't be representative of their overall ability. To counter this, we take the average of the scores of a players four highest-scoring games, and use it as a measure of performance. This method of score evaluation has been used in *Meta-T* research previously (Sibert, Gray, & Lindstedt, 2017).

We have generated two hypothesis with respect to outcomes of this experiment, relating to induction of flow state, and transfer to external tasks. We believe the manipulation which adaptively balances challenge and skill will lead to higher flow state than manipulations which produce a mismatch between challenge and skill. In this area, we believe we will find results similar to those found by Keller et al. (2011) and Tozman, Magdas, MacDougall, and Vollmeyer (2015), who found that a challenge skill balance led to a higher flow assessment.

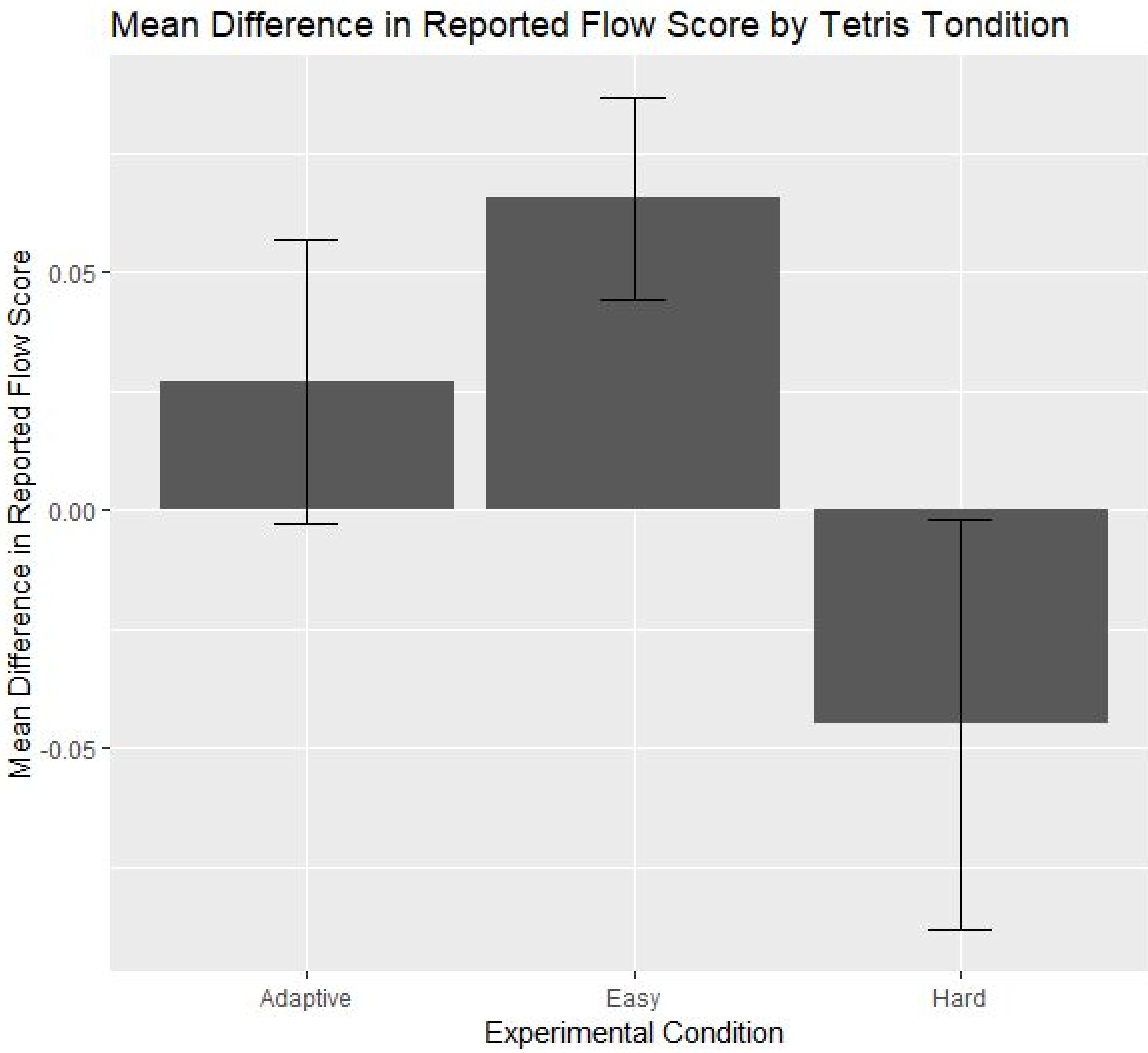
We believe that, if a flow state or some correlate of such is transferred from the experimental task to the transfer task, there should be an increase in performance in the transfer task. Many studies suggest a relationship between flow state and improved performance (Eisenberger, Jones, Stinglhamber, Shanock,& Randall, 2005; Fullagar, Knight, & Sovern, 2013; Jackson, Thomas, Marsh, & Smethurst, 2001), with some (Jackson et al. 2001) positing a causal relationship between flow and improved performance. Therefore we believe that if a flow state has transferred from an experimental task to a transfer task, there should be increased performance on the transfer task relative to baseline.

Hypothesis 1: Subjects who play in the "adaptive" experimental condition will report higher state flow than those in the "easy" or "hard" conditions.

