Balancing Risk and Reward to Develop an Optimal Hot Hand Game

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Abstract

This paper explores the issue of player risk-taking and reward structures in a game designed to investigate the psychological phenomenon known as the ‘hot hand’. The expression ‘hot hand’ originates from the sport of basketball, and the common belief that players who are on a scoring streak are in some way more likely to score on their next shot than their long-term record would suggest. That is, they are on a ‘hot streak’, or have the ‘hot hand’. There is a widely held belief that players in many sports demonstrate such streaks in performance; however, a large body of evidence discredits this belief. One explanation for this disparity between beliefs and available data is that players on a successful run are willing to take greater risks due to their growing confidence. We are interested in investigating this possibility by developing a top-down shooter. Such a game has unique requirements, including a well-balanced risk and reward structure that provides equal rewards to players regardless of the tactics they adopt. We describe the iterative development of this top-down shooter, including quantitative analysis of how players adapt their risk taking under varying reward structures. We further discuss the implications of our findings in terms of general principles for game design.

Key Words: risk, reward, hot hand, game design, cognitive, psychology
Introduction

Balancing risk and reward is an important consideration in the design of computer games. A good risk and reward structure can provide a lot of additional entertainment value. It has even been likened to the thrill of gambling (Adams, 2010, p. 23). Of course, if players gamble on a strategy, they assume some odds, some amount of risk, as they do when betting. On winning a bet a person reasonably expects to receive a reward. As in betting, it is reasonable to expect that greater risks will be compensated by greater rewards. Adams not only states that “A risk must always be accompanied by a reward” (2010, p. 23) but also believes that this is a fundamental rule for designing computer games.

Indeed, many game design books discuss the importance of balancing risk and reward in a game:

- “The reward should match the risk” (Thompson, 2007, p.109).
- “… create dilemmas that are more complex, where the players must weigh the potential outcomes of each move in terms of risks and rewards” (Fullerton, Swain, & Hoffman, 2004, p.275).
- “Giving a player the choice to play it safe for a low reward, or to take a risk for a big reward is a great way to make your game interesting and exciting” (Schell, 2008, p.181).

Risk and reward matter in many other domains, such as stock-market trading and sport. In the stock market, risks and rewards affect choices among investment options. Some investors may favour a risky investment in, say, nano-technology
stocks, since the high risk is potentially accompanied by high rewards. Others may be more conservative and invest in solid federal bonds which fluctuate less, and therefore offer less reward, but also offer less risk. In sports, basketball players sometimes take more difficult and hence riskier shots from long distance, because these shots are worth three points rather than two.

Psychologists, cognitive scientists, economists and others are interested in the factors that affect human choices among options varying in their risk-reward structure. However, stock markets and sport arenas are ‘noisy’ environments, making it difficult (for both players and researchers) to isolate the risks and rewards of any given event. Computer games provide an excellent platform for studying, in a well-controlled environment, the effects of risk and reward on players’ behaviour.

We examine risk and reward from both a cognitive science and game design perspective. We believe these two perspectives are complementary. Psychological principles can help inform game design, while appropriately designed games can provide a useful tool for studying psychological phenomena.

Specifically, in the current paper we discuss the development of a top-down shooter that can be used to investigate the psychological phenomenon known as the ‘hot hand’. We begin with an overview of this phenomenon and the current state of research, before outlining the unique requirements of a game designed to expand this research. In subsequent sections we describe three stages of game design and development.
This type of design could be characterised as iterative and player-centric (Sotamaa, 2007). While the game design in this instance is simple, due to the precise requirements of the psychological investigation, player testing is more formal than might traditionally be used in game development. Consequently, changes in player strategy can be precisely evaluated. At each stage of development we formulate a specific design for our game challenge. We then test the game to measure how players respond to the game’s risk and reward structure. We analyse these results in terms of player strategy and performance and then use this analysis to inform our next stage of design. In our final section we relate our findings back to more general principles of game design.

The Hot Hand

The expression ‘hot hand’ originates from basketball and describes the common belief that players who are on a streak of scoring are more likely to score on their next shot. That is, they are on a hot streak or have the ‘hot hand’. In a survey of 100 basketball fans, 91% believed that players had a better chance of making a shot after hitting their previous two or three shots than after missing their previous few shots (Gilovitch, Vallone, & Tversky, 1985).

