Curiously Motivated: Profiling Curiosity with Self-Reports and Behaviour Metrics in the Game "Destiny"

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ABSTRACT
Identifying player motivations such as curiosity could help game designers analyze player profiles and substantially improve game design. However, research on player profiling focuses on generalized personality traits, not specific aspects of motivation. This study examines how player behaviour indicates constructs of curiosity-related motivation. It contributes a more discriminating operationalization of game-related curiosity. We derive a curiosity measure from established self-report survey methodologies relating to social capital, behavioural activation, obsessive/harmonious passion, and BrainHex player types. We present the results of a cross-sectional study with data from 1,745 players of *Destiny*—a popular shared-world first-person shooter (FPS) game. Behaviour metrics were paired with four curiosity factors: 'social' curiosity, 'sensory/cognitive' curiosity, 'novelty-seeking' curiosity, and 'explorative' curiosity. Our findings provide key insights into the relationships between players curiosity and their in-game behaviour. We infer curiosity-related motivational profiles from behaviour metrics, and discuss how this may impact game design and player-computer interaction.

Author Keywords
Games; Personality; Curiosity; Motivation; Behaviour.

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INTRODUCTION
Video games and their virtual worlds are great sandboxes for the investigation of human behaviour. How people play a digital game can reveal things about their character, their personal attitudes, and even their motivations in life. Curiosity is a form of intrinsic motivation that plays a central role in many aspects of human behaviour. Beyond that, curiosity is a concept frequently used by game designers, because it drives player engagement and keeps people deeply involved with a game. For instance, in 2012 renowned game designer Peter Molyneux designed an experimental game [G1] which specifically revolved around the concept of curiosity. Players had to collectively dig through layers of small cubes, to discover the 'story' surrounding the giant cube that contained them. Early research into digital games indicated the possibility of constructing personality profiles from observations of a player's in-game behaviour [50, 54, 55]. However, the exact role different facets of curiosity play in digital game behaviour has not yet been studied, even though the satisfaction of appetitive motives such as curiosity is an integral component of player engagement [23, 26]. More broadly, curiosity has been identified as a motivational factor drawing people into playing today's most successful online games, such as the online shared-world shooter *Destiny* [G5]. In these online games, curiosity may manifest itself in many forms, including seeking information or experiences [63], and social curiosity [56] about other players.

However, there has not yet been an empirical attempt to measure the extent to which different components of curiosity (e.g., social, spatial, cognitive, sensory) affect an individual player's behaviour. To address this gap in the literature, we analyzed data from 1,745 players of the online shared-world shooter *Destiny*. The data was collected as part of a larger survey designed to measure social capital, behaviour activation, obsessive and harmonious passion, and different player types. These measures were not originally designed to assess curiosity as a construct in itself, but they each incorporated data with strong connections to the concept of curiosity. Based on our review of 'curiosity' concepts, we systematically selected all curiosity-related items from the relevant subscales used in the survey and used these to derive and assess a measure of player curiosity. We then conducted an exploratory factor analysis (EFA) to derive a multi-factor measure of game-related curiosity. Since we logged player identification tokens during self-reports, we were able to correlate behaviour metrics—obtained via telemetry—with the self-report scores. After establishing the relationship between self-reported curiosity factors and tracked behavioural data, we conducted multiple regressions to test how well motivational profiles could be inferred from in-game behaviour. We were able to demonstrate meaningful behavioural correlates with the curiosity-related motivational factors we had identified. For example, those with so-called 'completionist' tendencies (e.g., 'achievers' whose aim is to complete every task in the game) showed the strongest correlations with our metrics of exploration (see table 3) but also showed stronger tendencies toward obsessive engagement. In contrast, 'curious' players were more likely to exhibit a more harmonious, balanced attitude to playing the game (see table 2). In other words, it didn't seem to take over their lives.

These findings (and other connections we were able to establish between motivational factors and in-game behaviour) deepen our understanding of the ways in which different manifestations of curiosity are reflected in digital gaming behaviour. They constitute a significant first step toward a more differentiated operationalization of curiosity in games, which may in turn support the modelling of implicit user curiosity based on observations of user behaviour in virtual worlds. Besides these essential new findings, we contribute novel methodologies, specifically related to curiosity, which advance the study of motivational drivers for playing games. First, we propose a multi-factor scale to measure aspects of curiosity in online games (derived from established scales of motivation and player types). Second, we identify behavioural indicators in a large-scale online game dataset for a key group of game-related motivations. Third, we provide evidence that profiles of motivation and player types may be inferred from the logging and processing of in-game behaviour data, thus laying the foundation for automated player motivation classification—a result with potential applications well beyond the world of online gaming. The present study is the first to correlate intrinsic motivation aspects and player personality with behaviour metrics in a shared-world, online first-person shooter game. Compared to previous work on constructing player personality profiles from observations of in-game behaviour [6, 50, 55, 64], we contribute to the human-computer interaction (HCI) and player experience communities a novel analysis of the relationships between self-reported motivation and player personality, with a focal point on curiosity, as well as observations of in-game behaviour, backed by a large sample of 1,745 online players of the game *Destiny*.

RELATED WORK

Curiosity Research

Traditionally, the fields of philosophy and psychology [3, 4, 25, 40, 42] have investigated the nature, origins, and effects of curiosity—the inherent human appetite for new information. In the early 1950s, Berlyne [3, 4] formalized curiosity research through a series of experiments linking stimulus complexity and novelty to the reward value of exploratory behaviour. Building on these early findings, Loewenstein [25] operationalized curiosity in his *information gap* theory as the *perceived ability and desire to close a gap in one's knowledge.*

Curiosity in HCI and Games

Malone [27] developed design heuristics which suggested that computing systems should (a) provide an optimal level of informational complexity through novelty and surprise, and (b) offer ways to make users' knowledge structures more 'complete, consistent, and parsimonious'. HCI researchers have extended Malone's work, leveraging curiosity to enhance user activities in interactive systems. For example, Law et al. [22] employed curiosity as an incentive mechanism to increase crowd worker retention in an audio transcription task. Wilson et al. [60] used curiosity to increase correctness in end-user programming, and Wainer et al. [57] guided users' attention toward email inbox items using curiosity-inducing verbal stimuli. For digital games, Sedano et al. [45] identified curiosity as one of the key factors which arouse and sustain player engagement in pervasive game applications. Nacke et al. [28] developed BRAINHEX, a neurobiological gamer typology survey distinguishing a 'curiosity-driven' SEEKER type—explicitly linked to Malone's definition of curiosity—from six other player archetypes. In a review of techniques to integrate curiosity and uncertainty into game design, To et al. [51] discussed five game-related curiosity types, tying established constructs to Costikyan's theory of uncertainty in games [11].

