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Citation: Power, C., Denisova, A., Papaioannou, T. and Cairns, P. (2017). Measuring Uncertainty in Games: Design and Preliminary Validation. In: Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems. (pp. 2839-2845). New York, USA: ACM Press. ISBN 9781450346566

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Link to published version: http://dx.doi.org/10.1145/3027063.3053215

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Measuring Uncertainty in Games: Design and Preliminary Validation

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CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3053215

Abstract
Uncertainty is an important element of game play, which is widely believed to act as a precondition for player experience (PX). To investigate the concept and examine its relation to other PX concepts, we should be able to measure it. We present the design and preliminary results of the validation of the Player Uncertainty in Games (PUG) questionnaire. Based on various sources from games user research and work done with regards to searching digital archives, we designed a questionnaire that measures the experience of uncertainty in games. The scale was refined down to 66 items via interviews with players and expert reviews, which was then validated and further refined based on data gathered from gamers in an online survey. The Principal Component Analysis showed high level of internal consistency for the scale and each of its four factors: Disorientation, Exploration, Prospect, and Randomness. This work demonstrates the initial findings towards a validated tool for measuring uncertainty of players in digital games.

Author Keywords
Uncertainty; scale; questionnaire; digital games; player experience.

ACM Classification Keywords
K.8.0 [Personal Computing]: General - Games

Introduction

Uncertainty is an important element in games. Caillois [1] argues that the outcome of a game should be uncertain in order to be enjoyed and Costikyan [4] holds that uncertainty is at the heart of the appeal of games. Not knowing whether you can achieve something in a game is a source of challenge and winning out against that uncertainty is hard fun but even filling in the gaps and resolving ambiguities is a source of easy fun [14].

At the same time, too much uncertainty, or the wrong sort of uncertainty [12] can lead to reduced enjoyment. Thus, uncertainty is very relevant to building up the gaming experience of players but it is not clear what sort of uncertainty leads to what sort of player experience. In order to begin being able to investigate this area more, we propose that it is important to be able to measure players' sense of uncertainty in some reliable way. This paper therefore presents the development of a questionnaire to measure players' feelings of uncertainty when playing digital games. The questionnaire draws on existing work both in other interactive contexts from digital games and in the existing literature about digital games.

Uncertainty in Games

Callois [1] argues that the outcome of every type of play should be uncertain in order to be enjoyed, else if one is well trained or has the skills to defeat it with certainty it becomes no longer pleasing. Similarly, Malone [16] discusses the relation between challenge and uncertainty in games: he argues that challenge is an essential element of an enjoyable game play and for an activity to be challenging, it needs to have an uncertain outcome of a goal. However, not all game outcomes can be quantified as binary "win" or "lose", for example in *Journey*, and not all game outcomes are uncertain: everyone eventually loses at *Tetris*. However, uncertainty and mastering uncertainty may nonetheless be central to the appeal of games [4] because uncertainty also lies in other game elements, including the journey the player follows through the game or the problem-solving skills that they might require to make progress. What is appealing in games is that players have the choice to engage in an unknown experience with no certain outcome, or not known outcome, in order to test their abilities or skills without worrying about the consequences that might occur in real life situations.

Though uncertainty is recognised as a core component of gaming experience, there is not a lot of research on isolating this concept. The most notable work in this area is that of Costikyan [4]. Based on an analysis of numerous digital games, he suggests 11 sources of uncertainty, that is, elements within a game that can lead to uncertainty for the player. Briefly these are the following. *Performative uncertainty* refers to the uncertainty associated with physical performance, e.g. controlling an avatar or performing actions in the game; *Solver's uncertainty* is concerned with the ability of solving problems, e.g. solving puzzles; *Player unpredictability* refers to the uncertainty associated with other players, e.g. in a multiplayer game; *Randomness* refers to uncertainty emanate from random game elements, e.g. outcomes based on chance; *Analytic complexity* refers to uncertainty that comes from complex decision trees the player must parse in order to grasp the system, e.g. chess player performing a move; *Hidden information* refers to uncertainty that emanate from hidden game elements, e.g. player exploring a hidden map; *Narrative anticipation* is the uncertainty of not knowing the path or the sequence of events, e.g. the plot of a game; *Development anticipation* refers to the player anticipation of post-release content, e.g. a game expansion; *Schedule uncertainty* refers to the uncertainty that is connected to limited game mechanics

that result is short-timed game sessions, e.g. player waits for crops to grow before returning to the game; *Uncertainty of perception* refers to the difficulty of perceiving the game space, e.g. objects with hardly-recognisable shape; and Malaby's *semiotic contingency* refers to the unpredictability of a meaning that accompanies attempts to interpret a game's outcome [15], e.g. games creating cultural meaning. All of these sources of uncertainty can feed into the player's experience of the game though it is possible that they lead to similar felt experiences by the player, much as many different parts of a game can cause players to become engaged but that this leads to the same felt experience of engagement or immersion [2].