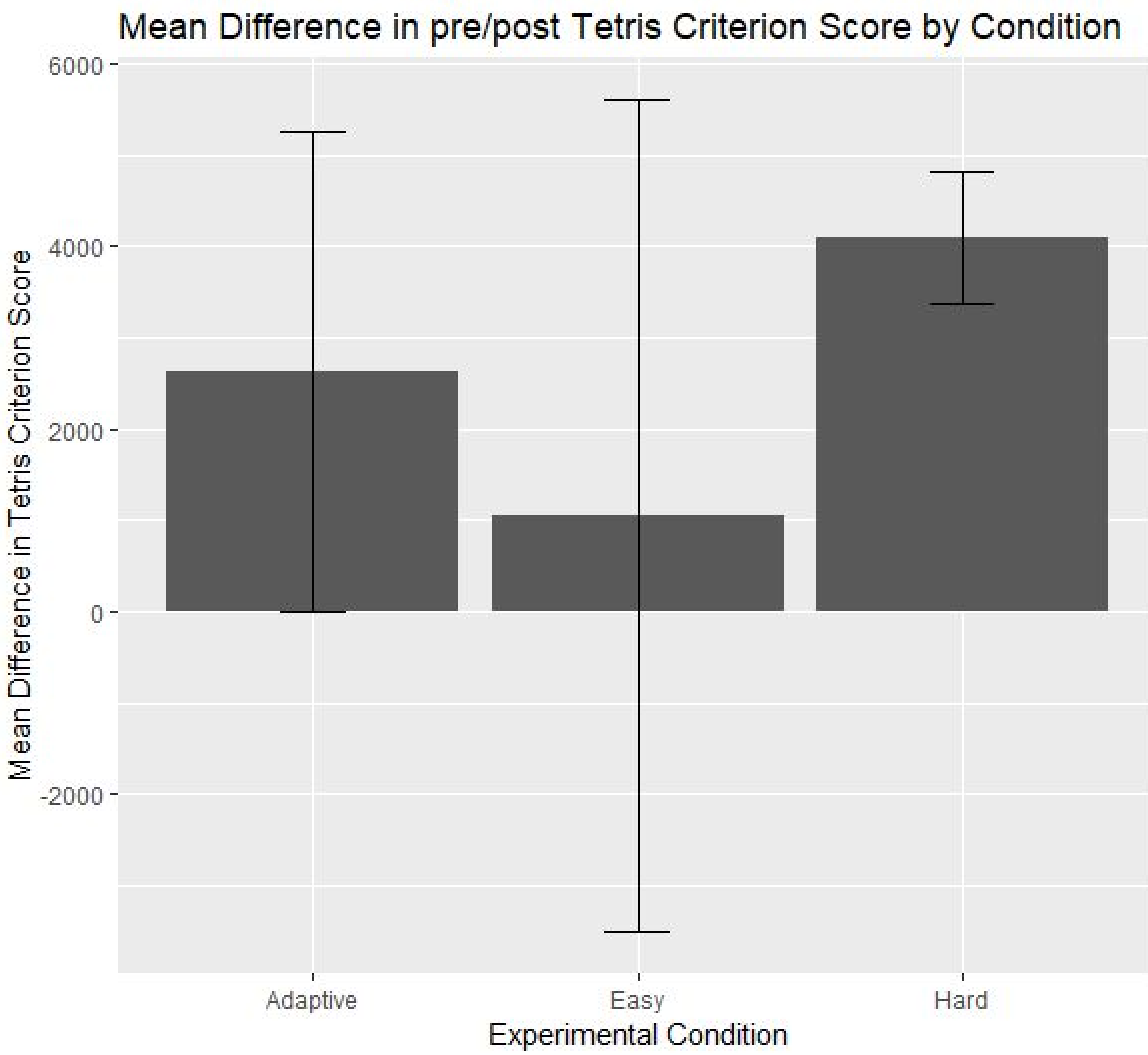
Hypothesis 2: Subjects who play in the "adaptive" experimental condition will perform better in the post task, relative to their performance in the pre task, than subjects who play in the "easy" or "hard" conditions.

Pilot data Thirty-five subjects total have been run, of which 13 were excluded due to incomplete data. The remaining 23 subjects were predominantly female (13 female, 10 male), of varying ages (M=21.56 years, SD=5.08).

To test hypothesis 1, an F test was performed to determine if there was a significant effect of the experimental condition on reported flow $F(2,20)=2.18$, $p=0.14$ (see Figure 4). No significant difference was found, likely due to the small sample size.



To test hypothesis 2, an F test was performed to determine if there was a significant effect of the experimental condition on difference in performance between the pre and post Tetris tasks $F(2,20)=0.32$, $p=0.73$ (see Figure 5). No significant difference was found.



One of the concerns involved with an attentional control task such as Tetris is that of the subject experiencing learning effects, and improving their performance over time for reasons unrelated to flow. This is part of the motivation for having the subject play the baseline task for 50 minutes before experiencing the experimental condition, as our reasoning was that if there was a strong learning effect present in performance on the task, it would eventually plateau as players became acclimated to the task (Ericsson, 2009; Gray & Lindstedt, 2017). To determine if 50 minutes was a sufficient amount of time, we examined the learning curves of performance (both individual, and by experimental group) on the initial baseline task and the experimentally manipulated task. In these conditions, both in the final score curves as well as curves measuring minimum path difference, initial latency, and feature score difference, no clear pattern was found which would indicate a strong distinguishable learning effect. We reason that since there was no visible learning effect found within these conditions, it is likely not a strong effect overall, and its role as a confounding variable will likely be minimal.

Proposed Study

The proposed study will be largely the same as Experiment 2, with some additional measures to capture several relevant aspects, such as a measure of perceived effort (which would let us separate that aspect from the challenge-skill balance) and a measure of the previous experience the subject has had with the game of Tetris.

The proposed study will test two hypotheses, relating to the ability of the task to induce flow, and the degree to which transfer effects are seen, respectively.

We believe that the adaptive variant of the task will lead to greater perceived flow than the easy task, which will have greater perceived flow than the hard task. As the method we use to measure perceived flow is administration of flow questionnaires, the first hypothesis is thus:

H1: Participants in the adaptive condition will report greater flow on the post-task FSS-2, relative to the baseline DFS-2, than those in the easy condition, and likewise those in the easy condition will report greater flow on the post-task FSS-2, relative to the baseline DFS-2, than those in the hard condition.

We also believe that the adaptive variant of the task will lead to improved performance on the baseline task than in the performance difference due to the easy task, which will have greater performance improvement than the baseline task following the hard task. Our method of evaluating performance on the Tetris task is by using a “criterion score”, which, as mentioned above, is the mean of the scores of the top four highest-scoring games played during the task. Thus, our second hypothesis is:

H2: a: There will be no significant difference between performance in the conditions in the initial baseline Tetris task, as the manipulation has not yet been applied.

b: Participants in the easy condition will have a greater criterion score, relative to the baseline task, than those in the adaptive condition. Likewise those in the adaptive condition will have a greater criterion score, relative to the baseline task, than those in the hard task.

c: Participants in the adaptive condition will have a greater criterion score on the post-Tetris contrast task, relative to the pre-Tetris baseline task, than participants in the easy condition. Likewise participants in the easy condition will have a greater criterion score on the post-Tetris contrast task, relative to the pre-Tetris baseline task, than participants in the hard condition.