Links Between Curiosity and other Motivations to Play

Given that curiosity is defined as 'an appetite for information' [25], it can manifest itself in many different forms. Curiosity is naturally interrelated with other human impulses, such as social interaction and general experience-seeking. While some works on social dynamics in online gaming [16, 24] highlight the relevance of social curiosity in large online gaming communities implicitly, Vella et al. [56] explicitly characterize games as a *site of intersection between social exploration and relationship maintenance*. Yee et al. [63] developed a three-factor scale to measure motivations for online gaming, distinguishing between IMMERSION, SOCIAL, and ACHIEVEMENT motivations. The authors identified positive links between IMMERSION motivation and intrinsically motivated exploration of a game's virtual world. Notably, one of the four items in the IMMERSION subscale [63] directly asked about the importance of *exploring the world just for the sake of exploring it*. An inverse relationship was found between this kind of exploration and the ACHIEVEMENT motivation. Schmitt and Lahroodi [44] highlighted the 'passion' aspect of curiosity as a desire that can become obsessive, at times demanding impulsive gratification *against our will and better judgment*. Indeed all four curiosity factors reported by the present study show significant positive correlations with the Obsessive passion subscale, demonstrating a link between curiosity in general as a motivator and obsessive attachment.

Analysis of In-Game Behaviour

Behavioural analytics in game development, just as in other academic fields, combines the study of behaviour, data mining, and data visualization; to take three examples [2, 12, 49]. This research domain is referred to as 'game analytics' [17]. Early work in this field is less than a decade old and focuses on how behavioural telemetry can improve the utility of user testing in major commercial games [19]. A second line of investigation has examined the games found on social networks such as *Facebook*, which put substantial amounts of information about the players into the hands of game companies for the first time [29]. A third avenue has emerged, concerned with the ever-growing numbers of games played on mobile phones as a key new element in the game industry, where the dominant free-to-play business model relies on sales made inside the games and is thus heavily dependent on behavioural analytics to optimize the monetization process [2, 48]. A fourth theme has recently started focusing on behavioural analysis in virtual reality. The latest advances in the field focus on creating efficient techniques for rapid analysis, stealth assessment through evidence-centred design (ECD) and machine learning algorithms for prediction, profiling, and adaptation. Research in behavioural data mining has led to a better understanding of human behaviour, learning, engagement, and interaction in games [48, 47].

Inferring Player Psychology from In-Game Behaviour

Following the introduction of behavioural tracking, there have been some attempts to correlate in-game behaviour with various psychometric self-report scales [6, 50, 55, 64]. This interests academia and industry because it allows us to draw inferences about why patterns of behaviour in very large sample cohorts occur as they do—some games in the mobile space have dozens and even hundreds of millions of players. There is, however, limited knowledge publicly available on this aspect of research, and evidence currently to be found in the public domain is highly fragmented and inconclusive. For example, Yee et al. [64], van Lankfeld et al. [55], and Spronck et al. [50] looked at this problem through the lens of personality research, leveraging the Five-Factor Model [14] to infer personality traits from behaviour metrics in the role-playing games *World of Warcraft* [G4], *Neverwinter Nights* [G3], and *Fallout 3* [G2] respectively. Differentiating their work from these studies, Canossa et al. [6] posited that *personality is a construct that attempts to describe what people might choose to do, while motivation attempts to infer why they do it*. They then explored correlations between behaviour metrics in the game *Minecraft* [G6] and different aspects of motivation—including a single-factor construct of curiosity (measured by the Reiss Motivation Profiler [41]) for a selected player sample. In comparison, our work uses a much larger sample and builds a player-specific curiosity scale based on empirically robust factors.

RESEARCH QUESTIONS

As discussed above, curiosity is related to other types of motivation, such as the desire for social interaction or simple fun-seeking, and it may be reflected in the expression of different player preferences. Although it has been widely accepted as a key factor driving player behaviour, there is no game-specific instrument measuring different elements of curiosity. Several scales exist, but they are designed for measuring curiosity outside of games [40, 42] while our objective in this study is to contribute to a much more nuanced view of game-related curiosity.

We propose a methodology that we believe could inform a more differentiated operationalization of curiosity in games. Building on widely adopted instruments of player motivation and typology, we generate a survey scale that investigates social, spatial, cognitive, and sensory aspects of curiosity in the context of digital games, and which at the same time refers back to player motivation and personality as fundamental anchor points. Thus, our study aims to answer two research questions:

RQ1: What curiosity factors can be derived from the previously adopted survey scales?

RQ2: Can we infer self-reports of curiosity from player behaviour data in the game world?

USE CASE: DESTINY

Destiny [G5] is a popular shared-world first-person shooter, released in September 2014, with almost 30 million players as of Q1 2016[1]. The game is set in what the developers describe as a 'mythic science-fiction' world. All the game's activities generate player rewards, including in-game currencies, weapons, and armour. The reward a player receives for an activity is usually randomly determined and some rewards are only available on completing specific tasks. The authors chose *Destiny* for use in the current study for multiple reasons. The high number of active players, the diversity of data available regarding players' in-game behaviour, and the wide range of activities for players to engage in, render *Destiny* a useful medium for research into game-related human behaviour. Moreover, *Destiny* lends itself particularly aptly to the study of curiosity, because it tracks the degree to which players try out new things and explore the game world. These activities are aggregated in a metric called the *Grimoire* score. This score rises whenever the player performs certain actions for the first time (e.g. creating a character of a certain class and race, discovering a new location, or performing certain tasks). The *Grimoire* score is shared across all of a player's characters and thus provides an objective proxy measure of a player's tendency toward exploratory behaviour spanning a broad range of possible types of interaction.