In other contexts, uncertainty is emerging as an experiential component of some interactions, in particular information seeking [18]. People engaged in information seeking tasks can experience anxiety or feelings of uncertainty that leave searchers bewildered and in need of personal reassurance. Such tasks could be viewed as sense-making activities [11], where uncertainty arises from an inability to make sense of the information found or where to find information that would lead to it making sense. This is not actually so dissimilar from digital games, in particular puzzle games like *Obduction* where the goal in the game is to make sense of a complex, surreal environment and unearth the human story beneath. Indeed, players often engage in particular forms of strategic learning across a range of games, such as forming an informal hypothesis, testing this hypothesis through "trial and error" or action repetition, and re-thinking the hypothesis [7]. Framed as such, game play is a process of constant learning and progress in sense-making [6].

Having identified uncertainty as a relevant experience during information search, Pugh and Power [19] went on to develop and validate a questionnaire for measuring the feelings of uncertainty of people doing information search. They found that there were three factors underpinning the felt experience: *Prospect*, when a person has a good sense of where to go next; *Disorientation* when a person had a poor sense of what they had already found out; and *Preparedness* how much (or little) a person felt ready going into a new search task. Understandably, these first two factors correlate somewhat though they also capture distinct concepts: a person can have little Disorientation but still have a poor sense of Prospect at the same time a person may be very disoriented around the information they do have but have a clear sense of what to do next.

In order to explore the relationship between uncertainty and other player experiences, uncertainty should be measured quantitatively. Questionnaires are a useful measure of player experiences , e.g. the Immersive Experience Questionnaire (IEQ) [8] and the Player Experience of Need Satisfaction (PENS) [20], but powerful though questionnaires can be [3], there is already a proliferation of questionnaires in games experience research [17] some with substantial conceptual overlap [5]. The goal here is not to add to an already well-populated field but instead to provide a mediating layer of player experience that is between the features of the game and the affective outcomes of the player.

This paper, therefore, provides a summary of the development of an instrument that measures the uncertainty that players feel when playing digital games. We present the design and preliminary validation results of the Player Uncertainty in Games (PUG) Questionnaire.

Methodology

The methodology used here follows a well-established procedure for scale developement, set out by Kline [13], of item analysis followed by exploratory factor analysis.

The questionnaire development process began with creating and refining an item pool based on the definition of a digital game by Costikyan's sources of uncertainty [4], and Pugh and Power's uncertainty questionnaire for digital archives [19]. A further set of items based on Juul's definition of game was used to cover aspects not covered by the other items [9]. These were then refined as detailed below before being administered to over 700 participants in an online survey. The collected data was then analysed using Principal Component Analysis (PCA) in order to extract the questionnaire's factors and reduce the number items further while maintaining the robustness of the questionnaire.

Item pool generation and refinement
The initial item pool was constructed based on three sources [10, 19, 4]. Costikyan's eleven sources of uncertainty [4] were used to compose items that are most relevant to gaming experiences of players. Three components were not include from his taxonomy, namely schedule uncertainty, development anticipation and semiotic uncertainty as these were deemed to happen to a player outside of the act of playing itself.

Pugh and Power's item pool was adapted to match the experience of playing digital games. Due to the different nature of browsing archives, which is largely concerned with performing the task most efficiently, and playing games, some questions were removed, while others were rephrased to reflect the experience of game play. For example, an original item: "I found using the search system intimidating" was modified into "I found the game mechanics to be overwhelming"'. Another example of the alteration is changing "I feel my search session produced results that have moved my research forward" to "I feel that I have progressed during the game session". This resulted in 67 items.

These initial items were evaluated in interviews with two game players. This led to rewording of some items, particularly around narrative uncertainty which, in several items, players did not recognise as relevant to their experience. Also, players discussed the consequence of the outcomes of play. This resonated with Juul's notion of "negotiable consequences" and in order not to overlook the possible relevance of this and related concepts, additional items were generated based on Juul's definition of game-features [9].

These items were then evaluated in interviews with two more players. This led to some further refinements of wording but also confirmed that players recognised the feeling of uncertainty while playing and that this was an important constituent of the play experience.

The full item pool contained 146 items. Expert evaluation was then conducted (by the authors) in order to further refine the scale, in particular, working to remove duplicate items or items similar in meaning. The review also ensured items related to the feeling of uncertainty, as opposed to other aspects of game play such as challenge. This reduced the number of questions to the final 66 items.

Survey procedure
The final scale was converted into an online survey using Google forms. It was distributed on various online game forums, including Steam Community Forum and Reddit. In order to gather responses from a diverse audience of digital game players we approached a number of different gaming communities, which consisted of Role-Playing Games (RPGs), First Person Shooters (FPSs), Action, Adventure, Simulation and Strategy games players.

