The Role of Uncertainty in Moment-to-Moment Player Motivation: A Grounded Theory

Shringi Kumari
University of York
York, UK
sk1382@york.ac.uk

Sebastian Deterding
University of York
York, UK
sebastian.deterding@york.ac.uk

Jonathan Freeman
Goldsmiths University
London, UK
j.freeman@gold.ac.uk

ABSTRACT

Uncertainty is widely acknowledged as an engaging characteristic of games. Practice and research have proposed various types and factors of game uncertainty, yet there is little work explaining when and why different kinds of uncertainty motivate, especially with respect to 'micro-level', moment-to-moment gameplay. We therefore conducted a qualitative interview study of players tracing links between uncertainty experiences, specific game features, and player motives. Data supports that uncertainty is indeed a key element in keeping players motivated moment-to-moment. We present a grounded theory of seven types of engaging gameplay uncertainty emerging from three sources - game, player, and outcome - and document links to likely underlying motives, chief among them curiosity and competence. Comparing our empirically grounded taxonomy with existing ones shows partial fits as well as identifies novel uncertainty types insufficiently captured in previous models.

Author Keywords

Games; Uncertainty; Player motivation; Moment-to-moment gameplay; Engagement.

CCS Concepts

•**Applied computing** → **Computer games;** •**Human-centered computing** → *User studies;*

INTRODUCTION

Uncertainty has long been recognized as a key ingredient of engaging gameplay [16, 33, 9, 59]. In his early typology of play, Roger Caillois [9] famously describes the relation between *alea*, chance-based play, and *agon*, skill-based strife, observing that either would lose its appeal if it lacked the fitting kind and degree of uncertainty, such as an instance of *agon* where the outcome is determined by luck or is certain from the outset. A great number of game designers and scholars have since reiterated the importance of uncertainty for a good player experience, and diversely tried to identify different kinds or sources thereof [25, 51, 35, 18, 66, 44]. Terminologies and theories vary. Thomas Malaby [50] for instance draws on sociological and anthropological thought on *contingency* to argue that games are engaging because their "contrived contingency" allows us to engage with the basic indeterminacy of human existence. Mark Johnson [33] meanwhile deploys Deleuze to tease apart different kinds of *unpredictability* in games of chance. But authors concur that some perceived lack of certain knowledge about what is the case, what to do, or what will happen at a future moment is core to the motivational pull of gameplay. Drawing on many of these sources and his own practical experience, game designer Greg Costikyan [16] developed an influential categorization of eleven sources of *Uncertainty in Games*, including e.g. stochastic randomness as in a *Roulette* game, hidden information (like the hidden cards of an opponent in *Poker*), or player unpredictability - not knowing how the opponent will act next. Building on this descriptive categorization of uncertainty as a *game feature*, Power and colleagues [59] have attempted to measure and differentiate uncertainty as a *player experience*. Their Player Uncertainty in Games Scale (PUGS) distinguishes five factors: uncertainty in decision-making, uncertainty in taking action, uncertainty in problem-solving, exploration behaviour to reduce uncertainty, and external uncertainty, capturing random(ized) outcomes.

Valuable as the typologies of Costikyan or Power (and the work informing them) are, they leave the basic question unanswered *when and why* uncertainty is engaging: What psychological mechanisms explain when and how different kinds of uncertainty motivate? Costikyan variously alludes to psychological constructs in footnotes, but as a designer, he chiefly teases apart structural game features, taking their motivational pull as a given. Power et al. similarly are more interested in reconstructing uncertainty as a definitional "foundational experience" *characteristic for play* than in understanding how it may *motivate* play [59]. Starting with Thomas Malone [51], researchers have suggested and empirically tested links between uncertainty and curiosity and suspense in games [82, 48, 1, 29], but such work has remained sparse and disconnected.

What's more, current constructs in game uncertainty research are not grounded in naturalistic observation. No matter if Caillois, Johnson, Costikyan, Power, or others: all develop theoretical models drawing on personal experience and prior scholarship. Factor analysis (as used by Power and colleagues) may reveal whether there is a structure among such theory-derived items that reflects a structure in people's self-reported experience, but not whether these items capture all, or even

CHI PLAY '19, October 22–25, 2019, Barcelona, Spain

ACM ISBN 978-1-4503-6688-5/19/10.

DOI: https://doi.org/10.1145/3311350.3347148

all important aspects of the phenomenon in question. One likely blind spot of existing research in this respect is that it chiefly relies on summative, post-hoc memories of a gameplay session. This brings with it the well-known issues of memory biases and post-hoc rationalization - the "memory experience gap" [53]: remembered experience is not lived experience, and yet it is lived experience that determines whether a player continues to play a game at any given moment (or stops), and forms the memories that inform their decision to pick it up again.

In contrast to summative gameplay memories stands what game designers call *moment-to-moment (m2m) gameplay* [81, 72, 71]. M2m gameplay describes experience on the level of second-to-second input-output pairings around the game's core loop [69], as opposed to the longer arcs and loops of game goals and player strategies [67, 78, 79, 56]. This distinction echoes game scholars like Salen and Zimmerman [65], who distinguish between a "micro" and "macro" level of player uncertainty, or Klimmt's [40] distinction of three analytic levels of entertainment experiences in gameplay, with "input-output loop" as the lowest level. Importantly for our context, game designers hold that smooth, engaging m2m gameplay makes or breaks player engagement and retention [13, 63]. This makes it relevant to capture and understand gameplay experience and underlying affordances at the m2m level. For the purposes of this paper, we will use *moment-to-moment (m2m) gameplay* to refer to game structures and player experiences that takes place on the time scale of seconds, with *moment-to-moment (m2m) motivation* describing players' motives for continuing gameplay from one second to the next.

To summarize, uncertainty is widely recognized as a key ingredient of engaging gameplay. Existing work provides descriptive typologies of structural game sources of uncertainty and dimensions of experienced player uncertainty, but neither are these typologies grounded in (or validated against) naturalistic observation, especially of lived moment-to-moment gameplay experience, nor do they provide explanatory models when and how uncertainty engages. We therefore conducted a qualitative study combining biographical interviews with video-aided recall of gameplay to construct a grounded theory of how uncertainty engages players in moment-to-moment gameplay.

METHOD

The work presented here is part of a larger exploratory grounded theory study of m2m motivation in so-called "casual games." We specially focused "casual games" for two reasons: (1) to counter-balance player motivation research, which preferentially studies console/PC AAA games [28, 84]; (2) methodologically, we sought contained games that would allow us to easily observe repeat moment-to-moment player experience around the game's core loop. While our data revealed a range of game features and connected motives, uncertainty quickly emerged as a central and highly differentiated category, warranting separate treatment. After developing a general grounded theory of m2m motivation in casual games, we therefore conducted a focused analysis of all data passages coded for uncertainty, which we report in this paper.

Participants and Material

Due to the focus of the larger study, we recruited active players of casual games on mobile devices. Based on prior literature, we operationalized our sample focus as "games one can learn and conclude a satisfying play session in 10 minutes." [12, 41, 83, 17, 34]. To avoid priming of e.g. negative stereotypes around the term, we were careful to never use the label "casual" with participants. We only spoke of "games which are easy to learn and access". We recruited and screened prospective participants through a questionnaire distributed via social media, in which they indicated their age, gender, and the games they regularly played. We purposely sampled participants from this pool who reported currently playing games that qualified as casual by our definition and offered a range of gender, age, and games played (see Table 1). In total, we collected data from 13 players, 7 women and 6 men, age 18 to 54. All participants spoke English and had prior familiarity with games. We stopped data collection at 13 participants when we reached theoretical saturation, which aligns with prior work indicating that saturation occurs around 12 participants[26].