The experiment will involve five tasks: three Tetris tasks, and two questionnaires, which are spread across 2 sessions, of 1 hour and 2 hours, respectively.

In the first session, subjects will begin by taking the Dispositional Flow Scale 2 (DFS2; Jackson & Eklund, 2002), which will measure their tendency to enter into a state of flow as a result of underlying dispositional or personality factors. This will give a baseline flow metric to which later measurements of flow can be compared to.

Subjects will also answer a number of questions relating to their previous experience with the video game Tetris, or similar real-time puzzle games, so that this factor can be taken into account in the analysis.

Following the DFS, subjects will play 50 minutes of a baseline Tetris task, termed pre-Tetris, which closely approximates conventional implementations of Tetris. This will be compared to the post-Tetris task, to determine performance differences due to flow state, as well as to allow subjects to gain a degree of familiarity with the game of Tetris.

In the second session, subjects will begin by playing one hour of the FlowTetris task. This task is similar to a baseline Tetris task, but difficulty is manipulated via a system which changes which piece is given to the player to place based on that pieces suitability for the current game board. The “easy” system gives the piece best suited for the current board, such that the player has very little difficulty in finding a good placement for that piece. The “hard” system gives the piece worst suited for the current board, such that the player will have quite a bit of difficulty finding a good placement for that piece. The “adaptive” system gives a piece of varying suitability for the current board, dependent on the maximum height of the accumulation of pieces at the bottom of the board. When the height of the accumulation is low, such as near the start of the game, when the player has not placed down many pieces, the system will give the player difficult pieces to find good placements for. As the height increases, the system will give easier pieces, and when the maximum height of the accumulation is near the top, and the player is close to losing, the system will give the easiest pieces to find a good placement for.

This “adaptive” system is designed to keep the player in a balance of challenge and skill, where the skill the player has in placing pieces on the board, and therefore their ability to keep the height of the accumulation to a minimum, is matched by the challenge offered by the system, which is manipulated by the pieces given by the system, and the difficulty the player will have in finding an optimal placement for them.

Each subject is randomly selected into either the easy, hard, or adaptive condition of the FlowTetris task, and this constitutes the between subjects manipulation of the experiment.

After the FlowTetris task, subjects will take the Flow State Scale 2 (FSS2; Jackson & Eklund, 2002). This will measure their flow state, and will be compared against their measurement in the DFS2, taken in the first session, to determine the effect of the FlowTetris task on their flow state, relative to a baseline measure of their general flow state.

Subjects will also be asked to rate on a continuous scale their subjective experience of workload after each task, in the same manner as is described in Gopher and Braune (1984). This will allow a comparison of perceived workload between tasks, which will allow for separation of perceived cognitive effort from the challenge skill balance. This will let us better determine if subjects are in a state of high-challenge and high-effort, or in a state of low-challenge and low-effort. Csikszentmihalyi (1997) characterizes only the former state as being conducive to flow, while the latter as being too passive to induce flow.

Following the FSS2, subjects will then play 50 minutes of a baseline Tetris task, termed post-Tetris, which is identical in functioning to the pre-Tetris task. Performance in this task will be compared to performance in the pre-Tetris task to see what effects on performance there are due to the condition subjects were placed in for the FlowTetris task.

We conducted an a priori power analysis using G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007) to test the difference between three independent groups using a repeated measures, between factors ANOVA, with three measurements being taken, an alpha of .05, and a small effect size (f=.25). Results showed that a sample size of 108 participants total, with n=36 subjects per group, is necessary to reach a power of 0.8.

References

Aubé, C., Brunelle, E., & Rousseau, V. (2014). Flow experience and team performance: The role of team goal commitment and information exchange. Motivation and Emotion, 38(1), 120-130.

Chanel, G., Rebetez, C., Bétrancourt, M., & Pun, T. (2008, October). Boredom, engagement and anxiety as indicators for adaptation to difficulty in games. In *Proceedings of the 12th international conference on Entertainment and media in the ubiquitous era* (pp. 13-17). ACM.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive psychology, 4*(1), 55-81.

Cooper, L. A. (1975). Mental rotation of random two-dimensional shapes. *Cognitive psychology, 7*(1), 20-43.

Csikszentmihalyi, M., & Csikszentmihalyi, I. S. (Eds.). (1992). *Optimal experience: Psychological studies of flow in consciousness*. Cambridge university press.

Csikszentmihalyi, M., & Larson, R. (2014). Validity and reliability of the experience-sampling method. In *Flow and the foundations of positive psychology* (pp. 35-54). Springer Netherlands.

Csikszentmihalyi, M. (1975). Play and intrinsic rewards. *Journal of Humanistic Psychology, 15*(3), 41-63. http://dx.doi.org/10.1177/002216787501500306

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. New York: Harper & Row.

Csikszentmihalyi, M. (1997). *Finding flow: The psychology of engagement with everyday life.* Basic Books.

Eisenberger, R., Jones, J. R., Stinglhamber, F., Shanock, L., & Randall, A. T. (2005). Flow experiences at work: For high need achievers alone?. Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 26(7), 755-775.

Ericsson, K. A. (Ed.). (2009). *Development of professional expertise: Toward measurement of expert performance and design of optimal learning environments*. Cambridge University Press.

Fahey, C. P. (2003). Tetris AI, Computer plays Tetris. http://colinfahey.com/tetris/tetris_en. Html.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Fullagar, C. J., Knight, P. A., & Sovern, H. S. (2013). Challenge/skill balance, flow, and performance anxiety. Applied Psychology, 62(2), 236-259.

Gopher, D., & Braune, R. (1984). On the psychophysics of workload: Why bother with subjective measures?. *Human Factors, 26*(5), 519-532.