The game has two basic modes: player-versus-environment (PvE) and player-versus-player (PvP). In PvE mode, players can engage in 'story missions' (up to 3 players cooperating), 'strikes' (3 players cooperating against large numbers of enemies), or 'raids' (which involve up to 6 players cooperating in longer, more difficult sequences of gameplay and which require high levels of collaboration). Additionally, players can choose (in groups of up to 3 players) to go 'on patrol', which involves traveling to a particular planet and attempting to complete various objectives as they become available ('on patrol' games include 'public events' which occur semi-regularly and generally require collaboration between larger

[1] http://tinyurl.com/activision-report-Q1-2016

numbers of players for their completion). Outside of specific mission-type objectives, players in *Destiny* can choose to focus on finding collectible items of various types. In PvP, *Destiny* offers many modes in which players compete (and cooperate) with other players. Some PvP modes involve players competing individually, while others require two teams (of 2 to 6 players). The objectives in PvP modes include gaining the most kills, and securing objectives and territory (e.g. capturing zones and seizing relics, or the defence of the same). In addition to the standard PvP modes, *Destiny* offers highly competitive, time-limited events (e.g. *Iron Banner* or *Trials of Osiris*) that offer players particularly valuable rewards. In both PvE and PvP, *Destiny* offers players 'quests' that require a sequence of activities and game objectives to be completed, in return for specific rewards.

DATA ACQUISITION AND PROCESSING

The present study combines two separate sets of data: (1) Survey data collected by the authors containing demographic information and self-reports about motivation and player types from 3,542 *Destiny* players. (2) Data on in-game behaviour obtained from *Destiny* server logs.

Survey Data

Our online survey was advertised in relevant *Destiny* player forums in the spring of 2016 and collected self-reported data from *Destiny* players. The survey comprised six sections. In the first section, we asked for demographic information: gender (96% male), age (M = 25 years; SD = 7.4), country of residence (the majority of respondents were from the United States of America, United Kingdom, Australia, Canada, New Zealand, Sweden, and Germany), experience with playing video games (57% reported to be *very experienced*), as well as average (M = 34.8 hours; SD = 25.5) and maximum (M = 58.8 hours; SD = 30.7) weekly playing time during the previous year. The second section asked for information related to *Destiny*, specifically the preferred platform to play the game, the player identification (ID), and the amounts of play time, as well as the respondents' team preferences: did they prefer playing *Destiny* with strangers, gaming friends, or real-life friends? The remaining four sections corresponded to existing psychometric scales of motivation and player typology (described below).

Social Capital. The SOCIAL CAPITAL scale [59] is an established 10-item instrument in games research [10, 52, 56, 65]. It asks about the degree to which individuals tend to engage in two different types of social interaction, referred to as *bridging* and *bonding* in the target activity (in this case, playing *Destiny*). Williams [59] describes *bridging* as an inclusive aspect of social capital which occurs when individuals from different backgrounds create new ties across the boundaries of existing social networks. In contrast, *bonding* is described as an exclusive aspect of social capital in which strongly-tied individuals, such as close friends, provide substantive support for one another. All items in the SOCIAL CAPITAL instrument are scored on a five-point Likert-type scale ranging from 'strongly disagree' to 'strongly agree'.

Obsessive/Harmonious Passion. The OBSESSIVE/HARMONIOUS PASSION scale [37, 53] used in our survey has ten items. Five of these measure the level of *harmonious* passion for an object or activity—in our case, harmonious passion (or engagement) with *Destiny*—while the other five items measure the level of *obsessive* engagement with the same object or activity. 'Harmonious passion' equates to the *autonomous* internalization of an activity into a person's identity (i.e., the person has freely chosen the activity with attached contingencies and the activity 'harmonizes' with other areas of their life. The activity does not, for example, stop them from going to work in the morning or doing the washing up). In contrast, 'obsessive passion' results from a *controlled* internalization of an activity into a person's identity (people feel compelled to engage in it) with the result that the activity conflicts with other aspects of day-to-day life [53]. The OBSESSIVE/HARMONIOUS PASSION scale is a widely adopted instrument for the study of player engagement in digital games [35, 36, 37, 58]. All items in the instrument are scored on a seven-point Likert-type scale ranging from 'do not agree' to 'strongly agree'.

Behavioural Activation System. The BEHAVIOURAL INHIBITION AND ACTIVATION SYSTEM (BIS/BAS) instrument [7] was developed to assess individual differences in the sensitivity of two different motivational systems: the behavioural activation system (BAS) which regulates appetitive motives causing humans to approach something desired (e.g., rewards), and the behavioural inhibition system (BIS) which regulates aversive motives causing humans to move away from something unpleasant (e.g. punishments). For compactness, we included only the FUN-SEEKING and REWARD RESPONSIVENESS subscales of the BAS section (which we collectively refer to as BEHAVIOURAL ACTIVATION or BAS in the following). All items in the scale are scored on a four-point Likert-type scale ranging from 'very false for me' to 'very true for me'. The BIS/BAS instrument has been used in many studies to evaluate player engagement with games [30, 34, 38, 39].

BrainHex. The BRAINHEX instrument [28] is a 21-item player typology survey, inspired by research results in neurobiology, and used to distinguish between the following seven archetypes of players: SEEKER (enjoys exploration), SURVIVOR (aroused by fear), DAREDEVIL (thrilled by risk taking), MASTERMIND (strategic problem solver), CONQUEROR (excited by defeating difficult challenges), SOCIALIZER (likes the interaction with other players), and ACHIEVER (motivated by long-term achievements). The BRAINHEX instrument has been successfully used to analyze player personality and motivation in recent studies [5, 21, 32, 33]. All items in the BRAINHEX instrument are scored on a three-point Likert-type scale with response items of 'I hate it!', 'It's okay', and 'I love it!'.