Data Collection and Analysis

To remain open to constructs and relations not already captured in prior theory, we intentionally chose an open, theory-generating approach. Specifically, we followed constructivist Grounded Theory as developed by Charmaz [11]. We looped data collection, transcription, coding/analysis, and memoing/theorizing to initially reconstruct players' own in-vivo labels and emic categorizations, to then develop our own higher-level constructs, following Charmaz' [11] sequence of initial, focused, axial, and theoretical coding. We started collecting data as combined episodic interviews and week-long play diaries, but quickly discovered that diary data remained relatively 'thin' and episodic interviews revealed a diversity of uncertainty experiences, but no good granular capture of linkages between gameplay experience and game features. We therefore enriched the interview with video-aided recall, which proved insightful. In total, we collected

- 5 semi-structured episodic interviews, each about 45 minutes in length; three in person, two over video-call.
- 2 diaries of play experiences over one week, using the episodic interview questions as a daily prompt;
- 9 video-aided recall semi-structured episodic interviews, again of about 45 minutes in length; six in person, three over video-call.

Beyond video-aided recall providing more and more detailed player reconstructions of m2m motivations and motivation-game feature links, we saw no major effect.

Our semi-structured episodic interviews [20] focused four broad dimensions: (1) players' m2m *experiences* motivating them to continue or discontinue a play session; (2) *game* factors players connected to these experiences; (3) *personal* factors (like dispositions or biographical situations) players connected to their gameplay; and (4) *contextual* factors (like situation and surroundings when playing). We asked participants to first describe in as much detail as possible their latest

Player ID	Gender	Age	Data Type	Game	Genre
P01	M	35 - 44	Interview, Diary Entry, Video-aided Recall Interview	G01: *Golf Clash* [49]	Sports
				G02: *Clash Royale* [80]	Strategy
P02	F	18 - 24	Interview	G03: *Cooking Fever* [55]	Simulation
				G04: *Temple Run* [77]	Platformer/ Runner
P03	M	25 - 34	Video-aided Recall Interview	G05: *Fruit Ninja* [75]	Puzzle
				G06: *Jetpack Joyride* [76]	Platformer/ Runner
P04	M	25 - 34	Video-aided Recall Interview	G07: *PinOut* [52]	Arcade Simulation
P05	M	18 - 24	Video-aided Recall Interview	G08: *Monument Valley* [23]	Puzzle
P06	F	25 - 34	Interview	G09: *Two Dots* [58]	Puzzle
P07	M	25 - 34	Video-aided Recall Interview	G10: *Exploding Kittens* [39]	Card Game
				G11: *Blaze Hopper* [74]	Platformer/ Runner
P08	F	18 - 24	Video-aided Recall Interview	G12: *Tap tap tap* [6]	Puzzle
P09	M	25 - 34	Video-aided Recall Interview	G13: *Tap Tycoon* [15]	Simulation
P10	F	25 - 34	Video-aided Recall Interview	G14: *Merge Plane* [22]	Simulation
P11	F	25 - 34	Video-aided Recall Interview	G15: *Super hexagon* [10]	Puzzle
P12	F	18 - 24	Interview	G16: *Picross* [14]	Puzzle
				G17: *Logic Puzzles* [7]	Puzzle
P13	F	45 - 54	Interview, Diary Entry	G18: *Candy Crush* [36]	Puzzle
				G19: *Candy Crush Soda* [38]	Puzzle
				G20: *Farm Heroes* [37]	Puzzle

Table 1. Participant demographics and the games they report on

recalled experience playing their chosen game, including situational and biographical circumstances. We then instructed participants to identify and describe particular in-game events that made gameplay engaging (or disengaging) and worth continuing (or discontinuing). (Sample questions provided as supplementary material).

In video-aided recall interviews [57], we asked participants to play the game they currently actively played for about 5-10 minutes, thinking aloud in the process. We video-recorded screen activity and player reactions and then conducted a follow-on interview where we replayed gameplay footage and stopped the video at key moments to probe deeper what participants experienced at that moment and what part of the game they ascribed this experience to, using the same guiding questions for m2m experience and game factors. We made observational notes about the interview situation to capture contextual factors.

We collected diary entries [5] initially to unearth patterns and deviations in player experience across game sessions, capture how fluctuations in contextual and personal factors, and player state changes before and after play session. We discontinued diaries as they required additional effort from participants yet duplicated the findings from episodic interviews.

We took extra care to avoid ambiguities and over-interpretation around player-reported experiences by asking players to restate the reported experience in different terms, or to provide an alternative example or explanation. Interviews were recorded and transcribed *ad verbum* along with data collected from online text exchanges where preferred. Following grounded theory principles of constant comparison and theoretical sampling [11], all data was coded and memoed as it was transcribed, comparing new information against existing codes and concepts, adding and revising concepts and relations as required by the data and re-coding existing data accordingly, and evolving the interview script and choosing new participants based on emerging questions and hypotheses.

RESULTS

As stated, our present analysis reviewed and reported not any and all forms of reported uncertainty, but only those instances where players reported that uncertainty motivated them to continue (or disengage) playing. Overall, data support *curiosity* as a common motivator across all uncertainty sources, stoked by some perceived information gap, provoking uncertainty-resolving action. The main structure that emerged were seven player-perceived sources of uncertainty, which could be grouped into three categories or stages:

(1) *Game uncertainty*, where uncertainty is produced by the game's content;
(2) *Player uncertainty* relating to the player's process of making decisions, interacting, and learning to adapt;
(3) *Outcome uncertainty* arising from how the game responds to player action.

These three form the m2m experiential sequence of how a player moves through the interaction with a game's core loop [69]: the game presents a new game state (1), prompting decisions and actions by the player (2), which results in an outcome (3) that manifests or leads to a new game state (1) (Figure 1).

In this section, we will present and illustrate each uncertainty source, sequenced by category, and explain when and how it motivates, linking player statements to matching known motivational constructs (summarized in Table 2).

Game Uncertainty

Game uncertainty is uncertainty afforded independently by the game system presenting new or reconfigured content to the

Uncertainty Source	Uncertainty Type	Conditions (When)	Motivations (Why)	Exemplary player thoughts
Game	Content	Game loop creates anticipation of new content.	Curiosity [70]	What's next? What if?
		Game loop creates anticipation of new goals.	Goal-setting [46], Achievement (Completion) [86]	What will the new goals be? Will I want to complete those goals?
		Game creates opportunity to explore (e.g. fog of war).	Creativity (Discovery) [86]	What new things could I find?
	Configuration	Game produces ongoing new configurations	Curiosity [70]	What will the new patterns be?
		Game enables mastery in predicting patterns	Competence need satisfaction [60]	Can I predict coming patterns?
		Game creates surprise with novel patterns	Excitement (Action) [86]	I didn't expect that pattern!
Player	Decision	Player is presented with an impactful choice.	Curiosity [70]	What choice will I take?
		Player is presented with a perceived free choice.	Autonomy [60], Sense of Agency [27]	I'm free to act in tune with my goals, values, and identity
		The player can plan ahead.	Strategy (Mastery) [86]	What strategy or sequence of decisions should I take?
	Interaction	Player needs to react to a game's event.	Curiosity [70]	Will I be able to act accurately and timely?
			Excitement (Action) [86]	That's so fast!
			Competence need satisfaction [60]	I interact competently.
		Player wants mastery following game's difficulty curve.	Achievement (Mastery) [86]	I'm mastering this.
	Adaptation	Player is curious about their ability to perform a task.	Curiosity [70]	How well can I adapt to challenges?
			Achievement [8], Achievement (Completion) [86]	Can I achieve all goals set out?
			Mastery [86]	Am I getting better?
			Competence need satisfaction [60]	Am I able to adapt competently?
Outcome	Result	Player is eager to see the outcome.	Curiosity [70]	What is the outcome of my actions?
		Player is eager to see how well they did.	Competence need satisfaction[60]	Is the feedback on my performance positive?
			Mastery [86]	Am I a master? Can I get there?
			Achievement Theory[8], Achievement[86]	Did I win/achieve goals? Am I closer to these targets?
	Opponent	Player is eager to see another player's reaction.	Curiosity [70]	How will the other react?
		Player is eager to compare progress	Social [86]	Am I closer to winning against them?