The questionnaire items were rated on a 5-point Likert scale anchored at the ends with Strongly Disagree and Strongly Agree. The order of the questions was randomised

in Google forms for each participant in order to avoid possible order-effects. Participants were asked to play a game of their choice for a typical playing session before filling out the survey in relation to that session of play.

Participants
Overall, 708 players took part in the online survey (600 men, 39 women, and 69 people who did not identify themselves with either gender or left the answer empty). After the initial screening of the data for incomplete or invalid responses, 674 valid responses were kept. Most participants were aged between 18 and 21 (292), followed by the ages 22-25 (148), 26-30 (117), 31-40 (103), above 41 (27), with 13 empty responses. The majority of the participants were frequent players, playing several times a week (656) and more than an hour on each game session (576).

Role-playing games (RPGs) were the most popular games played by our participants for the survey (204 participants), followed by First-Person Shooters (FPS) (141 participants), Strategy games (133 participants), Simulation games (103 participants), Action games (40 participants). Fewer than 20 participants played games in each of the categories Collectible Card Games, Adventure, Sports, Sandbox and Puzzle. Almost half of the participants played more than 2 hours (242 participants) or up to 2 hours (150 participants) in their session for the survey, followed by participants who played up to 1 hour (168 participants), up to 30 minutes (80 participants) and up to 10 minutes (33 participants).

Results

The initial screening of the data revealed that three items aimed at measuring uncertainty as a result of interaction with other players were omitted by many of our participants. Hence, we did not use these questions in the analysis of the gathered data.

A Principal Component Analysis (PCA) was used to extract the underlying factors of the scale and evaluate the items of the total scale. After the factor extraction, an internal consistency reliability analysis was conducted in order to test the consistent measurement of the constructs for each factor. Items that did not perform well in the correlation analysis with the overall scale were removed from the final questionnaire. Finally, the internal consistency of the trimmed scale and its sub-scales was analysed.

Principal Component Analysis
PCA was performed on the 63 items with oblique rotation (direct oblimin). The Kaiser-Meyer-Olkin (KMO) measure was used to verify the sampling adequacy, which was KMO = 0.914, and all KMO values for individual items were greater than 0.646. This suggests the data reflects good factors and all items are adequate for the analysis. The scree plot and parallel analysis suggested a three, four or five factor solutions. Four factors seemed to have the best balance of factors with good scale reliability and explicability. These four factors account for 35% of the variance in the data. Interpretation of the factors suggested the factors represent: *Disorientation*, the sense of being lost or confused in the game; *Exploration*, a sense of available actions and how to execute them; *Prospect*, understanding the overall goals and being able to form intentions and plans to reach them; and *Randomness* being the sense of chance determining what happens in the game. Disorientation correlates negatively with both Prospect ($r = -0.36$) and Randomness ($r = -0.32$).

Items that loaded on the same factor with load higher than 0.3 were selected to form sub-scales and item-total correlations below 0.4 were used to reduce the subscales further. The loadings of the final set of items on each of the original factors is given in Table 1.

	Disorientation	Exploration	Prospect	Randomness
1. I struggled to do the right actions.	.711			
2. The actions I had to perform were too demanding for my skills.	.685			
3. I was frustrated because I knew how to achieve a goal in the game, but was unable to do so.	.681			
4. I was not confident that I could perform some actions in the game.	.679			
5. I often felt I didn't know what to do next.	.649			
6. I thought I would fail at doing the right actions.	.608			
7 .I often felt lost.	.608			
8. I could not choose which actions were better.	.605			
9. I found it difficult to form strategies in the game.	.560			
10. I felt I was stuck during the game.	.558			
11. The game mechanics were overwhelming.	.556			
12. I found it difficult to keep track of all elements in the game.	.550			
13. I found myself going round in circles.	.507			
14. I needed to explore in order to know what to do next.		-.600		
15. I needed to discover things to make progress.		-.573		
16. I could perform new actions with which I was not familiar.		-.508		
17. I did not have much information on which action was better.		-.393		
18. I could not say if the game had other better outcomes.		-.378		
19. I had to think every possible way to overcome challenges.		-.364		
20. I could not say what will happen at the end of the game.		-.347		
21. I knew how each goal could be achieved.			.656	
22. I understood the game mechanics.			.655	
23. I knew what I had to do.			.637	
24. I knew exactly what was required from me in the game.			.588	
25. I could find the solutions required for achieving the goals of the game.			.550	
26. Random elements in the game were preventing me from achieving my goal.				-.688
27. I was relying on chance in the game.				-.675
28. The outcome of my actions was mainly influenced by chance.				-.654
29. The game was unfair.				-.498
30. I had to repeat the same actions over and over even though I didn't make any progress.				-.467
31. Unpredictable random elements were influencing my performance.				-.427

Table 1: Items and structure matrix of the trimmed uncertainty in games questionnaire.