We chose these four scales for our study because they are widely adopted tools for the study of player motivation and preferences (cf. [5, 10, 21, 34, 35, 38, 56, 58]), covering a broad range of human motivations with connections to different aspects of game-related curiosity. Examples of these mo-

Parent Scale	#	Survey Item	F1	F2	F3	F4
Bridging Social Capital	1	Interacting with people in *Destiny* makes me interested in things that happen outside of my town.	**.80**	.21	.09	.06
	2	Interacting with people in *Destiny* makes me want to try new things.	**.62**	.32	.10	.18
	3	Interacting with people in *Destiny* makes me interested in what people unlike me are thinking.	**.73**	.13	.10	.15
	4	Talking with people in *Destiny* makes me curious about other places in the world.	**.79**	.16	.10	.09
Harmonious Passion	5	The new things that I discover with this game allow me to appreciate it even more.	.22	**.63**	.18	.10
	6	This game allows me to live a variety of experiences.	.25	**.68**	.08	.15
BAS Fun-Seeking	7	I'm always willing to try something new if I think it will be fun.	.11	.07	.05	**.52**
	8	I crave excitement and new sensations.	.08	.11	.12	**.59**
BrainHex Seeker	9	Exploring to see what you can find.	.11	.11	**.58**	.12
	10	Wondering what is in an unexplored area.	.09	.10	**.73**	.07
SS loadings			2.33	1.08	0.97	0.74
Cronbach's alpha			.86	.67	.61	.50

Table 1. Summary of exploratory factor analysis results for the curiosity-related survey items. Factor loadings over .40 are written in boldface. F1 = Social Curiosity; F2 = Sensory/Cognitive Curiosity; F3 = Explorative Curiosity; F4 = Novelty/Fun-Seeking Curiosity (reprinted from [43])

tivations include 'tendencies toward social interaction with other players across the boundaries of existing social networks' [59], 'the formation of harmonious connections to a game by gaining new experience' [53], 'behavioural activation induced by novelty-seeking' [7], and 'inclinations toward curiosity-driven exploration of the game world' [28]. We highlight the specific connections between individual subscales and game-related curiosity below, when we describe the process of constructing a multi-factor scale for curiosity in games. For the complete survey text, we refer the reader to the supplementary material of this paper.

RQ1: Toward Four Factors of Curiosity

The four self-report 'base' scales in our survey were developed to measure constructs other than curiosity (as discussed above). However, a closer look at the semantics of the survey items and their design objectives revealed that specific items in each of these scales do in fact interrogate constructs of curiosity. Following up on this observation, we examined whether it was possible to construct a multi-factor 'curiosity' scale using survey items from these 'base' scales' existing motivation and player types. For this purpose, we extracted the ten curiosity-related survey items from the Social Capital, Obsessive/Harmonious Passion, Behavioural Activation, and BrainHex instruments, and performed an exploratory factor analysis (EFA) on these to examine their latent factor structures. In deriving a joint factor structure from item sets with different response scales, we follow a common methodology from personality psychology [1, 13, 61]. The precise wording of the items selected can be found in Table 1, and we will direct the reader to the specific positions when discussing the individual item groups.

Social Capital. In the design considerations for the Social Capital instrument, Williams [59] points out that the Bridging subscale is intended to measure the effects of social interaction on tendencies toward *interacting with people outside the local area, trying new things, and being curious about differences in others and different parts of the world*. We selected the first four items of the Bridging subscale, which address specific facets of curiosity, asking about the effect of social interaction with other players in the game on the desire to explore new things and places and to learn about people unlike oneself (Table 1, items 1 to 4).

Harmonious Passion. The connection between game-related curiosity and the design considerations of the Harmonious Passion subscale from the Obsessive/Harmonious Passion instrument was highlighted by Przybylski et al. [35], who stated that modern games are designed to offer players *meaningful choices that continuously balance their boundless curiosity against a finite pool of resources and talent*. We selected items three and five from the Harmonious Passion subscale, given their semantic relatedness to sensory and cognitive curiosity (Table 1, items 5 and 6).

BAS Fun-Seeking. Evaluating the BIS/BAS instrument, Carver et al. [7] report a statistically significant correlation between the BAS Fun-Seeking subscale and the Novelty-Seeking subscale of the Tridimensional Personality Questionnaire (TPQ) [8]. In this context, the construct of novelty-seeking, as measured by the TPQ, is defined as a tendency toward *exploration in pursuit of potential rewards* [7]. We decided to include only the first and last item of the four-item Fun-Seeking subscale in our factor analysis because they are the only ones directly to address the concept of novelty-seeking (Table 1, items 7 and 8).

BrainHex Seeker. One of the seven BrainHex player archetypes is referred to as the Seeker type. The authors characterize this player type by stating that the typical Seeker is *curious about the game world and enjoys moments of wonder* [28]. A strong connection is established between the BrainHex Seeker type on the one hand and Lazzaro's *Easy Fun* [23] and Malone's 'curiosity' [27] on the other hand. Lazzaro's *Easy Fun* refers to explorative play supported by aesthetic experiences and ambiguity or incompleteness of information. It could, therefore, be interpreted as 'cognitive curiosity', according to Loewenstein's classification [25]. Malone's concept of curiosity entails both sensory and cognitive components. We included items one and three from the BrainHex Seeker subscale in our analysis, since they interrogate a tendency toward explorative behaviour in games (Table 1, items 9 and 10).

RQ1: Results

After selecting the ten curiosity-related survey items, we conducted a maximum likelihood EFA on the ten items with orthogonal rotation (varimax) to determine whether the ten items could be grouped into multiple independent factors. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO $= .83$ [18].

All KMO values for individual items were $> .7$, which is well above the acceptable minimum of .5. Bartlett's test of sphericity, $\chi^2(45) = 2,757$, $p < .001$, indicated that correlations between items were sufficiently large for EFA. We ran an initial principal component analysis (PCA) to obtain eigenvalues for each component in the data. Four components had eigenvalues above Kaiser's criterion of 1.0 and in combination explained 71% of the variance. Given the large sample size, and the convergence of the scree plot and Kaiser's criterion on four components, we retained these four factors (F1 to F4) in our final analysis.