Table 2. Links illustrating conditions *when* uncertainty types are motivating and *why*

player. These invoke surprise and excitement over unexpected (or hopefully anticipated) game content or content configurations, as well as curiosity over what the game will present next.

Content Uncertainty

This uncertainty revolves around (1) new content and (2) new goals. (1) Players continue playing m2m as they are uncertain and therefore curious about what they will encounter: "*Although I have not reached too far in the new scene I am curious to see what comes next*", as [p03, g06] puts it. The imagined possibility of as-yet-unseen content generates excitement: "*what if you find the wardrobe and you go through it and you find another world on the other side, you know that's always been like the most exciting thing for me*" [p09, general]. To sustain both, the game needs to continuously serve novel content. Says [p08, g12]: "*I think it manages to keep my curiosity because there are levels after levels and the puzzle doesn't repeat*". From prior experience with the game or general gaming, players build up some-yet-uncertain expectations about possible new content, like new mechanics, and assess novelty as deviation against that. As [p06, g09] puts it, they "*prefer Two Dots over those [other games] because they became really dull after a while, whereas Two Dots at least there are things that keep changing, whereas those... they don't really change, the mechanics is basically the same.*" Players reported to stop playing when they formed the belief that there would be no more novel content to encounter: "*Overall it was a fun half an hour but I wouldn't return as it didn't promise anything different*" [p10, g14] This uncertainty-from-novelty goes hand in hand with uncertainty about the *timing* of novel or even known content: "*the one that you really want to get is that, is the advert (laughs), that's so clever, I am sitting here every time, please be an advert, please be an advert.*" [p09, g13] Behaviourally, players reported that new content uncertainty motivated them to explore the game: "*the kind of exploration element at the beginning of the games, I love when you start and it's all fog around you and you gotta kind of like figure it out and maybe there is something dangerous out there uhm, maybe there isn't but there's really kind of sort of quite always thrilling*" [p09, general]. Apart from players mentioning curiosity verbatim as their motivation to continue play and explore, the structural (novelty) and behavioural (exploration) features they call out all suggest *curiosity* as the underlying motive [70]. This general motivational construct, usually conceived as an emotion or need, links to player trait/preference constructs like *Discovery* [86, 30], *Seeker* [54], or *Explorer* [3].

(2) New content (like a new level or opponent) is often accompanied by or constitutes new goals, which players again found engaging: "*Excited to be going to the next level. A new level promises to bring new level of difficulty and new goals*" [p03, g06]. Such new goals can be explicit (as in a new quest) or self-generated by players: "*maybe as they added new islands I would want to conquer the new one*". [p07, *Pirate Kings* [21]] Players clearly identified a stream of new and changing goals

(and the prospective expectation thereof) as a motivation to continue playing, in line with motivational research on *goal-setting*: well-formed goals motivate people to work towards them [46], which is mirrored in player preference constructs like Yee's *Completion* [86]. This ties into uncertainty directly - new goals are uncertain novel content themselves - and indirectly, in that new goals are needed to challenge the player, forming a prerequisite to player uncertainty (see below).

Configuration Uncertainty

Beyond entirely new content, players are uncertain about novel configurations of already-known game elements. Here, curiosity-inducing uncertainty as the delta between experience-based predictions and actual content becomes even more pronounced. As [p11, g15] explains, "*it adds quite a lot to my experience ... one-identify the pattern; two-execute that pattern, and then do that while you recognise the next pattern after that. There's a lot of being able to, uhm, predict, with a degree of accuracy, what the next thing the game is gonna need you to do ... now that's where the next gap is', so it's a very seesaw process of, like - 'Where's the gap?', 'What are these gaps telling me about the sequence that is coming up?'*" In fact, players report implicitly testing their own ability to predict new game content as part of their gameplay skill, deriving engaging satisfaction from accurate predictions, which matches *Competence need satisfaction* as a motive described in self-determination theory [64]. "*You have the rhythm of the level and that kind of gives you an idea, the locations of the fruit - you can't say, guessing that makes it more fun, a completely predictable game will not be fun for long*" [p03, g05]. Again, this uncertainty often revolves around or prompts new goals and challenges: "*I am focused on the game and the upcoming obstacles and the unpredictability definitely keeps me focused on the game at the very moment*" [p03, g06]. The deviation of content from built-up expectations (and connected solution strategies) makes it an interesting challenge to the player's ability, prompting the next form of uncertainty, player uncertainty: "*That was uncommon pattern, the moment I saw that pattern I had a split second of hesitation that I didn't recognise it. ... Had I beaten this I would be feeling pretty smug*" [p11, g15].

Player Uncertainty

This category captures the player's experienced uncertainty about their own *decisions* (what to do and how), *interactions* (how well they can do it), and ability to *adapt* (whether they are able to grow and learn in the process).

Decision Uncertainty

Players reported being uncertain about what actions to take in what order when the game offered multiple alternatives. This could be choosing from options in a branching story, deciding between ducking or jumping in countering an obstacle, or simply when to hit a button: "*How hard to hit the ball, which direction it should go in ... you have to recognise them [the coming patterns] ... in the right time, and then counter it with similar decision-making*" [p01, g01]. This *decision uncertainty* is enabled by new goals and challenges posed by new content and configurations (see above), but also ties directly to the resulting uncertain outcome. In the moment, making decisions and predicting outcomes is experienced as directly connected: "*It would be, how much you want to hit, where you want to aim, how much you think it will bounce and where you think it will go plus the timing. It's everything included*". [p01, g01]

As casual games are rather linear and lack complex interactions between mechanics and decisions, they don't offer as broad and deep a network of interacting decisions to make as e.g. strategy games. Still, players reported being motivated to test their decision-making skills, strategies, and progress towards a goal, curious to see how their decisions turn out. Players frequently used the word "meaningful" to capture particular instances of resolving decision uncertainty that were motivating: "*They [the decisions] are extremely meaningful because it's, like-all I've been given is a set of obstacles; it's totally up to me how I want to actually engage with them.*" [p11, g15] As this statement indicates, for decision uncertainty to be meaningful, players need to experience a *sense of agency* [27]: they are in control of the decision. In addition, that decision needs to have an expected impact on an outcome in the game "*[you] couldn't really have a more meaningful choice than somethings that's like 'Am I going to do something with a certain amount of risk that might kill me?*" [p11, g15], notably an outcome the player cares about: "*so the choices you make are essentially, affect the outcome of the game, so it does make you engaged because you are concerned with the outcome of the game*" [p01, g01]. Another way of parsing the motivational pull of such decisions is *autonomy need satisfaction* as construed in self-determination theory [64]: being able to make choices that matter to them, players feel that they act from a perceived internal locus of causality, with volition and willingness. In addition, decisions are motivating by the thrill of testing one's competence: "*there was a decision: to just see if I can make it... that's quite thrilling, because it's like 'Oh, I did make it!'*" [p11, g15] In short, decision uncertainty is "meaningful" as in engaging when players perceive that (1) they have a choice they are in control of and this choice will impact the game state in a way that matters to the player (sense of agency and/or autonomy), which is enhanced when the decision promises to (2) test the player's competence. A lack of perceived choice or feeling of helplessness led to disengagement, as stated by [p06, g09] about not wanting to play a level: "*I've had levels basically where the entire screen was almost covered in flame and there was absolutely no option.*"

Compounding immediate 'low-level' decisions, players reported decision uncertainty in arranging multiple actions ("*lining it up so that, then I can try to get a perfect shot and if I get a perfect shot then all this would align and then the ball will go wherever I want it to go*" [p01, g01]) or juggling between different longer-term strategies: "*I wonder if I can out that [collected resource] towards making some big leap or it might be ready to prestige now, you know or maybe in an hour or when I go to sleep*" [p09, g13]. Beyond agency, autonomy, and competence, this engaging quality of strategic decision-making fits the *Strategy* sub-component of Yee's motivational model [86].