While intuitively these beliefs and predictions seem reasonable, no evidence for the hot hand was found in the field-goal shooting data of the 1980-81 Philadelphia 76ers, or the free-throw shooting data of the 1980-81 and 1981-82 Boston Celtics (Gilovitch et al., 1985). With few exceptions, subsequent studies across a range of sports confirm this surprising finding (Bar-Eli, Avugos, & Raab, 2006) - suggesting that hot
and cold streaks of performance could be a myth.

However, results of previous hot hand investigations reveal a more complicated picture. Specifically, previous studies suggest that a distinction can be made between tasks of ‘fixed’ difficulty and tasks of ‘variable’ difficulty. A good example of a ‘fixed’ difficulty task is free-throw shooting in basketball. In this type of shooting the distance is kept constant, so each shot has the same difficulty level. In a ‘variable’ difficulty task, such as field shooting during the course of a basketball game, players may adjust their level of risk from shot-to-shot, so the difficulty of the shot varies depending on shooting distance, the amount of defensive pressure, and the overall game situation.

Evidence suggests it is possible for players to get on hot streaks in fixed difficulty tasks such as horseshoe pitching (Smith, 2003), billiards (Adams, 1996), and ten-pin bowling (Dorsey-Palmenter & Smith, 2004). In variable difficulty tasks however, such as baseball (Albright, 1993), basketball (Gilovitch et al., 1985), and golf (Clark, 2003a, 2003b, 2005), there is no evidence for hot or cold streaks - despite the common belief to the contrary.

The most common explanation for the disparity between popular belief (hot hand exists) and actual data (lack of support for hot hand) is that humans tend to misinterpret patterns in small runs of numbers (Gilovitch et al., 1985). That is, we tend to form patterns based on a cluster of a few events, such as a player scoring three shoots in a row. We then use these patterns to help predict the outcome of the next event, even though there is insufficient information to make this prediction.
(Tversky & Kahneman, 1974). In relation to basketball shooting, after a run of three successful shots, people would incorrectly believe that the next shot is more likely to be successful than the player’s long term average. This is known as the hot-hand fallacy.

A different explanation for this disparity is that hot-handed players tend to take greater risks due to their over-confidence (Smith, 2003). That is, as a player has a run of successes they decide to take on more difficult shots, make more complex moves, or increase the speed at which they perform a task. Increasing the difficulty could reduce the players’ chances of success in such a way to counteract any measure of hot performance. The recorded data would then show no increase in their likelihood of success during a hot streak. While this hypothetical account receives tentative support by drawing a distinction between fixed and variable difficulty tasks (as the hot hand is more likely to appear in fixed tasks, where players cannot engage in a more difficult shot), this hypothesis requires further study.

Unfortunately, trying to gather more data to investigate the hot hand phenomenon from sporting games and contests is fraught with problems of subjectivity. How can one assess the difficulty of a given shot over another in basketball? How can one tell if a player is adopting an approach with more risk?

An excellent way to overcome this problem is to design a computer game of ‘variable’ difficulty tasks that can accurately record changes in player strategies. Designing such a game, which we call a 'hot hand game', is the main focus of this paper. Such a game can potentially answer a number of questions:
1. How do players respond to a run of success or failure in a game challenge?
2. Will a player take on more difficult challenges if they are on a hot streak?
3. Will they lower their risk if they are on a cold streak?
4. How will this variable risk level impact on their overall measure of performance?
5. How can the hot hand principle be used in the design of game mechanics?

Game Requirements

A hot hand game that addresses the above questions has special requirements. First and foremost, we require players to be willing to adjust their level of risk throughout the game, and thus explore a range of possible strategies. To ensure this exploring behaviour the game requires a well-balanced risk and reward structure. If one risk level provides substantially more reward than any other, players will learn this reward structure over time, and be unlikely to change strategy in response to runs of success and failure. We would thus like each risk level to be, for the average player, equally rewarding. In other words, regardless of the level of risk adopted, the player has about the same chance of obtaining the best score.