Gray, W. D., & Lindstedt, J. K. (2017). Plateaus, dips, and leaps: Where to look for inventions and discoveries during skilled performance. Cognitive science, 41(7), 1838-1870.

Harmat, L., de Manzano, Ö., Theorell, T., Högman, L., Fischer, H., & Ullén, F. (2015). Physiological correlates of the flow experience during computer game playing. *International Journal of Psychophysiology*, 97(1), 1-7.

Heyne, K., Pavlas, D., & Salas, E. (2011, September). An investigation on the effects of flow state on team process and outcomes. In Proceedings of the human factors and ergonomics society annual meeting (Vol. 55, No. 1, pp. 475-479). Sage CA: Los Angeles, CA: SAGE Publications.

Hjortskov, N., Rissén, D., Blangsted, A. K., Fallentin, N., Lundberg, U., & Søgaard, K. (2004). The effect of mental stress on heart rate variability and blood pressure during computer work. *European journal of applied physiology, 92*(1-2), 84-89.

Hockey, R. (2013). *The psychology of fatigue: Work, effort and control*. Cambridge University Press.

Jackson, S. A. (2000). Joy, fun, and flow state in sport. *Emotions in sport*, 135-155.

Jackson, S. A. (1995). Factors influencing the occurrence of flow state in elite athletes. *Journal of applied sport psychology*, *7*(2), 138-166.

Jackson, S. A., & Marsh, H. W. (1996). Development and validation of a scale to measure optimal experience: The Flow State Scale. *Journal of sport and exercise psychology, 18*(1), 17-35.

Jackson, S. A., & Eklund, R. C. (2002). Assessing flow in physical activity: The flow state scale–2 and dispositional flow scale–2. *Journal of Sport and Exercise Psychology, 24*(2), 133-150.

Jackson, S. A., Martin, A. J., & Eklund, R. C. (2008). Long and short measures of flow: The construct validity of the FSS-2, DFS-2, and new brief counterparts. *Journal of Sport and Exercise Psychology, 30*(5), 561-587.

Jackson, S. A., Thomas, P. R., Marsh, H. W., & Smethurst, C. J. (2001). Relationships between flow, self-concept, psychological skills, and performance. Journal of applied sport psychology, 13(2), 129-153.

Jorna, P. G. (1992). Spectral analysis of heart rate and psychological state: A review of its validity as a workload index. *Biological psychology, 34*(2-3), 237-257.

Juvina, I., Nador, J., Larue, O., Green, R., Harel, A., & Minnery, B. (2018). Measuring individual differences in cognitive effort avoidance. *Proceedings of the 40th Annual Meeting of the Cognitive Science Society*, Madison, WI.

Keller, J., Bless, H., Blomann, F., & Kleinböhl, D. (2011). Physiological aspects of flow experiences: Skills-demand-compatibility effects on heart rate variability and salivary cortisol. *Journal of Experimental Social Psychology, 47*(4), 849-852.

Keller, J., & Bless, H. (2008). Flow and regulatory compatibility: An experimental approach to the flow model of intrinsic motivation. *Personality and social psychology bulletin, 34*(2), 196-209.

Kool, W., McGuire, J. T., Rosen, Z. B., & Botvinick, M. M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology: General, 139*(4), 665.

Lazarovitz, S. M. (2004). Team and individual flow in female ice hockey players: The relationships between flow, group cohesion, and athletic performance (Doctoral dissertation, ProQuest Information & Learning).

Lewis, I. J., & Beswick, S. L. (2015). Generalisation over details: the unsuitability of supervised backpropagation networks for tetris. Advances in Artificial Neural Systems, 2015, 4.

Lindstedt, J. K., & Gray, W. D. (2015). Meta-T: Tetris® as an experimental paradigm for cognitive skills research. *Behavior research methods, 47*(4), 945-965.

Nakamura, J., & Csikszentmihalyi, M. (2014). The concept of flow. In *Flow and the foundations of positive psychology* (pp. 239-263). Springer Netherlands.

Pilegard, C., & Mayer, R. E. (2018). Game over for Tetris as a platform for cognitive skill training. *Contemporary Educational Psychology, 54*, 29-41.

Plotnikov, A., Stakheika, N., De Gloria, A., Schatten, C., Bellotti, F., Berta, R., ... & Ansovini, F. (2012, July). Exploiting real-time EEG analysis for assessing flow in games. In *Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 688-689). IEEE.

Sibert, C. (2015). *Improving novice Tetris players with feedback from AI model based tutors* (Master's Thesis, Rensselaer Polytechnic Institute).

Sibert, C., Gray, W. D., & Lindstedt, J. K. (2015). Tetris-: Exploring Human Performance via Cross Entropy Reinforcement Learning Models. In *CogSci*.

Sibert, C., Gray, W. D., & Lindstedt, J. K. (2017). Interrogating Feature Learning Models to Discover Insights Into the Development of Human Expertise in a Real-Time, Dynamic Decision-Making Task. *Topics in cognitive science, 9*(2), 374-394.

Taatgen, N. A., Juvina, I., Schipper, M., Borst, J. P., & Martens, S. (2009). Too much control can hurt: A threaded cognition model of the attentional blink. *Cognitive psychology, 59*(1), 1-29.

Thiery, C., & Scherrer, B. (2009). Building controllers for Tetris. *Icga Journal, 32*(1), 3-11.

Thompson, J. J., McColeman, C. M., Stepanova, E. R., & Blair, M. R. (2017). Using Video Game Telemetry Data to Research Motor Chunking, Action Latencies, and Complex Cognitive‐Motor Skill Learning. *Topics in cognitive science, 9*(2), 467-484.

Tozman, T., Magdas, E. S., MacDougall, H. G., & Vollmeyer, R. (2015). Understanding the psychophysiology of flow: A driving simulator experiment to investigate the relationship between flow and heart rate variability. *Computers in Human Behavior, 52*, 408-418.

Westbrook, A., & Braver, T. S. (2015). Cognitive effort: A neuroeconomic approach. *Cognitive, Affective, & Behavioral Neuroscience, 15*(2), 395-415.

Webster, J., Trevino, L. K., & Ryan, L. (1993). The dimensionality and correlates of flow in human-computer interactions. *Computers in human behavior, 9*(4), 411-426.