Interaction Uncertainty

Interaction uncertainty regards players' practical ability to perform a chosen action. Players are uncertain if they can execute an action timely and accurately to influence the outcome in their favor. The required timing and accuracy tests and thus stokes uncertainty about the player's skills: "*There's a pretty high chance that actually I'm probably not gonna make it in time unless I was actually quick enough to pick up on it ... I've totally internalised that, so it's more like 'Get, get to the gap' and, sometimes, I overshoot or undershoot - isn't that just another skill-level thing*"[p11, g15]. Other skills tested included multi-tasking and attention-switching between e.g. present and oncoming challenges ("*If I were uber awesome I should probably check the top, so I can better react to the coming challenge*" [p09, g13]), and learning controls: "*The control is only clicks, which I do with my left thumb. I have tried switching fingers to see what works best, and landed on this. This was through the evaluation of the scores I made and the general stability of my character during that level*" [p03, g06]. Players reported being immediately motivated by curiosity in the extent of their own abilities and how to control the game [70].

In addition, if game feedback tells players that they succeed, they consequently experience what can be construed as competence need satisfaction [64] or mastery [86]: "*...the points where I tap in quick succession, feeling like the expert*" [p07, g11].

Especially in real-time game, the sheer risk of losing at averting one's attention briefly motivated m2m continuation: "*... the fact that you get the tasks to complete really fast one after the other one is something that keeps you stay and playing*"[p08, g12]; "*...but, the chance, like-I often feel, like, the moment I can and take my foot of the pedal to go like 'Oh, yeah!', like, I've probably just died*" [p11, g15]. The unresolved ongoing tension of losing risk coincided with higher levels of arousal, fitting Yee's *Excitement* motivational subcomponent [86].

Adaptation Uncertainty

Beyond each individual interaction, players are uncertain how well they can adapt to the game's challenges. They are uncertain if they will be able to tackle a challenge, as a player describes, "*Trying to see if I can catch that extra fruit this time, now that I know that is coming. Will my reaction be as fast as the game throws fruits at me. ... Mine [their motivation] is this. To score better each time*" [p03, g05]; "*I'm trying to get to the situations which I feel I could do better at in comparison to my previous runs and then see if I do*" [p05, g08]. To fuel such motivations to display *achievement* [8, 86] or experience *competence* [64], tasks needed to be perceived as challenging, that is, their desired outcome given the player's self-perceived skills was seen as uncertain: " *I want to see if I can keep the character steady enough to not get killed*" [p03, g06].

Players also explicitly framed this as curiosity in their abilities: "*I had a streak, and I was good, and, like, now I've satisfied my curiosity about whether or not I could do it further*" [p11, g15], or as another player puts it "*[I] want to see how far can I reach? Can I reach the next level. Every level has an instruction and goal at the beginning and I wanted to see if I can reach that goal*" [p03, g06].

Players are motivated to continue as they are not fully certain if there is more they can learn, as one player remarks in line with Koster's *Theory of Fun* [62]: "*as soon as you learn everything in a game, there is no reason to play*" [p05, g08]. Independent of curiosity about their current ability, this also shows curiosity in what there is to learn as part of a given game [70].

Outcome Uncertainty

This category captures uncertainty over not knowing the game's or another player's reaction after the player has performed an action: (1) game-related result uncertainty and (2) other-related opponent uncertainty. Players are curious about what is going to happen, whether they predicted the outcome correctly, and whether they accomplished affecting a desired outcome. Thus, outcome uncertainty is tightly connected with player and game uncertainty.

Result Uncertainty

Players describe game results of their actions to be motivating if they are neither too predictable nor too unpredictable: "*I should be at least able to, say if I played 20 times, I atleast say 50% of the time I should be able to get a perfect shot..*" [p01, g01]. A completely predictable outcome is reported as disengaging: "*A completely predictable game will not be fun for long*" [p03, g05]. On the other hand, players feel no control if the outcome is fully unpredictable: It is "*definitely not fun*" that "*in the shootout, you can't predict at all*" [p01, g01], or as another player reports: "*I just couldn't really get on with it in the sense that, yeah, there was none of this sense that I was in control, and I couldn't predict what was gonna happen next.. I would consider myself quite an experienced gamer - and even with that... -I still couldn't work it out.*" This could make the game outcome appear: " *I'm thinking if I'm losing in a game is 'Oh, the game's decided we are going to lose now'*" [p12, general].

Players generally prefer that the outcome relies on their skill rather than something they can't control: "*... if it were skill then it would have been (rewarding) but I don't know what you need to do to make it a perfect shot. I think it's timing, if the arrow goes and you have to time it, but there is no real way to gauge*" [p01, g01]. While luck was reported as a positive experience ("*The thrill that I got lucky, whenever the right card came along*" [p07, g10]), players are disengaged if a game's outcomes are 'too' random for them: "*I got bored of it. It's a very, very simple game, and it's a bit too much based on randomness*" [p04, g07].

In such instances with not 'too much' luck, resolving outcome uncertainty would also resolve player uncertainty about and curiosity in their own skill overall: "*I would clearly know if I am playing better or not, because I am doing something wrong and then I can fix that. Either by playing a lot or by something*" [p01, g01]. Relatedly, it satisfies player's curiosity in their ability to predict their performance. A healthy amount of performance predictability keeps players in the 'right' zone suitable to each player. As a player describes, "*I very rarely get frustrated with logic puzzles cause I know I can do them*

... cause logic puzzles all generally follow the same sort of pattern.... So, I know, eventually, I will get through it" [p12, g17]. However, this basic expectation of competency should not tip over into certainty of success: "*if I knew I could do it I would do it and then move on to something I can't do*" [p05, g08].

Connected, resolving outcome uncertainty would resolve uncertainty about self-set or game-set goals and expectations: "*The expectation was within 60 seconds. I took 38 seconds*" [p03, g06]. Thus, where player uncertainty taps *competence* [64], *mastery* [86], and *achievement* [8, 86] in the form of expecting or wanting, outcome uncertainty provides satisfaction on beating and the opposite on failing expectations: "*I get disappointed when I go less than I thought* " [p10, g14]. Beating expectations also afforded positive surprise: "*The first time it did that I freaked out ...when I tap instead of getting like 10 dollars or whatever it is, I am getting starting with 2AD meaning that like on my first*" [p09, g13]. This cycle of acting, expecting and outcome, and outcome reveal keeps players engaged from moment to moment: "*from moment to moment I want to see if I can keep the character steady enough to not get killed*" [p03, g06].

Outcome uncertainty connects to and resolves decision uncertainty in the same way, as it satisfies player's curiosity how their decisions pan out: "*so the choices you make are essentially, affect the outcome of the game, so it does make you engaged because you are concerned with the outcome of the game*" [p01, g01]. This entails resolving uncertainty about the relative size of the decision's impact: "*how much you think it will bounce and where you think it will go plus the timing*" [p01, g01].

Finally, resolving outcome uncertainty feeds forward into game uncertainty in the form of anticipated new content and goals: "*I get to have other new tasks if I get to a higher score*" [p08, g12]. Players are eager to see the outcome to plan further: "*if we get one more thing up to a eleven hundred, then I get plus two hundred percent on everything, that's pretty significant... I'd like to get either the theme park or the bank to (upgrade)*" [p09, g13]. Some players would seek out all possible outcomes as they were curious in the different content they provided: "*And I played it through a class each, so the different character classes, and I played it through to try to get the different endings*" [p06, *Vampire: The Masquerade* [61]].