The second requirement for an optimal hot hand game is that it allows measurement of players’ strategy after runs of both successes and failures. If people fail most of the time, we won’t record enough runs of success. If people succeed most of the time, we won’t observe enough runs of failure. Thus, the core challenge needs to provide a probability of success, on average, somewhere in the range of 40-60%.

In our efforts to design this simple action game we find that even subtle changes to
risk and reward structures impact on a player’s risk-taking strategy. We now describe three stages of design and development of our hot hand game. In our final discussion we will relate the findings back to more general issues of game design.

Stage One - A Simple Action Game

The game for our study is a top-down shooter developed in Flash using Actionscript. There is no narrative or backstory to the game. The game screen shows two spaceships, representing an alien and the player-shooter (Figure 1). The simple interface provides feedback about the current number of kills and the time remaining. During the game the player’s spaceship remains stationary at the bottom centre of the screen. Only a single alien spaceship appears at any one time. It moves horizontally back-and-forth across the top of the screen, and bounces back each time it hits the right or left edges. The player shoots at the alien ship by pressing the spacebar. For each new alien ship the player has only a single shot with which to destroy it. If an alien is destroyed the player is rewarded with a kill. The player’s goal is to gain as many kills as possible in a set amount of time.
Each alien craft enters from the top of the screen and randomly moves towards either the left or right edge. It bounces off each side of the screen, moving horizontally and making a total of eight passes before flying off. Initially the alien ship moves swiftly, but it decelerates at a constant rate, moving more slowly after each pass. This game therefore represents a variable difficulty task – a player can elect a desired level of risk as the shooting task becomes less difficult with each pass of the alien.

The risk and reward equation is quite simple for the player. The score for destroying an alien is the same regardless of when the player fires. Since the goal is to destroy as many aliens as possible in the game period, the player would benefit from shooting as quickly as possible; shooting in the early passes rewards the player with
both a kill and more time to shoot at subsequent aliens. However, because the alien
ship decelerates during each of the eight passes, the earlier a player shoots the
more likely a player will miss the target. If a shot is missed, the player incurs a 1.5
second time penalty. That is, the next alien will appear only after a 1.5 second delay
which is additional to the interval experienced for an accurate shot.

After self-testing the game, we deployed it so that it could be played online. Five
players were recruited via an email circulated to students, family and friends. Players
were instructed to shoot down as many aliens as possible within a given time block.
They first played a practice level for six minutes before playing the competitive level
for 12 minutes. The number of alien ships a player encountered varied depending on
the player’s strategy and accuracy. A player could expect to encounter roughly 10
alien ships for every 60 seconds of play. At the completion of the game the player’s
response time and accuracy were recorded for each alien ship.

Recall that one of the game requirements was that players take shots across a range
of difficulty levels, represented by passes (later passes mean less difficult shots) –
this simple test provides evidence that a player is willing to explore the search space
and alter her or his risk-taking behaviour throughout the game. Typical results for
Players one and two are shown in Figure 2. In general players tended to be very
exploratory during the practice level of the game, as indicated by a good spread of
shots between alien passes one and eight. During the competitive game time
however players tended to invest in a single strategy, as indicated by the large
spikes seen in Figure 2, block 2. This suggests that players, after an exploratory
period, attempted to maximise their score by firing on a single, fixed pass.
Figure 2: Results for two typical players in Stage one of game development. The upper row shows data for Player 1, and the bottom row shows data for Player 2. The left column presents the number (frequency) of shots taken on each pass in the practice level, while the right column indicates the number of shots taken on each pass in the competition level. For example, in the competition level, Player 1 attempted 81 shots on the fourth pass, and no shots during passes 1, 7, and 8. Note that players experimented during the practice level, as evident by the evenly spread distribution of shots across passes in the left panels, but then adopted a fixed strategy during the competitive block, evident by spikes at pass 4 (Player 1) and pass 5 (Player 2). For each panel, n is the overall number of shots attempted by the player in that block, m is the mean firing pass, and sd is the standard deviation of the
number of attempted shots.

In psychological experiment terms, this fixation on a single strategy is known as ‘investment’. At the end of the game the players reported that, because deceleration was constant, they could always shoot when the alien was at a specific distance from the wall if they stuck to the same pass. Players thus practiced a timing strategy specific to a particular alien pass (i.e., a specific difficulty level). The number of kills per unit time (i.e., the reward) was therefore always highest for that player when shooting at the same pass, thus they ‘invested’ in that strategy. In the example graphs (Figure 2), one player invested in learning to shoot on pass four, the other, on pass five. This type of investment runs counter to one requirement from a hot hand game, creating a major design flaw that needed to be fixed in the next iteration.