Vollmeyer, R., & Rheinberg, F. (2006). Motivational effects on self-regulated learning with different tasks. *Educational Psychology Review, 18*(3), 239-253.

Appendix 1: Figures

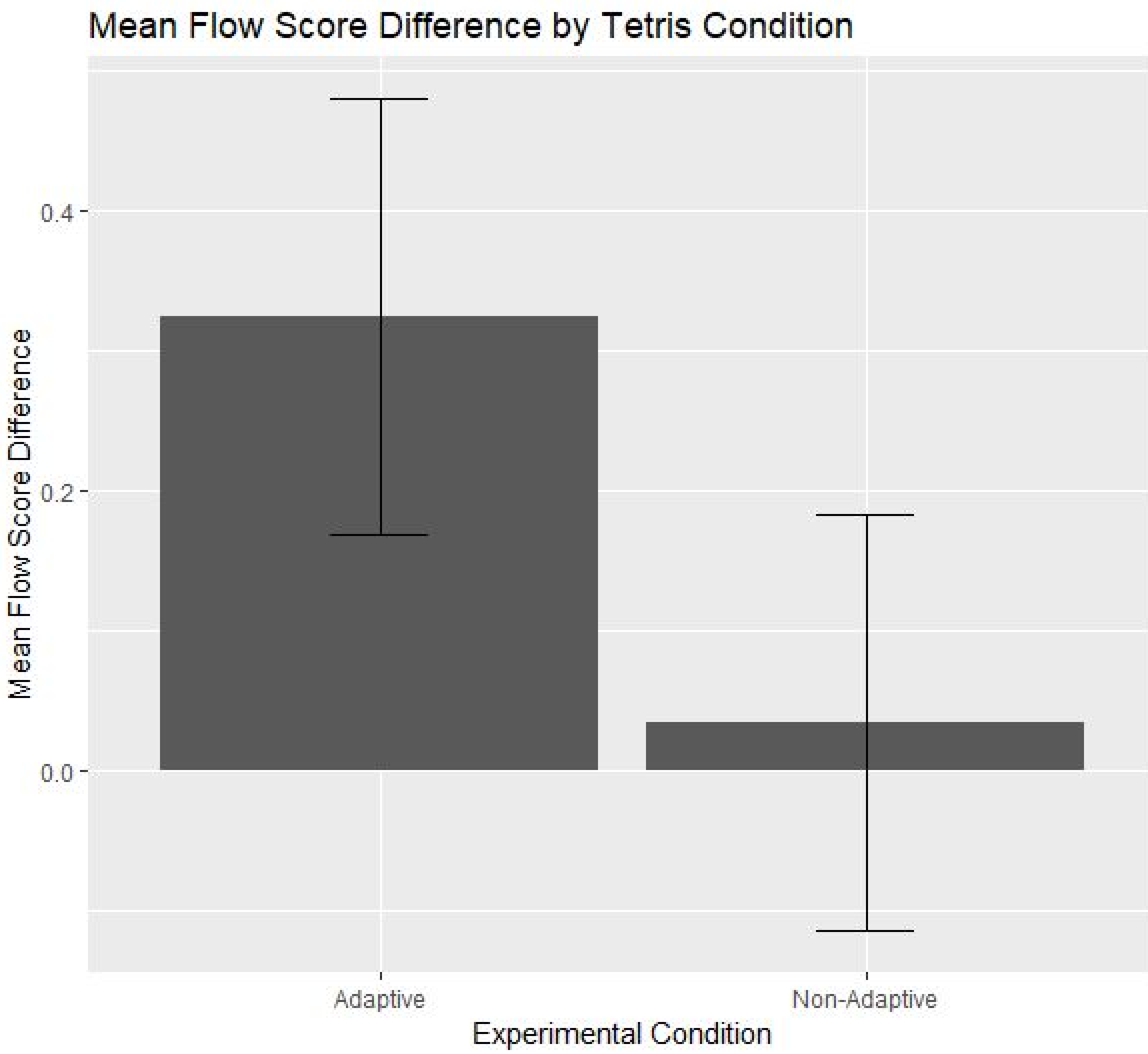


Figure 1: Mean Flow Score Difference by Tetris Condition, with error bars representing standard error. Figure is scaled to maximum possible difference between flow scores, which individually are normalized between 0 and 1.