A player summarizes the importance of the outcome itself and the related uncertainty - "*[I want the game to] show areas I would not immediately expect from the core mechanics ... if the game manages to give me moments where I care about what happens, it's worth to keep playing if that feeling dies down over time or never comes up, I don't bother*" [p05, g08].

Opponent Uncertainty

This category captures uncertainty over an opponent's reactions in a multiplayer game. Players plan based on their expectations of the opponents plans and abilities: "*You can see the other guys amassing troops at your borders, you don't know when they're going to attack, so you're shoring up defenses*" [p07, *Risk* [73]]. This also stokes decision uncertainty about the players' own strategies - which one to choose and how it will resolve: "*you probably have a strategy as to how you're going to break into the other guys camp and take over all his territory and these are strategies over a few moves, so you're definitely invested in a few turns*" [p07, *Risk* [73]]. Players are also uncertain of their opponent's skill, which keeps them guessing the outcome of the game: "*... depending on the other player's skill you may be able to win*" [p01, g02]. And they are uncertain about the moves the other will perform each turn: "*Obviously there are chances the other player will also make a mistake*" [p01, g02]. Players stop playing if they feel matched with an other in such a way that they can already predict the outcome: "*I sometimes blame the matchmaking algorithm for teaming us against someone who's really good*" [p12, general]. Along with the other motivations attached to outcome uncertainty already mentioned, interacting with others can create social motivations like relatedness need satisfaction [64] or [8] achievement, connected to player preferences captured in Yee's *Social* competent [86].

DISCUSSION

Zooming out, we see three contributions our data makes to the current discourse around game uncertainty: (1) it presents an uncertainty taxonomy that is grounded in naturalistic observation, corroborating and challenging existing theory-led taxonomies; (2) it explicates conditions *when* certain uncertainty types become motivating as well as the underlying motivations explaining *why* these types of uncertainty propel players m2m; (3) it identifies novel uncertainty types, especially content and outcome uncertainty, which were insufficiently captured in previous models.

Sources of Uncertainty

Our data provided a taxonomy of game uncertainty sources grounded in the m2m phenomenal experience of 'going through' a game's core loop in the course of seconds (Figure 1). (1) Players experience *Game Uncertainty* over what novel content and content configurations the game will present to them, which entail implicit or explicit new goals. (2) Players then experience *Player Uncertainty* over their own reaction to the game's new material: what actions to take, how they will and should execute on their choices, and whether they bring the competence to do both well. (3) As the players ponder and perform actions, they experience *Outcome Uncertainty* about what the outcome of their actions would be. They look forward to see how their decisions actions pan out, how good they actually prove to be, and what new content may be unlocked as a result. Overall, these three sources of uncertainty work in a tight loop of game prompt, player action, and game reaction. This is supported e.g. gambling research [85] finding a link between *Decision* and *Outcome uncertainty*, and Johnson [33] observing that *Game uncertainty* informs player actions. Costykian [16] has a concurrent running commentary throughout his book that information gaps in the game lead to player's uncertainty.

Causes and Conditions of Motivating Uncertainty

As illustrated in the section above (summarised in Table 2), amongst other motivational constructs, curiosity which is a

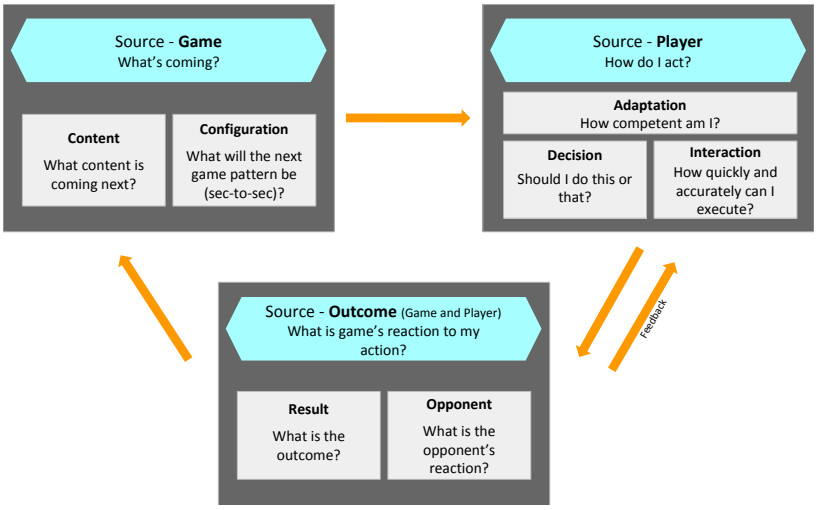

Figure 1. Relationship between the sources of uncertainty

well identified motivational construct within games [43, 24] and outside, [4, 70] comes out as a common motivator across all uncertainty sources which falls in line with our current understanding of curiosity being evoked by uncertainty and the need to solve it [82, 47, 45].

Game Uncertainty

Content Uncertainty fuels curiosity when player's previous experience or experience of current game loop creates anticipation for new content in comparison to their expectations. Players are motivated by a sense of discovery if the game provides opportunity to explore for content. New content create motivation to set self-goals or achieve game-goals. *Configuration Uncertainty* stokes curiosity when players expect game to produce new patterns. It also motivates players to continue as they want to see if their competence of predicting game patterns and the excitement when they find something unexpected. This makes player expect more surprises as they continue to play.

Player Uncertainty

Players feel motivated if they are presented with an impactful choice - it makes them curious about the choice they would make, if they perceive this choice as free they further feel autonomy and a sense of agency that they are influencing the changes in game state. If players react with this sense of agency they feel their skill is valued, helping them to feel competent. They are curious to see if they are able to interact skillfully, and are excited to follow the game's action reaction cycle. Adaptation uncertainty keeps players curious about their ability to perform a task as they play the game, this additionally invokes the motivation to achieve, to seek mastery, and thus evaluated their competence.

Outcome Uncertainty

Uncertainty regarding the outcome creates player curiosity. An outcome whose uncertainty is not too dependent on randomness (so it can test/express skill), and that is not neither too certain nor too uncertain keeps players engaged and motivated to see the results. This feedback into their perceive competence, sense of achievement and mastery, motivating players to engage further in the game's loop with new content cycle. Playing with other players adds human unpredictability in the reaction creating a social motivation to engage in addition to the others.

Comparison with Existing Typologies

In this section we illustrate how our results match with and deviate from prior work classifying game uncertainty (Table 3). This mapping is based on our own reading of the literature to the best of our ability.

Player Uncertainty

While Callois' and Johnson's models do not discuss *Player Uncertainty* explicitly, it overlaps significantly with categories proposed by Costikyan [16] and PUGS [59]. Our *Interaction Uncertainty* maps neatly onto Costykian's *Performative Uncertainty*, performing accurate physical interaction, as does *Decision Uncertainty* with both *Analytic Complexity* (strategic decision making with regard to several possible alternative plans) and *Solver's Uncertainty*, finding one correct solution, as in a puzzle. Interestingly, Costykian misses out the most basic decision uncertainty of how to act next (e.g., should I run or jump in Super Mario Bros. [19]). Moreover, in our data, players didn't voice experienced distinctions between *Analytic Complexity* and *Solver's Uncertainty*.