Table 1 shows the factor loadings after rotation. The oblique rotations oblimin and promax yielded the same factor structure as had been extracted using the orthogonal varimax rotation, indicating a stable pattern of four largely independent factors. Factor F1 had a high reliability, Cronbach's $\alpha = .86$, whereas factors F2 and F3 had moderate reliabilities with α values of .67 and .61 respectively. Factor F4 had relatively low reliability, $\alpha = .50$. However, Kline acknowledges that, for psychological constructs like curiosity, Cronbach's α can, realistically, be expected to be below .7 because of the diversity of the constructs being measured [20]. That said, our findings with respect to F4 should be interpreted with caution.

The four factors, extracted in the EFA, precisely reflect the four different subscales from which we extracted the survey items: BRIDGING SOCIAL CAPITAL (F1), HARMONIOUS PASSION (F2), BRAINHEX SEEKER (F3), and BAS FUN-SEEKING (F4). This is evidence that the four item groups measure four different factors of curiosity. In reference to the semantic connections between the items in each of the curiosity subscales, we refer to the following factors (F1-F4) in the remainder of this paper: F1 as SOCIAL CURIOSITY, F2 as SENSORY/COGNITIVE CURIOSITY, F3 as EXPLORATIVE CURIOSITY, F4 as NOVELTY-SEEKING CURIOSITY. Figure 1 shows an overview of the four curiosity factors determined through factor analysis and some of the behaviours correlated with those factors.

RQ2: Correlating Self-Reports and Behavioural Data

Destiny tracks thousands of behavioural features about individual players. However, in any work attempting to correlate in-game behaviour with psychological factors, an initial challenge lies in isolating those behaviours with the most predictive potential [2, 48]. There are two approaches to such an analysis: either a 'bottom-up', exploratory approach where high numbers of variables are correlated with the self-report scores, or a 'top-down' approach where hypotheses are used to define which behaviours to work with. While the exploratory approach can result in over-featuring and false positives, the top-down approach is exclusive, ignoring behaviours not included in the hypotheses. Hence, in this study,

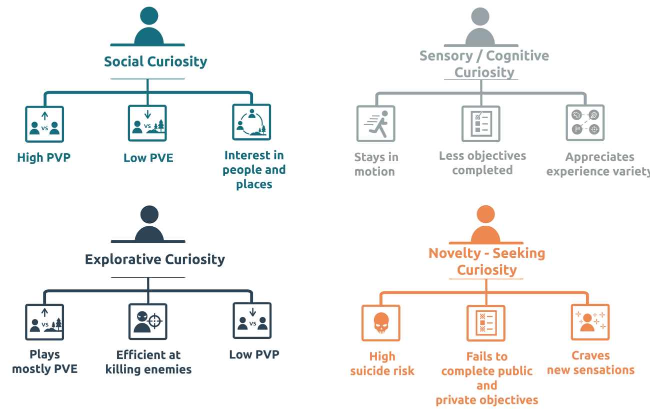

Figure 1. The four curiosity factors and their correlated game behaviours emerging from the Destiny dataset (reprinted from [43]).

a combined approach was used, where an initial set of behavioural metrics was selected based on related work and theory, and these metrics were then used to formulate a series of hypothesized correlations of curiosity factors. The correlations were then inspected in a range of related behaviours in Destiny that fit the curiosity factors. Furthermore, we included data from both gameplay options in *Destiny* (e.g., PvE and PvP play), and from across the spectrum of activities in the game, including rates of objective completion, performance, and exploration.

This process resulted in 42 variables that were used in the analysis process. Some of the metrics were specific to PvE (5) or PvP (15) game modes, though the majority were aggregates across these two modes (22), for example, the *Grimoire* score. For compactness, we summarize all behaviour metrics in the table in the supplementary material of this paper. The relevant table provides a short description of each metric, as well as the mean and standard deviation for each. To account for different play durations, certain variables were normalized as a function of time.

Data Cleaning and Filtering

To filter out survey participants who were answering without reading the questions, two validation questions were inserted into the survey asking participants to select specific answers. Discarding all incomplete entries and those with incorrect answers to the validation questions reduced the original set of 3,542 submissions to 1,745 valid survey responses.

Survey responses were deduplicated on a per-player-ID basis, retaining only the most recent entry for each set of duplicates. Subsequently, survey and behavioural data were matched based on player ID. Participants who had not entered a player ID at all or whose ID could not be matched to behavioural data were excluded. This cleaning procedure resulted in 1,267 unique entries, combining survey responses and behavioural metrics for each individual player.

In a final processing step, we removed outliers from the data set, following principles of Sifa et al. [49]. This was done by iterating over all 42 behaviour metrics and 60 survey items (i.e., 102 variables in total) and marking as outliers all values that were outside the 1st-99th percentile range. To limit the outlier removal process to a reasonable extent, variables which had more than 2.5% of the values in the aforementioned range were not included in the process. All entries containing at least one outlier value in any one of the 102 variables were discarded. This process resulted in 932 entries used for data analysis.

Correlations

After extracting the four self-report curiosity factors in the first step of our analysis, we examined the correlations between these and the 42 behavioural metrics.

Since all survey items were scored on Likert-type ordinal scales, we opted for Spearman's ρ as a non-parametric correlation coefficient. Given that each of the four extracted curiosity factors (F1-F4) was composed of survey items from just one instrument in each case, we adopted the scoring schemes from the corresponding 'parent' instrument. Consequently, no additional hybrid scoring scheme had to be created for our newly extracted curiosity subscales. Following the procedure described by Yee et al. [64], we used the analytic method developed by Sherman and Funder [46] to address the increased risk of experiment-wise error in large correlation tables. This technique answers whether the observed number of significant correlations in the data set is significantly higher than the number of correlations one would expect to find by chance.

RQ2: RESULTS

In the cross-correlation of behaviour metrics and self-report scores, we observed a total of 286 statistically significant correlations, ($p < .05$), where only 35 would be expected by chance [46]. Similarly, in the cross-correlation of all self-report scores, we observed 133 statistically significant correlations ($p < .05$), where only 7 would be expected by chance. The probabilities of these numbers of observed correlations were both $p < .001$, providing strong evidence that the observed correlations—as a whole—are not random.