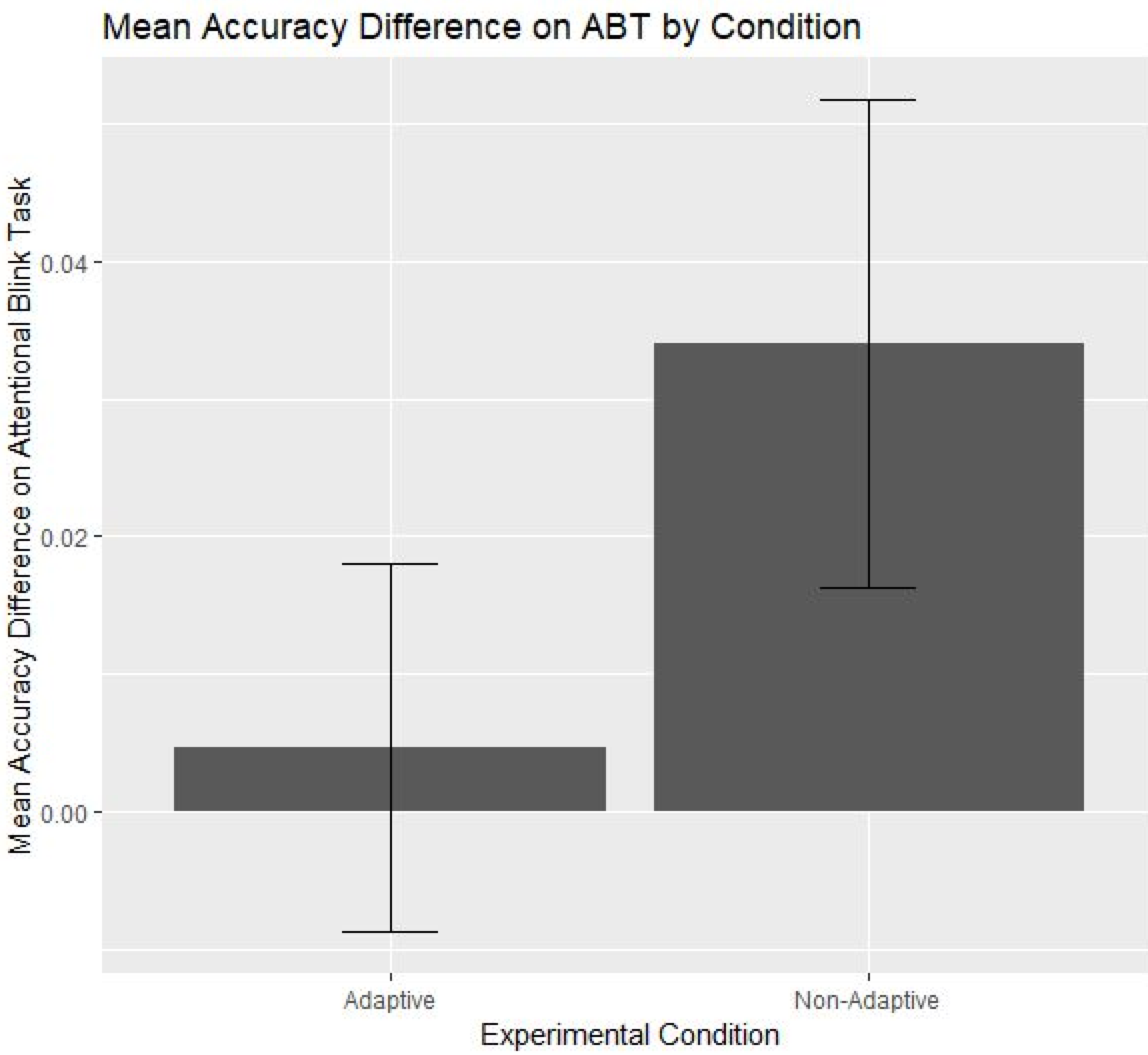


Figure 2: Mean ABT Accuracy difference by Tetris Condition, with error bars representing standard error

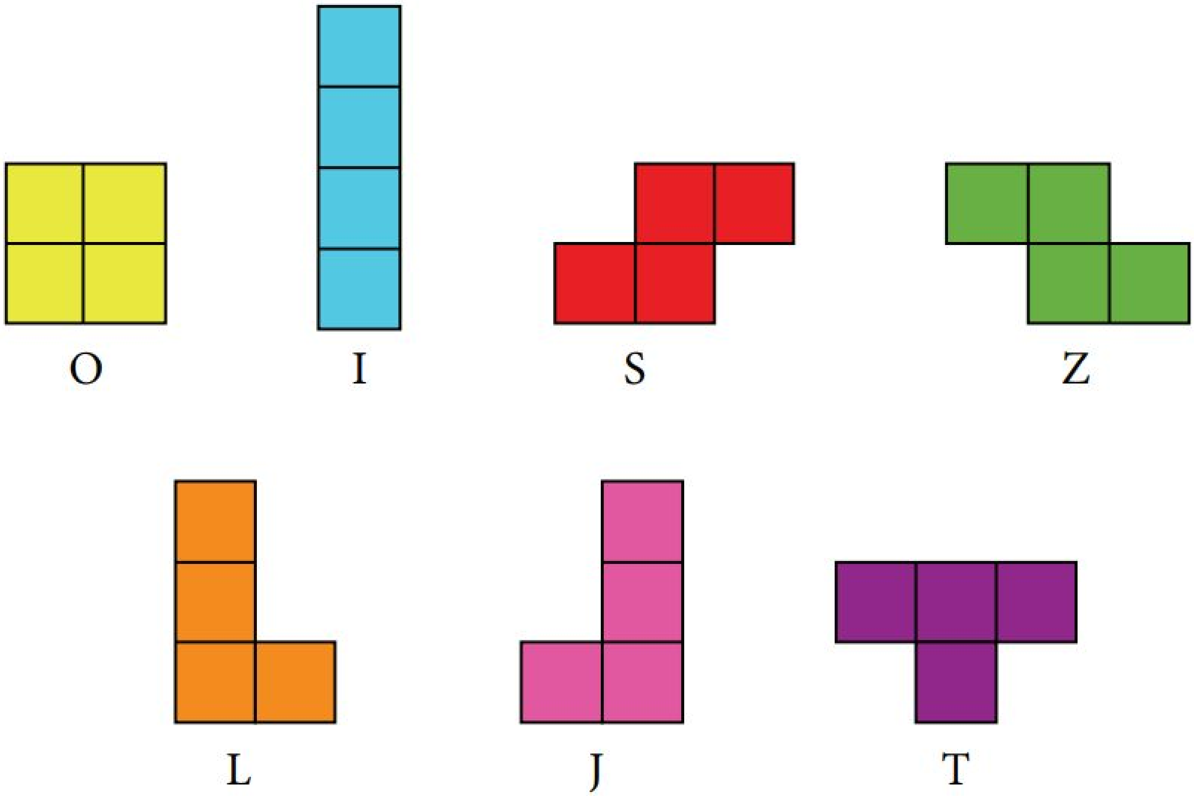


Figure 3: The seven Tetris Tetrominoes, also known as zoids, along with their standard naming convention. Adapted from “Generalisation over details: the unsuitability of supervised backpropagation networks for tetris” by I. J. Lewis and S. L. Beswick, 2015, *Advances in Artificial Neural Systems*, 2015, p. 2. Copyright 2015 I. J. Lewis and S. L. Beswick, reprinted under Creative Commons Attribution License.