Moving on to PUGS, *Player Uncertainty* loosely maps with three factors of the PUGS scale [59]: *Uncertainty in Taking Action* (*UTA*) maps our *Interaction uncertainty* and *Adaptation Uncertainty*. By its name, one would expect *Uncertainty in Decision-Making* (*UDM*) to fit our *Decision Uncertainty*, which revolves around identifying 'optimal' actions, decisions, and strategies. Only one of the items in PUGS *UDM* factor captures this quality: "I could not choose which actions were better". The rest of the items revolve around players being uncertain if their actions are impactful or in anyway connected to the outcome. Our data suggests that players only experience *Decision Uncertainty* to be motivating when their decisions

Model	Uncertainty Types						
Our Model	Game		Player			Outcome (Game and Player)	
	Content Uncertainty	Configuration Uncertainty	Interaction Uncertainty	Decision Uncertainty	Adaptation Uncertainty	Result Uncertainty	Opponent Uncertainty
Costikyan	Hidden Information Narrative Anticipation	**Perceptual Uncertainty** Narrative Anticipation	**Performative uncertainty** Narrative Anticipation	Solver's uncertainty Analytical Complexity Narrative Anticipation	Perceptual Uncertainty Performative uncertainty Narrative Anticipation	**Randomness** Narrative Anticipation	**Player unpredictability** Narrative Anticipation
Caillois						**Chance**	Chance
Johnson	Chance Randomness Instability	Chance Instability				Luck Chance	Luck Chance
Power et al.	Exploration		Taking action	Decision Making Problem Solving	Taking action Problem Solving	Decision Making External	External
Bold - strong mapping.							

Table 3. Mapping of our uncertainty model against prior work

are perceived to be clearly 'meaningful' as in having a clear impact on the outcome. Thus, a game could score high on the PUGS *UDM* factor and be de-motivating, as the factor conflates (engaging) uncertainty about which option to choose with (disengaging) uncertainty about whether said choice will have an impact.

The third PUGS factor connected to *Player Uncertainty* is *Uncertainty in Problem-Solving* (*UPS*), capturing whether players understand the game and how it is to be played. We did not find instances of this in our data, presumably for three reasons: (1) it will likely show with inexperienced players new to a game, while our participants reported on games they were already familiar with; (2) it focuses a macro level as opposed to our investigation of the moment-to-moment level; (3) it again captures a likely undesirable, dis-engaging form of uncertainty, where we focused motivating uncertainties. In summary, existing models do not capture the interaction nuances of *Decision Uncertainty* and do not report *Adaptation Uncertainty* as a stand alone category thus not discussing it in much detail.

Game Uncertainty

In our model, *Game Uncertainty* comprises *Content Uncertainty* and *Configuration Uncertainty*. The closest match to *Content Uncertainty* is Costikyan's *Hidden information*, the uncertainty of not fully knowing the game state, like not knowing what cards an opponent holds, although notably this does not extend to uncertainty about entirely new content, which featured strongly in our data. Costikyan's *Uncertainty of Perception* captures uncertainty around the player's current grasp of the game state, which somewhat maps with *Configuration Uncertainty* (in terms of knowing the game state) and *Adaptation Uncertainty* (in terms of the player's ability to grasp the game state). But again Costykian is more focused on how this uncertainty tests a player skill and overlooks the curiosity value of novel game states. Johnson's *Randomness* captures unpredictability in the starting conditions of a game. This partially maps with *Content Uncertainty*, but only at the stage where players talk about initial game content, not the ongoing stream our players reported on. In PUGS, the 2-item *Exploration* (*EXP*) subscale maps with the exploration behaviours players reported on *Content Uncertainty*; however the items do not speak to uncertainty of new content or configurations that the game presents unprompted. In short, existing models capture *Game Uncertainty* very partially, missing out on *Configuration Uncertainty* and *Content Uncertainty* around new content generated by the game unprompted.

Outcome Uncertainty

Outcome Uncertainty of our model is uncertainty in how the game (*Result Uncertainty*) or other player(s) (*Opponent Uncertainty*) react to the player's actions. Costikyan's *Player unpredictability* matches the latter: the inability to predict what other players will do in a multiplayer game. *Result Uncertainty* in our proposed model goes notably beyond Costikyan's *Randomness*, which refers to uncertainty where the outcome depends on an probabilistic process. Players in our study report being curious about how the game will react to whatever action they perform, no matter if said reaction is partly or fully randomised or not. An item on PUGS *UDM* captures the *Outcome uncertainty* of players not knowing if the game has multiple outcomes, players did not report this in our study even when they talked about games with multiple endings. *EXU* explores the role of chance in the game and effect of random elements on players, similar to an aspect of *Outcome Uncertainty* of players not being able to predict what the outcome of their actions would be and how that would feed back into their own performance. However, *EXU* does not address the uncertainty and curiosity around what the game's reaction would be when the players have used skill.

While Caillois does not propose a detailed uncertainty typology his play category of *alea* or *Chance* strongly aligns with *Result Uncertainty* in our model. He says, "for nothing in life is clear, since everything is confused from the very beginning, luck and merit too" [9], carefully addressing that challenge and chance although opposite must also be complementary. This maps directly with our findings that whether the game is more skill based or more luck based, the outcome of a game event must be somewhat uncertain, for the gameplay to be engaging. Johnson's *Chance* is unpredictability that occurs during the play of a game, such as an unpredictable move made by a non-player character. Any unpredictability sourced by the game during gameplay is grouped under *Chance* including uncertainty around the result of a game event, for instance the

unpredictability of the outcome of a die roll in the board game, Snakes and Ladders. Thus all kinds of *Game uncertainty* and *Outcome uncertainty* of our model is basically chance in their model. *Luck* is unpredictability at the end of a game, where luck is the extent to which player action can influence the outcome of the game. *Outcome Uncertainty* at the end phase of the game maps with *Luck*.

Summary Comparison

Overall, Costikyan's [16] eleven sources of uncertainty map most strongly with our model. One important divergence (among the smaller one's outlined above) is Costikyan's broad category of *Narrative Anticipation*: the desire to find out how the story or play arc of a game unfolds. It cuts across *Game*, *Player*, and *Outcome Uncertainty* in terms of players wanting to see new content and how the game and others respond to their actions. This was not reported as a collective anticipation by players instead as anticipation around each category of uncertainty described in the model.

PUGS developed by Power et al. [59] aims to measure uncertainty as a "foundational experience" of gameplay, which they are then interested in manipulating by e.g. increasing or decreasing "fog of war" [42]. Their categories show little overlap with ours because (a) they descriptively focus *any* kind of uncertainty, where our model captures *engaging* uncertainty, (b) they are interested in summative dimensions of overall gameplay, whereas our model disentangles a phenomenal sequence of causes and experiences in m2m gameplay, and (c) their model is limited to assessing structures within items proposed by prior theoretical models, where our model is grounded in open naturalistic observation.

Johnson's [33] nomenclature proposes an analytic distinction of unpredictability according to phases in a game; this again leads him to not capturing any *Player Uncertainty*.

Overall, while our empirically grounded model supports several prior theoretical categories in existing models, it goes beyond their scope identifying novel uncertainty types like *Content*, *Adaptation* and *Outcome Uncertainty*. And focusing on the m2m sequential beats of uncertainty in games, their conditions, and the motivations explaining *why* different sources of uncertainty lead to better player experience, it arguably advances our ability to guide game designers in affording engaging uncertainty in games.

CONCLUSION

In this paper, we presented a grounded theory of how game uncertainty affects players' moment-to-moment motivation in casual games, based on qualitative episodic and video-aided recall interviews. We found that uncertainty plays a key role in motivating players to continue playing from one moment to another. We developed an empirically grounded taxonomy of seven sources of uncertainty across the input-output loop spanning the game, the player, and their interaction in an outcome. With this we contribute to *how, when and why* uncertainty motivates showing that uncertainty types are not isolated but inform each other in a continuous loop keeping the players engaged. This taxonomy partially maps onto existing taxonomies, especially that of game designer Costikyan, providing converging evidence for their validity, as well as highlighting certain aspects overlooked by existing taxonomies. We were also able to tentatively link different uncertainty sources to corresponding existing motivational constructs, chief among them curiosity, but also sense of agency, competence, achievement, mastery, and goal-setting. This lends support to prior claims linking game uncertainty to curiosity, while differentiating such blanket claims with more detailed suggested mechanisms around different kinds of uncertainty sources.