A reliability analysis was performed on each of the four subscales. Three of the sub-scales yielded good levels of internal consistencies as measured by Cronbach's α: Disorientation ($\alpha = 0.870$) Prospect ($\alpha = 0.748$) and Randomness ($\alpha = 0.727$). Exploration ($\alpha = 0.573$) had only weak internal consistency however we retained it because it was a coherent set of conceptually relevant items.

Discussion and Future Work

Uncertainty seems to be a feeling that players of digital games recognise and can express. From this work, 4 distinct but related factors have emerged as contributing to that overall feeling. While the factors Prospect and Disorientation would seem like flip sides of a coin, the only slight negative correlation suggests that they are distinct concepts. Certainly, all players can relate to games that are "on rails" with only one path to complete the goal. Similarly, when disorientation gets too high, players will lose track of what they need to accomplish in a game. However, it is less clear what transitions look like between these states, which is a focus of our future work. Exploration was retained because it captures the situation of players knowing what the goal of the game is, but being unable to link the actions in the game to the goal. For example, in *Monkey Island*, players encounter a troll and are told they must pay an unexpected toll, however they need to work out which of the many objects in their inventory will satisfy the puzzle. Finally, the weak correlation between Randomness and Disorientation randomness may be dismissed by players as being out of their control so not leading to lostness or confusion. In future work, we aim to validate this questionnaire and use it to explore how uncertainty varies between different game types and its relation to other player experience concepts.

REFERENCES

1. Roger Caillois and Meyer Barash. 1961. *Man, play, and games*. University of Illinois Press.
2. Paul Cairns. 2016. Engagement in Digital Games. In *Why Engagement Matters*. Springer International Publishing, 81–104.
3. Paul Cairns and Anna L Cox. 2008. *Research methods for human-computer interaction*. Vol. 12. Cambridge University Press New York (NY).
4. Greg Costikyan. 2013. *Uncertainty in games*. MIT Press.
5. Alena Denisova, A Imran Nordin, and Paul Cairns. 2016. The Convergence of Player Experience Questionnaires. In *CHI Play 2016*. ACM, 33–37.
6. James Paul Gee. 2007. Good video games and good learning. (2007).
7. Ioanna Iacovides, Anna Cox, Richard Kennedy, Paul Cairns, and Charlene Jennett. 2015. Removing the HUD: The Impact of Non-Diegetic Game Elements and Expertise on Player Involvement. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*. ACM, 13–22.
8. Charlene Jennett, Anna L Cox, Paul Cairns, Samira Dhoparee, Andrew Epps, Tim Tijs, and Alison Walton. 2008. Measuring and defining the experience of immersion in games. *International journal of human-computer studies* 66, 9 (2008), 641–661.
9. Jesper Juul. 2011. *Half-real: Video games between real rules and fictional worlds*. MIT press.
10. Jesper Juul. 2013. *The art of failure: An essay on the pain of playing video games*. MIT Press.
11. Gary Klein, Brian M Moon, and Robert R Hoffman. 2006. Making Sense of Sensemaking 1: Alternative Perspectives. *IEEE intelligent systems* 21, 4 (2006), 70–73.
12. Christoph Klimmt, Tilo Hartmann, and Andreas Frey. 2007. Effectance and control as determinants of video game enjoyment. *Cyberpsychology & behavior* 10, 6 (2007), 845–848.
13. Paul Kline. 2000. *A psychometrics primer*. Free Assn Books.
14. Nicole Lazzaro. 2004. Why we play games: Four keys to more emotion without story. In *GDC*.
15. Thomas M Malaby. 2007. Beyond play a new approach to games. *Games and culture* 2, 2 (2007), 95–113.
16. Thomas W Malone. 1982. Heuristics for designing enjoyable user interfaces: Lessons from computer games. In *Proceedings of the 1982 conference on Human factors in computing systems*. ACM, 63–68.
17. A Imran Nordin, Alena Denisova, and Paul Cairns. 2014. Too Many Questionnaires: Measuring Player Experience Whilst Playing Digital Games. In *Seventh York Doctoral Symposium on Computer Science & Electronics*, Vol. 69.
18. Joseph Pugh and Christopher Power. 2015. Swimming the Channels: An Analysis of Online Archival Reference Enquiries. In *Human-Computer Interaction*. Springer, 99–115.
19. Joseph Pugh and Christopher Power. 2017. A scale for measuring uncertainty in information seeking. In preparation.
20. Richard M Ryan, C Scott Rigby, and Andrew Przybylski. 2006. The motivational pull of video games: A self-determination theory approach. *Motivation and emotion* 30, 4 (2006), 344–360.