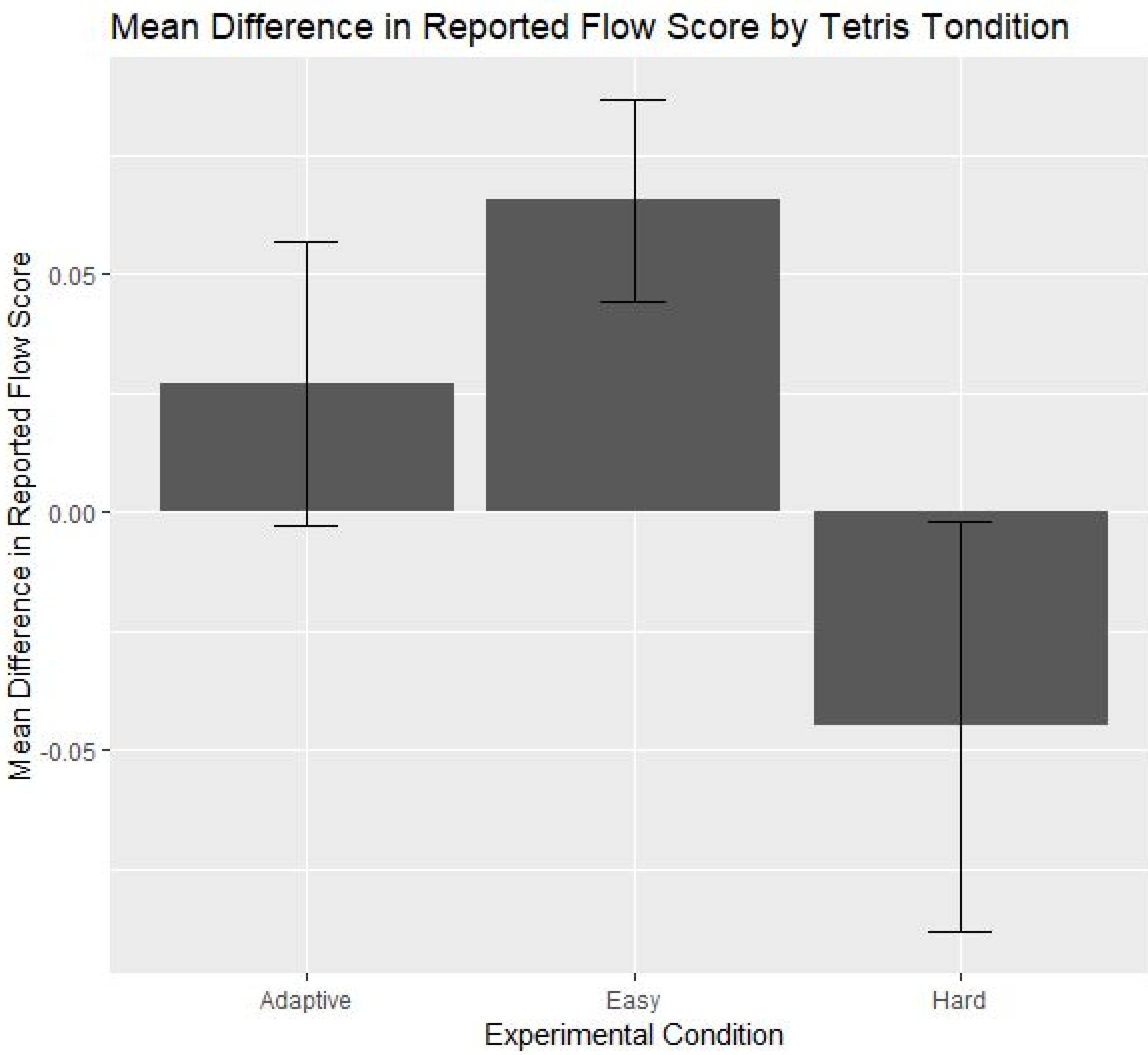


Figure 4: Mean difference in reported flow score by Tetris condition. Error bars represent standard error.