Limitations and Future Work

The present study has been intentionally limited to casual games, suggesting expansion and replication for other game types. While our participants were reasonably diverse, they do represent a culturally homogeneous (European and Indian) sampling of the world population. As a qualitative study following grounded theory, we can claim qualitative validity and reliability in that we made our data collection and analysis processes transparent and followed principles of constant comparison and theoretical sampling. But the presented findings are obviously not statistically reliable, suggesting follow-on quantitative work. We have presented motivational links (esp. with curiosity, mastery, achievement and competence) at a level of granular analysis that calls for future work exploring other player experiences like challenge [2, 68] and how uncertainty, breakdowns and breakthroughs [31, 32] are interwoven at a micro level gameplay. That said, we believe that the presented taxonomy of game uncertainty enriches our current understanding especially from the perspective of m2m engagement, and puts it on a more reliable footing of systematic naturalistic observation.

ACKNOWLEDGMENTS

This work was supported by the EPSRC Centre for Doctoral Training in Intelligent Games & Games Intelligence (IGGI) [EP/L015846/1], and the Digital Creativity Labs (digitalcreativity.ac.uk), jointly funded by EPSRC/AHRC/Innovate UK under grant no. EP/023265/1.

REFERENCES

[1] Sami Abuhamdeh, Mihaly Csikszentmihalyi, and Baland Jalal. 2015. Enjoying the possibility of defeat: Outcome uncertainty, suspense, and intrinsic motivation. *Motivation and Emotion* 39, 1 (2015), 1–10.

[2] Ernest Adams. 2014. *Fundamentals of game design*. Pearson Education. 323–338 pages.

[3] Richard Bartle. 1996. Hearts, clubs, diamonds, spades: Players who suit MUDs. *Journal of MUD research* 1, 1 (1996), 19.

[4] D E Berlyne. 1960. Conflict, arousal, and curiosity. (1960), 11164–11000.

[5] Niall Bolger, Angelina Davis, and Eshkol Rafaeli. 2003. Diary methods: capturing life as it is lived. *Annu. Rev. Psychol.* 54 (2003), 579–616.

[6] Bart Bonte. 2015. *tap tap tap*. Game [Android]. (28 March 2015). Bart Bonte, Aalter, Belgium.

[7] Chris Boyle. 2019. *Simon Tatham's Puzzles*. Game [Android]. (26 March 2019). Chris Boyle, .

[8] Joachim C Brunstein and Günter W Maier. 2005. Implicit and self-attributed motives to achieve: two separate but interacting needs. *J. Pers. Soc. Psychol.* 89, 2 (Aug. 2005), 205–222.

[9] Roger Caillois. 2001. Man, games, and play. *Trans. Meyer Barash. Chicago: University of Illinois Press* (2001).

[10] Terry Cavanagh. 2012. *Super Hexagon*. Game [iOS]. (31 August 2012). Terry Cavanagh, Monaghan, Ireland.

[11] Kathy Charmaz. 2014. *Constructing Grounded Theory*. SAGE.

[12] K W Cheng. 2011. Casual gaming. *VU Amsterdam* (2011).

[13] Adrian Chmielarz. 2012. Why we need to kill gameplay to make better games. `http://www.theastronauts.com/2012/11/why-we-need-to-kill-gameplay-to-make-better-games/`. (Nov. 2012). Accessed: 2018-9-29.

[14] Floralmong company. 2017. *Picross Luna - A forgotten tale*. Game [Android]. (23 January 2017). Floralmong company.

[15] Game Hive Corp. 2015. *Tap Tycoon*. Game [iOS]. (16 December 2015). Game Hive Corp., Toronto, Canada.

[16] Greg Costikyan. 2013. *Uncertainty in Games*. MIT Press.

[17] Dave Rohrl, Jonathan Greechan, Michelle Lee, Brian Robbins, Dan Prigg, Juan Gril, Steve Meretzky. 2009. 2008-2009 Casual Games White Paper. *A Project of the Casual Games SIG of the IGDA* (2009).

[18] Bernie DeKoven. 2002. *The well-played game: a playful path to wholeness*. iUniverse.

[19] Nintendo Creative Department. 1985. *Super Mario Bros.* Game [SNES]. (13 September 1985). Nintendo, Kyoto, Japan.

[20] Uwe Flick. 2000. Episodic interviewing. *Qualitative researching with text, image and sound* (2000), 75–92.

[21] Jelly Button Games. 2018a. *Pirate Kings*. Game [iOS], Android. (28 June 2018). Jelly Button Games, Tel Aviv-Yafo, Israel.

[22] Merger Games. 2018b. *Merge Plane*. Game [iOS]. (10 August 2018). Merger Games, Santa Rosa, United States.

[23] Ustwo Games. 2014. *Monument Valley*. Game [iOS]. (03 April 2014). Ustwo Games, London, England.

[24] Rosemary Garris, Robert Ahlers, and James E Driskell. 2002. Games, Motivation, and Learning: A Research and Practice Model. *Simul. Gaming* 33, 4 (Dec. 2002), 441–467.

[25] Russell Golman, George Loewenstein, and Nikolos Gurney. 2015. Information Gaps for Risk and Ambiguity. *Available at SSRN 2605495* (May 2015).

[26] Greg Guest, Arwen Bunce, and Laura Johnson. 2006. How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field methods* 18, 1 (Feb. 2006), 59–82.

[27] Patrick Haggard. 2017. Sense of agency in the human brain. *Nat. Rev. Neurosci.* 18, 4 (April 2017), 196–207.

[28] Juho Hamari and Janne Tuunanen. 2014. Player types: A meta-synthesis. (2014).

[29] Paul A Howard-Jones and Skevi Demetriou. 2009. Uncertainty and engagement with learning games. *Instructional Science* 37, 6 (2009), 519.

[30] Robin Hunicke, Marc LeBlanc, and Robert Zubek. 2004. MDA: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI*, Vol. 4. aaai.org, 1722.

[31] Ioanna Iacovides, James C Aczel, Eileen Scanlon, and Will IS Woods. 2011. What can breakdowns and breakthroughs tell us about learning and involvement experienced during game-play. In *Proceedings of the 5th European Conference on Games Based Learning*. Academic Publishing International Reading, UK, 275–281.

[32] Ioanna Iacovides, Anna L Cox, Patrick McAndrew, James Aczel, and Eileen Scanlon. 2015. Game-play breakdowns and breakthroughs: exploring the relationship between action, understanding, and involvement. *Human–computer interaction* 30, 3-4 (2015), 202–231.

[33] Mark R Johnson. 2018. *The Unpredictability of Gameplay*. Bloomsbury Academic.

[34] Jesper Juul. 2010. *A Casual Revolution: Reinventing Video Games and Their Players*. MIT Press.

[35] Jesper Juul. 2011. *Half-Real: Video Games between Real Rules and Fictional Worlds*. MIT Press.

[36] King. 2012. *Candy Crush Saga*. Game [iOS]. (14 November 2012). King, Stockholm, Sweden.

[37] King. 2013. *Farm Heroes Saga*. Game [Android, iOS]. (26 March 2013). King, Stockholm, Sweden.

[38] King. 2014. *Candy Crush Soda Saga*. Game [Android, iOS]. (20 October 2014). King, Stockholm, Sweden.

[39] Exploding Kittens. 2015. *Exploding Kittens*. Game [iOS]. (16 December 2015 2015). Exploding Kittens, Beverly Hills, California.

[40] Christoph Klimmt. 2006. *Computerspielen als Handlung: Dimensionen und Determinanten des Erlebens interaktiver Unterhaltungsangebote*. Herbert von Halem Verlag.

[41] Annakaisa Kultima and Juho Karvinen. 2016. Idea practices and attitudes towards innovation in game development. (2016).