Stage Two - Encouraging Exploratory Play

The aim of the second stage of design was to overcome the problem of players’ investment in a single strategy. The first change was to vary the position of the player’s ship so that it no longer appeared in the same location at the centre of the screen but rather was randomly shifted left and right of centre each time a new alien appeared (Figure 3). Thus, on each trial, the shooter’s location was sampled from a uniform distribution of 100 pixels to the left or to the right of the centre. This manipulation was intended to prevent the player from learning a single timing-sequence that was always successful on a single pass (such as always shooting on pass four when the alien was a certain distance from the side of the screen). Additionally, we tested two different initial speeds and deceleration rates for the alien
ship. These manipulations allowed us to further examine how altering the games core mechanics may alter players’ firing strategy.

![Figure 3: The screen in Stage two of game development. The blue rectangle appears here for illustration purposes and indicates the potential range of locations used to randomly position the player’s ship. It did not appear on the actual game screen.](image)

Once again we deployed an online version of the game and recorded data from 11 players. Five players played the faster version and six played the slower version of the game. Players once again played a practice level for six minutes before they played the competitive level for 12 minutes.

The results for all individual players in the competitive game level are shown in
Figure 4. Introducing random variation into the players firing position significantly decreased players’ tendency to invest in and fixate on a single pass. This decrease in investment is highlighted by the increase in the variance seen in Figure 4 when compared to Figure 1. Thus, the slight changes in gameplay had a significant effect on players’ behaviour, encouraging them to alter their risk-taking strategy throughout the game. Furthermore, this change helps to meet the requirements necessary for hot hand investigation. This desired change in players’ behaviour was present in both speed versions of the game.

Figure 4: Individual player results for the competition level in Stage two testing. The top row presents the number (frequency) of shots taken on each pass in the faster version, while the bottom row indicates the number of shots taken on each pass in the slower version. Player’s tendency to fire on a single pass in the competition level has been significantly reduced compared to Stage one, as evidenced by the reduction in spikes and, in most cases, increase in variance. For each panel, n is the overall number of shots attempted by the player in that block, m is the mean firing pass, and sd is the standard deviation of the number of attempted shots.

In Figure 5 we present data averaged across all players for both the practice and
competitive levels. This summary highlights how altering the game’s mechanics influenced player strategy. The upper row corresponds to the faster version (i.e., the alien had a greater initial speed and decelerated more rapidly), while the bottom row corresponds to the slower version. The left column corresponds to the practice level (not shown in Figure 4), while the right column corresponds to the competitive level.

Figure 5: Average player results for Stage two. The left column presents the number (frequency) of shots taken on each pass in the practice level, while the right column indicates the number of shots taken on each pass in the competition level. For each panel, m is the mean firing pass and n is the overall number of shots attempted by the player in that block. As indicated by the mean firing pass, players attempted earlier shots in the slower version of the game. Additionally, a comparison of mean firing pass for practice and competition levels for both game versions highlights that
as the game progressed, players fired later.

A comparison of mean firing pass between the fastest and slowest versions indicates that players were more likely to shoot at an earlier pass in the slower version of the game. In the faster version, the distribution of firing pass was ‘pushed’ against the right end, meaning that players were mostly taking shots at later, slower passes. This means that players might be able to take earlier, riskier shots if they feel confident (as might occur after a series of kills). However, it leaves little opportunity to shoot later, if they feel less risk prone (as might occur after a series of misses).

Given that we wish players to be able to adjust their risk in both directions during the experiment, the slower version was deemed more suitable for hot hand investigation. Figure 5 also highlights that for both game versions, players shooting strategy altered in a predictable manner as the game progressed. For example, the mean firing pass for the practice level (e.g., $m = 6.04$) was smaller than that seen in the competitive level ($m = 6.52$). Thus players tended to shoot later in the competitive level. This suggests that the reward structure of the game was biased towards firing at later passes, and that as players became familiar with this reward structure they altered their gameplay accordingly.