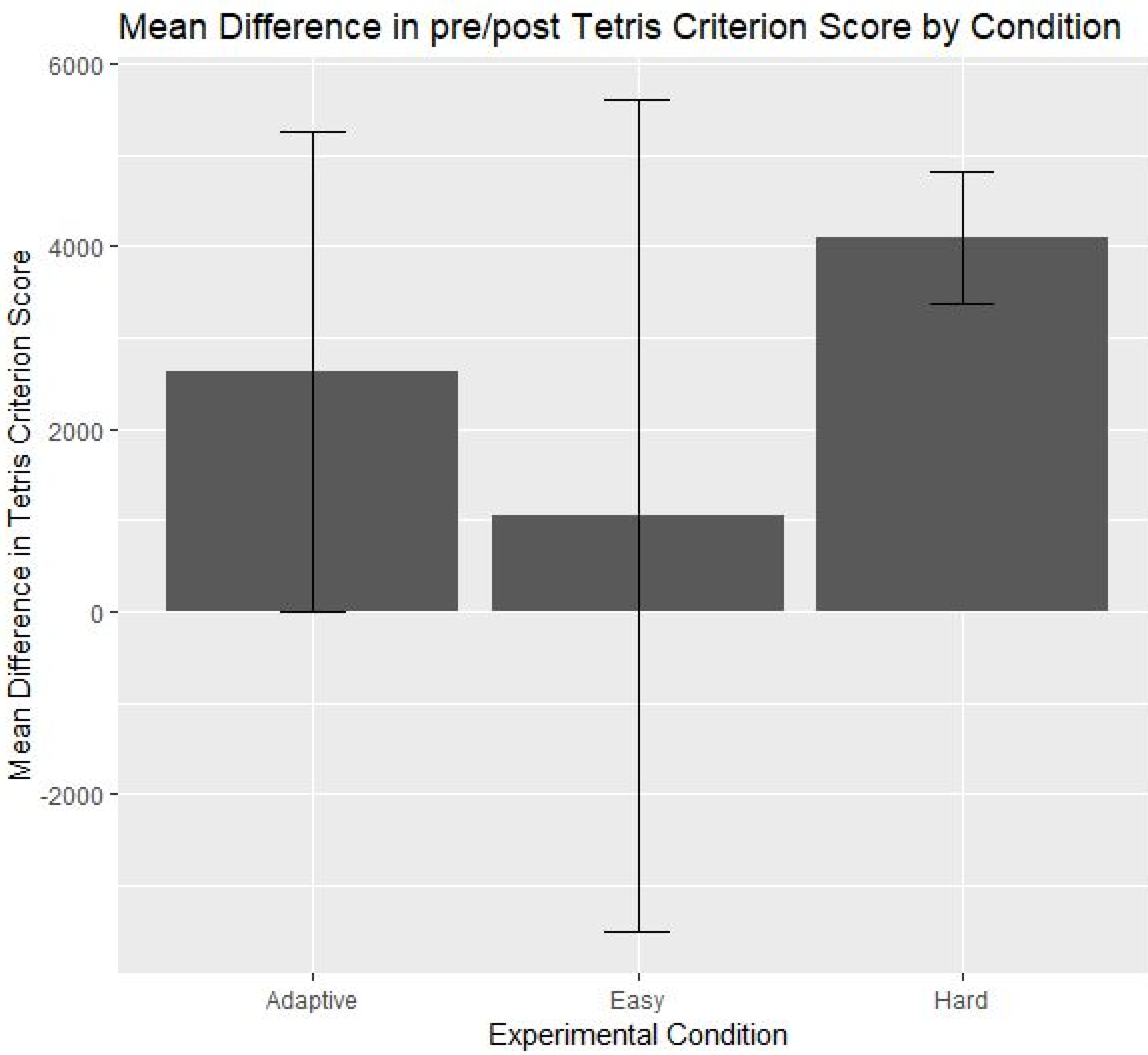


Figure 5: Mean difference in reported flow score by Tetris condition. Error bars represent standard error.

Appendix 2: Flow Scales

The following flow questionnaires are adapted from the Dispositional Flow Scale 2 (DFS-2) and Flow State Scale 2 (FSS-2), (Jackson & Eklund, 2002), with minor changes in prompting to ensure that the subject evaluates their flow experience as a habitual mental state (as in the DFS-2) or with respect to the task which immediately preceded the administration of the scale (as in the FSS-2)

DFS-2

Responses are prompted by the following:

When you do things in your everyday life, how often would you say the following statements match your mental state?

Responses to all items follow a Likert-type scale format, requiring subjects to choose among the following answers:

- **Never**
- **Rarely**
- **Sometimes**
- **Frequently**
- **Always**

Subjects are presented with the following

1. When I do a challenging task, I believe my skills will allow me to meet the challenge.
2. When I do a task, I make the correct movements without thinking about trying to do so.
3. When doing tasks, I know clearly what I want to do.
4. When I'm doing a task, it is really clear to me how my performance is going.
5. When I do a task, my attention is focused entirely on what I am doing.
6. When I do a task, I have a sense of control over what I am doing.
7. When I do a task, I am not concerned about what others may be thinking of me.
8. When I do a task, time seems to alter (either slows down or speeds up).
9. When I do a task, I really enjoy the experience.
10. When I do a challenging task, my abilities match the high challenge of the situation.
11. When I do a task, things just seem to be happening automatically.
12. When I do a task, I have a strong sense of what I want to do.
13. When I do a task, I am aware of how well I am performing.
14. When I do a task, it is no effort to keep my mind on what is happening.
15. When I do a task, I feel like I can control what I am doing.

16. When I do a task, I am not concerned with how others may be evaluating me.
17. When I do a task, the way time passes seems to be different from normal.
18. When I do a task, I love the feeling of the performance and want to capture it again.
19. When I do a challenging task, I feel I am competent enough to meet the high demands of the situation
20. When I do a task, I perform automatically, without thinking too much.
21. When I do a task, I know what I want to achieve.
22. When I do a task, I have a good idea while I am performing about how well I am doing.
23. When I do a task, I have total concentration.
24. When I do a task, I have a feeling of total control.
25. When I do a task, I am not concerned with how I am presenting myself.
26. When I do a task, it feels like time goes by quickly.
27. When I do a task, the experience leaves me feeling great.
28. When I do a task, the challenge and my skills are at an equally high level.
29. When I do a task, I do things spontaneously and automatically without having to think.
30. When I do a task, my goals are clearly defined.
31. When I do a task, I can tell by the way I am performing how well I am doing.
32. When I do a task, I am completely focused on the task at hand.
33. When I do a task, I feel in total control of my body.
34. When I do a task, I am not worried about what others may be thinking of me.
35. When I do a task, I lose my normal awareness of time.
36. When I do a task, the experience is extremely rewarding.

FSS-2

Responses are prompted by the following:

How much would you agree that each statement below matched your mental state during the task you just did?

Responses to all items follow a Likert-type scale format, requiring subjects to choose among the following answers:

- **Strongly Disagree**
- **Disagree**
- **Neither agree nor disagree**
- **Agree**
- **Strongly Agree**

Subjects are presented with the following

1. I was challenged, but I believed my skills would allow me to meet the challenge.
2. I made the correct movements without thinking about trying to do so.
3. I knew clearly what I wanted to do.
4. It was really clear to me how my performance was going.
5. My attention was focused entirely on what I was doing.
6. I had a sense of control over what I was doing.
7. I was not concerned about what others may have been thinking of me.
8. Time seemed to alter (either slowed down or sped up)
9. I really enjoyed the experience.
10. My abilities matched the high challenge of the situation.
11. Things just seemed to be happening automatically.
12. I had a strong sense of what I wanted to do.
13. I was aware of how well I was performing.
14. It was no effort to keep my mind on what was happening.
15. I felt like I could control what I was doing.
16. I was not concerned with how others may have been evaluating me.
17. The way time passed seemed to be different from normal.
18. I loved the feeling of the performance and want to capture it again.
19. I felt I was competent enough to meet the high demands of the situation.
20. I performed automatically, without thinking too much.
21. I knew what I wanted to achieve.
22. I had a good idea while I was performing about how well I was doing.
23. I had total concentration.
24. I had a feeling of total control.
25. I was not concerned with how I was presenting myself.
26. It felt like time went by quickly.
27. The experience left me feeling great.
28. The challenge and my skills were at an equally high level.
29. I did things spontaneously and automatically without having to think.
30. My goals were clearly defined.
31. I could tell by the way I was performing how well I was doing.
32. I was completely focused on the task at hand.
33. I felt in total control of my body.
34. I was not worried about what others may have been thinking of me.
35. I lost my normal awareness of time.
36. I found the experience extremely rewarding.