[42] Shringi Kumari, Christopher Power, and Paul Cairns. 2017. Investigating Uncertainty in Digital Games and Its Impact on Player Immersion. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '17 Extended Abstracts)*. ACM, New York, NY, USA, 503–509.

[43] Nicole Lazzaro. 2004. Why We Play Games: Four Keys to More Emotion Without Story.

[44] Marc LeBlanc. 2006. Tools for creating dramatic game dynamics. *The game design reader: A rules of play anthology* (2006), 438–459.

[45] Jordan A Litman and Tiffany L Jimerson. 2004. The measurement of curiosity as a feeling of deprivation. *J. Pers. Assess.* 82, 2 (2004), 147–157.

[46] Edwin A Locke and Gary P Latham. 1990. A theory of goal setting & task performance. 413 (1990).

[47] George Loewenstein. 1994. The psychology of curiosity: A review and reinterpretation. *Psychol. Bull.* 116, 1 (July 1994), 75–98.

[48] J Derek Lomas, J Derek Lomas, Kenneth Koedinger, Nirmal Patel, Sharan Shodhan, Nikhil Poonwala, and Jodi L Forlizzi. 2017. Is Difficulty Overrated? (2017).

[49] Playdemic Ltd. 2017. *Golf Clash*. Game [Android, iOS]. (18 January 2017). Playdemic, Wilmslow, England.

[50] Thomas M Malaby. 2007. Beyond Play: A New Approach to Games. *Games and Culture* 2, 2 (April 2007), 95–113.

[51] T W Malone. 1982. Heuristics for designing enjoyable user interfaces: Lessons from computer games. *Proceedings of the 1982 conference on Human factors* (1982).

[52] Mediocre. 2016. *PinOut*. Game [iOS]. (27 October 2016). Mediocre, MalmÃű, Sweden.

[53] Talya Miron-Shatz, Arthur Stone, and Daniel Kahneman. 2009. Memories of yesterday's emotions: does the valence of experience affect the memory-experience gap? *Emotion* 9, 6 (Dec. 2009), 885–891.

[54] Lennart E Nacke, Chris Bateman, and Regan L Mandryk. 2014. BrainHex: A neurobiological gamer typology survey. *Entertain. Comput.* 5, 1 (Jan. 2014), 55–62.

[55] Nordcurrent. 2014. *Cooking Fever*. Game [Android, iOS]. (27 September 2014). Nordcurrent, Vilnius, Lithuania.

[56] Shubhankar Parijat. 2017. Call of Duty 2017 Maps Will Focus On Second To Second Experiences, Suggests Job Listing. https://gamingbolt.com/call-of-duty-2017-maps-will-focus-on-second-to-second-experiences-suggests-job-listing. (Jan. 2017). Accessed: 2018-9-29.

[57] Jori Pitkänen. 2015. Studying thoughts: Stimulated recall as a game research method. In *Game Research Methods*. 117–132.

[58] Inc. Playdots. 2014. *Two Dots*. Game [Android, iOS]. (29 May 2014). TenCent Games, Shenzhen, China.

[59] Christopher Douglas Power, Paul Antony Cairns, Alena Denisova, Themis Papaioannou, and Ruth Gultrom. 2018. Lost at the Edge of Uncertainty: Measuring Player Experience in Digital Games. *Int. J. Hum. Comput. Interact.* (Sept. 2018), 14.

[60] Andrew K Przybylski, C Scott Rigby, and Richard M Ryan. 2010. A Motivational Model of Video Game Engagement. *Rev. Gen. Psychol.* 14, 2 (June 2010), 154–166.

[61] White Wolf Publishing. 1991. *Vampire: The Masquerade*. Tabletop. (1991). White Wolf Publishing, Stockholm, Sweden.

[62] Koster Raph. 2005. A theory of fun for game design. (2005).

[63] Brenda Romero. 2011. Design Truth 1. `https://bbrathwaite.wordpress.com/2011/01/13/design-truth-1/`. (Jan. 2011). Accessed: 2018-9-29.

[64] R M Ryan and E L Deci. 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* 55, 1 (Jan. 2000), 68–78.

[65] Katie Salen, Katie Salen Tekinbaş, and Eric Zimmerman. 2004. *Rules of Play: Game Design Fundamentals*. MIT Press.

[66] Katie Salen and Eric Zimmerman. 2004. Rules ofplay: Game design fundamentals. *Cambridge: The MITPress* (2004).

[67] Kevin Saunders and Jeannie Novak. 2012. *Game Development Essentials: Game Interface Design*. Cengage Learning.

[68] Jesse Schell. 2014. *The Art of Game Design: A book of lenses*. AK Peters/CRC Press. 181–182 pages.

[69] Miguel Sicart. 2015. Loops and Metagames: Understanding Game Design Structures. In *Foundations of Digital Games*.

[70] Paul J Silvia. 2012. Curiosity and motivation. *The Oxford handbook of human motivation* (2012), 157–166.

[71] Seth Sivak. 2012. GAME 3400 Level Design - Moment Based Design. `https://www.slideshare.net/sjsivak/game-3400-level-design-moment-based-design`. (Sept. 2012). Accessed: 2018-9-29.

[72] Swink Steve. 2007. Gamasutra - Game Feel: The Secret Ingredient. `http://www.gamasutra.com/view/feature/2322/game_feel_the_secret_ingredient.php?print=1%3C/FONT%3E%3C/A%3E%3C/PRE%3E%3CPRE`. (Nov. 2007). Accessed: 2018-9-29.

[73] SMG Studio. 2017. *RISK: Global Domination*. Game [iOS], Android. (25 August 2017). SMG Studio, Chippendale, Australia.

[74] Smash Head Studio. 2018. *Blaze Hopper*. Game [Android]. (07 May 2018). Smash Head Studio, Bengaluru, Karnataka.

[75] Halfbrick Studios. 2010. *Fruit Ninja*. Game [Android, iOS]. (21 April 2010). Halfbrick Studios, Brisbane, Australia.

[76] Halfbrick Studios. 2011a. *Jetpack Joyride*. Game [iOS]. (01 September 2011). Halfbrick Studios, Brisbane, Australia.

[77] Imangi Studios. 2011b. *Temple Run*. Game [iOS]. (04 August 2011). Imangi Studios, North Carolina, United States.

[78] Matt Suckley. 2017. Why PlayRaven is ditching second-to-second gameplay in favour of rich metagame. `http://www.pocketgamer.biz/news/64873/why-playraven-favours-metagame/`. (Jan. 2017). Accessed: 2018-9-29.

[79] Tony Sundell and View my Complete Profile. 2016. Second to Second Gameplay. `http://indiedevjourney.blogspot.com/2016/03/second-to-second-gameplay.html`. (2016). Accessed: 2018-9-29.

[80] Supercell. 2016. *Clash Royale*. Game [Android, iOS]. (02 March 2016). Supercell, Helsinki, Finland.

[81] Steve Swink. 2009. *Game Feel: A Game Designer's Guide to Virtual Sensation*.

[82] Alexandra To, Ali Safinah, Geoff F Kaufman, and Jessica Hammer. 2016. Integrating Curiosity and Uncertainty in Game Design. In *DiGRA/FDG*.

[83] Gregory Trefry. 2010. *Casual game design: designing play for the gamer in all of us*. CRC Press.

[84] Jason VandenBerghe. 2016. Engines of Play: How Player Motivation Changes Over Time. `https://www.gdcvault.com/play/1023329/Engines-of-Play-How-Player`. (2016).

[85] George H Weiss. 1979. The Theory of Gambling and Statistical Logic (Richard A. Epstein). (1979).

[86] Nick Yee. 2016. The Gamer Motivation Profile: What We Learned From 250,000 Gamers. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '16)*. ACM, New York, NY, USA, 2–2.