Given the need to minimise such bias for hot hand investigation, we examined the risk and reward structure for the slower version on the basis of average player performance. We were particularly interested in the probability of success for each pass, and how this probability translated into our reward system. Recall that firing on later passes takes more time but is also accompanied by a higher likelihood for
success. As the aim of the hot hand game is to kill as many aliens as possible within a 12 minute period, both the probability of hits as well as the time taken to achieve these hits are important when considering the reward structure.

We therefore analysed how many kills per 12-minute block the average player would make if they consistently fired on a specific pass for each and every alien that appeared. For example, given the observed likelihood of success on pass one, how many kills would a player make by shooting only on pass one? How many kills on pass two and so on. Results of this examination are reported in Figure 6. Figure 6A shows the average number of shots taken by players on each pass of the alien (overall height of bar) along with the average number of hits at each pass (height of yellow part of the bar). Figure 6B uses this data to plot the observed probability of success and shows that the probability for success is higher for later passes. This empirically validates that later passes are in fact ‘easier’ in a psychological sense.
Figure 6: Averaged results and some modelling predictions from the slower game version in Stage two of game development. Panel A shows the number of hits (yellow) and misses (blue) for each pass, averaged across players. Together, the overall height of each bar gives the number of total shot attempts. Panel B depicts the average probability of success for each pass, given by the proportion of hits (yellow area in panel A) out of overall shot attempts. Based on the empirical results, Panels C and D show the predicted number of successful shots if players were consistently shooting on only one pass for the entire game (see text for details).
These probabilities allow empirical estimation of the number of total kills likely to be attained by the average player if they were to shoot on only one pass for an entire 12 minute block. By plotting the number of total kills expected for each pass number, we produce an optimal strategy curve for the current game, as shown in Figure 6C. The curve is monotonically increasing, indicating that the total number of kills expected of an average player increases as the pass number increases. In other words, players taking less difficult shots are expected to make more hits within each game. The reward structure is clearly biased toward later passes, which validates the change in player strategy (i.e. firing on later passes) as the game progressed. As the players became accustomed to the reward structure, their strategy shifted accordingly.

As indicated by Figure 6C, firing on pass eight is the ‘optimal’ strategy for the average player. In game terms it might be considered an exploit to shoot on pass eight. Given that an exploit of this kind reduces the likelihood of players firing earlier in response to a run of successful shots, the current design still failed to meet the requirements for our hot hand game.

One simple adjustment to overcome this issue was to reduce the penalty period after an unsuccessful shot. While the current time penalty for a missed shot was set to 1.5 seconds, the ability to vary this penalty allows a deal of flexibility within the reward structure. Given that players make many more shots, and thus many more misses, if they choose to fire on early passes - decreasing the time penalty for a miss substantially increases the relative reward for firing on early passes.
Figure 6D shows the optimal model for the game if the penalty for missing is reduced from 1.5 seconds to 0.25 seconds. This seemingly small change balances the reward structure so that players are more evenly rewarded, at least for passes three to eight. Estimation of accuracy rate on passes one and two were based on a small number of trials, which make them problematic for modelling; participants avoided taking early shots, perhaps because the alien was moving too fast for them to intercept. Allowing for players to fire on passes three to eight still provided us with sufficient number of possible strategies for a hot hand investigation.

Stage Three - Balancing Risk and Reward

In stage two of our design we found that players were biased towards shooting on later passes of the alien ship. We wanted to spread this distribution of strategies across a broader range; we especially wanted to include more early passes of the alien ship. We found that the slower version of the game supported this and therefore adopted this game mechanic for stage three.

In stage two we also uncovered an exploitation strategy in the risk and reward structure of the game where players could perform optimally by shooting on pass eight of the alien. We suspect this influenced players to fire at later passes of the alien. Using empirical data to model optimal player performance suggested that reducing the time penalty for a miss to 0.25 seconds would overcome this problem. We therefore introduced this modification to the slower version of the game.

This modified version of the game was made available online and data were
recorded from five players. Averaged results from all players show that players shot at roughly the same mean pass of the alien in the practice level and the competitive level (Figure 7). This figure contrasts with Figure 4 which highlights the players’ tendency to fire at later passes in the 12 minute competitive level. This data confirms the empirical choice of a 0.25 second penalty, and provides yet another striking example of how subtle changes in reward structure may influence gamer behaviour.