Due to space limitations, we do not discuss every significant correlation in the following, but instead try to identify meaningful clusters of correlations and highlight particularly strong relationships. A complete listing of all correlations between curiosity factors and behaviour metrics is in Table 2.

Correlations among self-report scores

As expected, curiosity factors were not perfectly correlated, but were strongly positively correlated with the respective subscales from which they were extracted: SOCIAL CURIOSITY (F1) was strongly correlated with BRIDGING SOCIAL CAPITAL, $\rho(930) = .91$, $p < .001$, SENSORY/COGNITIVE CURIOSITY (F2) was strongly linked to the HARMONIOUS PASSION scale, $\rho(930) = .87$, $p < .001$, EXPLORATIVE CURIOSITY (F3) showed a strong relationship with the BRAINHEX SEEKER type, $\rho(930) = .85$, $p < .001$, and NOVELTY-SEEKING CURIOSITY strongly related to the BAS FUN-SEEKING scale, $\rho(930) = .84$, $p < .001$.

We found strong positive correlations between SOCIAL CURIOSITY and BONDING SOCIAL CAPITAL, $\rho(930) = .48$, $p < .001$, HARMONIOUS PASSION, $\rho(930) = .46$, $p < .001$, and the BRAINHEX SOCIALIZER type, $\rho(930) = .42$, $p < .001$. NOVELTY-SEEKING CURIOSITY was positively linked to BAS REWARD RESPONSIVENESS, $\rho(930) = .42$, $p < .001$. Correlations of the same directionality and of similar strength were found for the corresponding 'base' scales, BRIDGING SOCIAL CAPITAL and BAS FUN-SEEKING. These correlations are displayed in Table 3.

	Curiosity			
Behaviour Metric	CSoc	CSens	CExp	CNovS
Total				
Activities Entered	−.02	−.02	**−.07***	−.03
Objectives Compl.	**−.07***	**−.15*****	.00	**−.17*****
Resurr. Performed	**.08***	**.10****	−.02	**.08***
Resurr. Received	**.11*****	**.10****	−.04	**.13*****
Orbs Dropped	.04	.02	.05	−.01
Orbs Gathered	**.14*****	.05	−.03	.01
Kills Deaths Ratio	−.03	.00	**.12*****	−.05
Kills Deaths Assists	−.03	.00	**.11*****	−.05
Kills	−.05	−.01	**.11*****	**−.07***
Deaths	.01	−.02	**−.10****	.02
Assists	−.02	−.03	**−.08***	.01
Suicides	**.14*****	**.17*****	.03	**.14*****
Ability Kills	−.02	.00	**.09****	−.06
Precision Kills	−.03	.01	**.08***	−.05
Most Precision Kills	**.13*****	**.08****	**.06***	.06
Avg. Kill Distance	.01	−.04	.01	−.01
Max. Kill Distance	**.16*****	**.09****	.06	**.09****
Longest Kill Spree	**.09****	**.07***	**.13*****	.04
Avg. Lifespan	−.01	.02	**.10****	−.02
Longest Single Life	**.14*****	**.14*****	.02	**.10****
Grimoire Score	**.20*****	**.14*****	**.08***	.04
PvE Play Time Ratio	.00	.06	**.12*****	.02
PvE				
Activities Cleared	**−.12*****	**−.09****	**−.07***	.02
Court of Oryx Attempts	**−.09****	.01	.03	**−.07***
Court of Oryx Compl.	**−.08***	.01	.03	**−.07***
Public Events Joined	**−.09****	−.01	.05	**−.12*****
Public Events Compl.	**−.09****	−.02	.05	**−.12*****
PvP				
Activities Won	**.13*****	.05	.06	.03
Zones Captured	**−.10****	**−.12*****	.03	**−.10****
Zones Neutralized	**−.12*****	**−.12*****	−.04	**−.08***
Relics Captured	**.07***	.06	−.06	.04
Close Calls	−.01	.04	−.04	−.01
Defensive Kills	−.03	**−.12*****	.01	**−.09****
Domination Kills	−.03	**−.07***	.04	−.03
Offensive Kills	.00	−.05	.05	−.02
Avg. Score per Kill	−.06	.02	.03	−.05
Avg. Score per Life	−.02	.03	.03	−.04
Best Game Score	**.15*****	**.12*****	.04	.02
Combat Rating	.01	.00	.06	.01
Score	**.14*****	.05	−.02	−.01
Team Score	**.13*****	.03	−.03	−.03
Win Loss Ratio	**.08***	−.03	.03	−.04
Cronbach's α	.86	.67	.61	.50

Table 2. Correlations between behavioural metrics and self-report scores. Note: Spearman coefficients $p < .05$ are written in boldface. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. Abbreviations: CSoc = SOCIAL CURIOSITY; CSens = SENSORY/COGNITIVE CURIOSITY; CExp = EXPLORATIVE CURIOSITY; CNovS = NOVELTY-SEEKING CURIOSITY (reprinted from [43]).