Recall that we began with a requirement for each level of assumed risk (which pass to shoot on) the game to be equally rewarding (total number of kills) for the average player. By balancing the reward structure, the design from stage three is now consistent with this requirement for investigating the hot hand.

Finally we had a second requirement that the game challenge had a level of difficulty such that players would succeed on about 40-60 percent of attempts. A figure of around 50 percent would allow us to compare player strategy in response to runs of both success and failure. That is, testing for both hot and cold streaks. As highlighted by Figure 8, the overall probability of success does indeed meet this criteria – the game now meets the two essential criteria required to investigate the hot hand phenomenon.
Figure 7: Average player results for Stage three of game development. The left plot presents the number (frequency) of shots attempted on each pass in the practice level, while the right plot indicates the number of shots taken on each pass in the competition level. As indicated by the mean firing pass, under a balanced reward structure players no longer attempt to shoot on later passes as the game progresses.
Figure 8: Averaged results from the competition level of Stage three of game development. Panel A shows the number of hits (yellow) and misses (blue) for each pass, averaged across players. Together, the overall height of each bar gives the number of total shot attempts. Panel B depicts the average probability of success for each pass, given by the proportion of hits (yellow area in panel A) out of overall shot attempts. In Panel B, ps is the overall probability of success (hits).

Discussion

We set out to design a computer game as a tool for studying a fascinating and widely studied psychological phenomenon called the ‘hot hand’ (e.g., Gilovitch, Valone, & Tversky, 1985). For this we needed a game that allowed us to investigate player risk-taking in response to a string of successful or unsuccessful challenges.
We designed a simple top-down shooter game where players had a single shot at an alien spacecraft as it made eight passes across the screen. During the game the player faced this same challenge a number of times. The goal of the game was to kill as many aliens as possible in a set amount of time. The risk in the gameplay reduced on each pass as the alien ship slowed down. Shooting successfully on earlier passes rewarded the player with a kill and made a new alien appear immediately. Missing a shot penalised the player with an additional wait time before the next alien appeared.

As a hot hand game it was required to meet specific risk and reward criteria. Players should explore a range of risk-taking strategies in the game and they should be rewarded in a balanced way commensurate with this risk. We also wanted the game challenge to have an average success rate around of 50 percent so that we could use the game to gather data about player’s behaviour in response to both success and failure.

To achieve our objective we developed the game in an iterative fashion over three stages. At each stage we tested an online version of the game, gathering empirical data and analysing the players’ strategy and performance. In each successive stage of design we then altered the game mechanics so they were balanced in a way that met our specific hot hand requirements. The design changes and their effects are summarised in Table 1.
<table>
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<th>Stage</th>
<th>Requirements</th>
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| Design Problems | • Design must meet specific requirements for experimenting with hot hands  
| | • Players must be willing to adjust their level of risk throughout the game, and thus explore a range of possible strategies  
| | • Must allow the measurement of a players’ strategy after runs of both successes and failures by ensuring the game challenge has an average success rate around 50% |
| Stage One | One |
| Design Problems | • Players invest in a single strategy rather then exploring a range of options |
| Design Solutions | • Changed mechanics (add variability to player’s ship position)  
| | • Trialed two speeds and deceleration rates of alien to examine effect on player strategy |
| Stage Two | Two |
| Design Effects | • Random location of ship removed investment strategy  
| | • Slower speed provides better distribution of responses - allowing players to adjust strategies involving either more or less risk |
| Design Problems | • The reward structure favours an exploitation strategy of firing on pass 8 (or as late as possible). |
| Design Solutions | • Reduce missed time penalty from 1.5 sec to 0.25 sec based on average probability of success |
| Stage Three | Three |
| Design Effects | • Players rarely attempt shots on pass 1-2 but the game illicits a good range of firing on passes 3-8  
| | • Success rate for the challenge is within 40-60% range  
| | • Game is suitable for our hot hands experiment |

Table 1. A summary of changes to design in each of the stages and the effect of these changes on meeting the hot hand requirements.
The game design arrived at in stage three is now suitable to investigate and potentially answer important questions about the hot hand. For example, how do players alter their strategy in terms of risk when they have a string of successes or failures? From a psychological perspective this promises further answers in regards to whether the hot hand is a fallacy or not.