	Curiosity				Social Capital		BAS		Passion		BrainHex						
	CSoc	CSens	CExp	CNovS	Bri	Bon	Rew	FunS	Obs	Har	Seek	Surv	Dare	Mast	Conq	Soc	Ach
Mean	13.2	10.2	1.4	6.3	34.9	28.2	17.4	12.0	14.1	24.1	1.9	1.0	2.0	2.0	1.9	0.3	1.7
St. Dev.	4.1	2.6	0.9	1.2	8.5	10.3	2.0	2.3	7.2	5.7	1.3	1.4	1.1	1.1	1.3	1.6	1.6
CBri	1.00																
CHar	**.43*****	1.00															
CSeek	**.24*****	**.26*****	1.00														
CNovS	**.25*****	**.25*****	**.19*****	1.00													
Bri	**.91*****	**.51*****	**.25*****	**.30*****	1.00												
Bon	**.48*****	**.31*****	**.10****	**.12*****	**.49*****	1.00											
Rew	**.23*****	**.32*****	**.16*****	**.42*****	**.31*****	**.19*****	1.00										
FunS	**.27*****	**.24*****	**.19*****	**.84*****	**.30*****	**.16*****	**.44*****	1.00									
Obs	**.23*****	**.33*****	**.11*****	**.10****	**.29*****	**.16*****	**.23*****	**.14*****	1.00								
Har	**.46*****	**.87*****	**.24*****	**.25*****	**.55*****	**.38*****	**.33*****	**.23*****	**.33*****	1.00							
Seek	**.28*****	**.29*****	**.85*****	**.22*****	**.28*****	**.11****	**.16*****	**.21*****	**.10****	**.28*****	1.00						
Surv	**.12*****	**.12*****	**.15*****	**.12*****	**.15*****	.02	**.17*****	**.12*****	**.08***	**.14*****	**.22*****	1.00					
Dare	**.16*****	**.21*****	**.30*****	**.27*****	**.20*****	**.12*****	**.23*****	**.27*****	**.17*****	**.21*****	**.31*****	**.20*****	1.00				
Mast	**.17*****	**.12*****	**.20*****	**.23*****	**.20*****	**.17*****	**.14*****	**.21*****	.05	**.13*****	**.19*****	**.13*****	**.25*****	1.00			
Conq	**.20*****	**.14*****	**.16*****	**.16*****	**.23*****	**.17*****	**.14*****	**.17*****	.00	**.14*****	**.15*****	**.10****	**.23*****	**.31*****	1.00		
Soc	**.42*****	**.30*****	**.26*****	**.23*****	**.47*****	**.28*****	**.18*****	**.25*****	**.11*****	**.31*****	**.32*****	**.19*****	**.26*****	**.21*****	**.23*****	1.00	
Ach	**.15*****	**.20*****	**.26*****	**.08***	**.20*****	**.13*****	**.17*****	**.09****	**.23*****	**.21*****	**.21*****	**.06***	**.19*****	**.19*****	**.11****	**.19*****	1.00
Cronbach's α	.86	.67	.61	.50	.90	.92	.69	.69	.86	.78	.60	.29	.19	.41	.35	.35	.58

Table 3. Descriptive statistics and cross-correlation of self-report scores. Spearman coefficients $p < .05$ are written in boldface. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. Abbreviations: CSoc = SOCIAL CURIOSITY; CSens = SENSORY/COGNITIVE CURIOSITY; CExp = EXPLORATIVE CURIOSITY; CNovS = NOVELTY-SEEKING CURIOSITY; Bri = BRIDGING SOCIAL CAPITAL; Bon = BONDING SOCIAL CAPITAL; Rew = BAS REWARD RESPONSIVENESS; FunS = BAS FUN-SEEKING; Obs = OBSESSIVE PASSION; Har = HARMONIOUS PASSION; Seek = BRAINHEX SEEKER; Surv = BRAINHEX SURVIVOR; Dare = BRAINHEX DAREDEVIL; Mast = BRAINHEX MASTERMIND; Conq = BRAINHEX CONQUEROR; Soc = BRAINHEX SOCIALIZER; Ach = BRAINHEX ACHIEVER (reprinted from [43]).

Curiosity subscale scores and behaviour metrics correlations

In the following, we highlight selected clusters of correlations between the curiosity factor scores and behavioural metrics. Results are grouped by the curiosity sub-scale.

SOCIAL CURIOSITY was positively linked to *Grimoire* score (strongest correlation among all curiosity factors, $\rho(930) = .20$, $p < .001$), the number of resurrections performed, the number received, the number of orbs gathered, and the overall score, team score, best game score, and win-loss ratio in the group of PvP performance metrics. It was also the only curiosity factor that was positively linked to the number of relics captured in the PvP game mode. Negative correlations were observed between SOCIAL CURIOSITY and the number of objectives completed, public events joined and completed, including *Court of Oryx* events, and the number of zones captured and cleared.

SENSORY/COGNITIVE CURIOSITY also showed positive correlations with *Grimoire* score, the number of resurrections performed, the number received, the longest single life, and the best game score. Inverse relationships were found between SENSORY/COGNITIVE CURIOSITY and the number of objectives completed, activities completed, zones captured and neutralized, and 'defensive' and 'domination' kills in the category of PvP metrics.

EXPLORATIVE CURIOSITY was positively correlated with the relative time spent in the PvE game mode, performance metrics such as kills/deaths ratio, number of kills, longest kill spree, and average lifespan. It was the only curiosity factor that did not show any significant correlations with the number of resurrections performed, the number received, or any other of the PvP metrics. Negative correlations were observed between EXPLORATIVE CURIOSITY and the number of activities entered, activities completed, deaths and assists.

NOVELTY-SEEKING CURIOSITY showed positive correlations with the number of resurrections performed, the number received, suicides committed, maximum kill distance, and longest single life. Negative correlations were observed between NOVELTY-SEEKING CURIOSITY and the number of objectives completed, the number of kills, and also with the number of public events joined and completed, including *Court of Oryx* events, the number of zones captured and neutralized, and 'defensive' kills in the PvP category. We found no other significant correlations between this curiosity factor and any of the other behaviour metrics.

Predicting Self-Reports from Behaviour

RQ2 asks how well self-reports of 'curiosity' and associated player motivations and preferences can be inferred from observing player behaviour in the game world. Our main objective was thus not to describe the influence of individual predictor variables but instead to evaluate how well motivational profiles could be inferred from in-game behaviour. To this end, we adapted the procedure from Yee et al. [64] and conducted multiple regressions, one for each of the curiosity factors. For each factor, we selected the 20 strongest behavioural indicators, using these as predictor variables to infer the self-report score. We again split the report of our regression results into the four curiosity factors. For replicability, we classify effect sizes according to Yee et al. [64], who follow Cohen's notion that an R of .30 is a medium effect, while an R of .10 is a small effect [9].

Curiosity Factor	R	Adj. R^2	STE	F	p
Social	.32	.08	3.93	4.96	<.001
Sensory/Cognitive	.26	.05	2.54	3.30	<.001
Explorative	.24	.04	0.88	2.91	<.001
Novelty-Seeking	.26	.05	1.15	3.28	<.001

Table 4. Multiple regressions on the CURIOSITY factors (reprinted from [43]).