Although such a finding is of interest to psychologists it could also provide useful principles for game design. For example, it might allow the designer to engineer a hot streak so that a player would take more risks or be more explorative in their strategies. Of course in a game it might even be appropriate to use a cold streak to discourage a player's current strategy. The game mechanics could help engineer these streaks in a very transparent way without breaking player immersion.

Exploring the principle of hot hand in game design has a promising future in further investigations. However, our current study has already provided some useful insights that inform more general principles of game design. In particular, we discuss the use of empirical data in the design process. We also discuss the issue of exploitation and other subtleties of player behaviour we observed when trying to balance the risk and reward structure of the current game.

Books on game design tend to describe an iterative design process. Iterative processes allow unforeseen problems to be addressed in successive stages of design. This is especially important in games where the requirements for the game mechanics are typically only partially known and tend to emerge as the game is built and played. Salen and Zimmerman describe this iterative process as “play-based”
design and also emphasise the importance of “playtesting and prototyping” (2004, p. 4). For this purpose successive prototypes of the game are required. Indeed we began with only high-level requirements and used this same iterative, prototyping approach to refine our gameplay. The main difference in our approach is that we more formally tested players and gathered empirical data in each stage. It is unlikely that subjective feedback alone would have allowed us to make the subtle change to game mechanics that were required.

Another common principle referred to in game literature is player-centred design which is defined by Adams as “a philosophy of design in which the designer envisions a representative player of a game the designer wants to create.” (2010, p. 30). Although player-centred design is often a common principle referred to in game design texts there is some suggestion that design is often based purely on designer experience (Sotamaa, 2007). Involving players in the design process typically involve more subjective feedback from approaches such as focus groups and interviews which have been generally used in usability design. In our study, when designing even a simple game challenge it is clear that the use of empirical data to measure how players approach the game and how they perform can be another vital element in balancing the gameplay.

We also recognise some dangers with this approach, as averaging player performance can hide important differences between players. It would be nice to have a model of an ideal player but it is unlikely such a player exists. In fact there are many different opinions about who the ‘player’ is (Sotamaa, 2007). The empirical data therefore need to be gathered from the available players population. If there are
broad differences among these players then it may require the designer to sample
different groups, for example, a group of casual players and a group of hard-core
gamers.

Given that our game requirements are rather unique and the game quite simple, the
use of empirical data in our design process helped reveal some subtle problems in
the balance of the gameplay. For example, during the initial testing of the game we
found that players tended to invest in a single playing strategy. Further analysis
revealed a potential exploit in the game. Players could always optimise their total
number of kills by shooting on the last pass of each alien ship.

The issue of exploits in games is often debated in gaming circles and is also well
studied in psychology. Indeed trade-offs between exploitation and exploration exist in
many domains (e.g., Hills, Todd, & Goldstone, 2008; Walsh, 1996). External and
internal conditions determine which strategy the organism, or the player, will take in
order to maximise gains and minimise loses. For example, when foraging for food,
the distribution of resources matters. Clumped resources lead to a focused search in
the nearby vicinity where they are abundant (exploitation), whereas diffused
resources lead to broader exploration of the search space.

Hills et al. showed that exploration and exploitation strategies compete in mental
spaces as well, depending on the reward for desired information and the toll incurred
by search time for exploration. In the context of our game, a shooting strategy that
pays off early in the game may bias players to shoot at fixed passes (exploitation)
and not look for alternative, possibly more rewarding shooting strategies.
This exploit was unintentionally included in our game mechanics. It is unlikely we could have predicted this without collecting empirical data from players. A further useful feature of gathering this data was that it allowed us to predictably remodel the mechanics of the game using a measurement of average player performance. In stages one and two players lost 1.500 seconds each time they missed an alien. In stage three we reduced this penalty to 0.25 seconds based on our analysis and modelling of player behaviour. This small change was enough to change players’ behaviour and encourage them to risk earlier shots at the alien. The fact that our game is quite simple in nature reinforces the difficulty of designing a well-balanced risk and reward structure.

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