The results for the regression models of the four curiosity factors are shown in Table 4 (including R, adjusted R^2, residual standard errors (STE), F values, and p values). All of the multiple regressions yielded results deemed significant, suggesting that behaviour metrics can indeed be used to construct statistically significant models for inferring curiosity. The model for SOCIAL CURIOSITY had a 'medium' effect, while the other three models had 'close-to-medium' effects.

DISCUSSION

We matched self-reports of player motivation and preferences with a detailed set of behavioural observations for 932 individual players as identified by their player IDs (after outlier removal). Compared to previous work examining how in-game behaviour correlates with player personality or motivation as a whole, the present study contributes a building block toward a new operationalization of player curiosity (indeed, of various specified aspects of player curiosity) by constructing a scale based on reliable psychometric measures.

Expression of Curiosity in Games. The four factors emerging from our factor analysis reflect distinct aspects of game-related curiosity. SOCIAL CURIOSITY (F1) asks about the degree to which social interaction with other players in the game leads to curiosity about people unlike oneself, as well as new activities and places in the real world. In contrast, SENSORY/COGNITIVE CURIOSITY (F2) relates to the internal world of the game and assesses how strongly a player associates experience variety with game appreciation. EXPLORATIVE CURIOSITY (F3) measures individual differences in attitudes toward exploring the game world. Finally, NOVELTY-SEEKING CURIOSITY (F4) identifies the degree to which behavioural activation is induced by the motive of novelty-seeking.

Correlating our self-reported factors of curiosity many behaviour metrics, we identified meaningful behavioural correlates for many of these constructs (RQ2). The exploration of these results will be grouped by the curiosity subscale.

SOCIAL CURIOSITY was significantly positively correlated with measures logically expected to increase when playing with other players, such as resurrections performed, resurrections received, and orbs gathered. It was also the factor which displayed the most positive significant correlations with measures of performance in the PvP game mode, such as activities won, win/loss ratio, game score, highest game score, and team score. Conversely, negative correlations observed between social curiosity and every PvE behaviour metric, from number of objectives completed to public events completed indicated a lower interest in activities that take place in heavily single-player game modes. Furthermore, players high in social curiosity also displayed a propensity for having longer maximum kill distances, single life duration, and better *Grimoire* scores overall. This pattern of results may have been generated because an inclination toward social curiosity leads to more time spent in PvP and therefore more practice with a harder game mode. This in turn may lead to more opportunities to raise *Grimoire* scores in PvP. Designers of such shared-world games seeking to attract the patronage of players motivated by social curiosity should thus focus on enhancing opportunities for text and speech communication between players.

SENSORY/COGNITIVE CURIOSITY was significantly negatively correlated with many measures of performance in PvP, a game mode which frequently involves staying in one place to defend zones, while the opposition does not have far to move in their attempts to capture zones. These negatively correlated measures included zones captured, zones neutralized, and defensive kills. This may be because positive associations between variety and fun may lead these players to move around the map more during PvP games, leading to more 'best game scores' and correspondingly less time spent on geographically fixed objectives. Players motivated by sensory/cognitive curiosity also displayed significant positive correlation with longest single life, and significant negative correlation with objectives completed. These two results may be because variety-seeking distracts from objective completion, inadvertently leading to longer lives because activities are left before their relatively more difficult denouements. Game designers catering towards players motivated by this curiosity factor should consider game modes which favour fast movement and require less strategy, while at the same time providing regular opportunities for new activities.

EXPLORATIVE CURIOSITY was reflected in higher ratios of play time spent in the PvE game mode, which facilitates an exploration-driven playing style. Players driven by explorative curiosity also displayed significant positive correlations with measures of combat efficiency such as kills to deaths ratio, kills/deaths assists, longest kill spree, and total kills. This may be because a preference for exploring new areas may lead to more encounters with enemies and therefore more experience with, and chances to, kill enemies. Being the only curiosity factor not significantly correlated with PvP metrics or with the use of resurrections indicates a lower level of interaction with other players, potentially positioning players driven by explorative curiosity as opposite to those motivated by social curiosity. Designers seeking to cater to explorative players should design large game worlds which hide the content of unexplored areas as far as possible. Providing significant rewards for explorative behaviour in new areas would enhance the experience of these players. Lower interest in other players displayed by gamers driven by explorative curiosity could inform the design of privacy settings, allowing players more options in their interactions with other players.

NOVELTY-SEEKING CURIOSITY was significantly positively correlated with suicides and resurrections received which may mean that seeking novelty leads to an increased danger of accidental deaths, in turn necessitating a higher rate of resurrections. A belief that novelty is related to fun may also result in a player joining and completing fewer public events, as well as completing fewer objectives. This may be because seeking novelty distracts from the fixity of completing objectives. Games designed to cater to these players should concentrate on shorter and more varied objectives as well as environments which are highly differentiated and distinctive.

Player Motivations Related to Curiosity. We also showed that statistically significant regression models can be constructed for each of the four factors of self-reported curiosity we investigated, suggesting that nuanced profiles of curiosity and associated player motivations and preferences can be inferred merely from observing a player's behaviour in the *Destiny* game world (RQ2). This is particularly useful for the construction of implicit user models incorporating curiosity-related motivation. Being able to infer such profiles of curiosity and associated motivation implicitly from behaviour logs has direct relevance not only to games, but HCI research as a whole, taking into account the field's long-standing interest in personalization and interface customization [15, 31].

Design Implications. Our findings suggest ways in which designers of interactive systems can cater to different aspects of curiosity. One could match mission rewards to correlated game behaviours, matching the primary curiosity profile of the user. For example, by offering a player-interaction animation as a reward to a SOCIAL CURIOSITY player and PvE gear to EXPLORATIVE CURIOSITY players. Moreover, the insight that 'completionist' attitudes show a resemblance to curiosity—with a few decisive differences—in how they manifest in digital gaming behaviour, implies that design decisions should be made with care to ensure the system matches the intended user preferences. In addition to interface customization, the ability to infer motivational profiles (without the need for time-consuming self-reporting measures) lends itself to the enhancement of team matching and recommender systems by inserting these profiles into the calculation of similarity between users.

While we focus on game-related curiosity in this work, we note that being able to measure different aspects of curiosity through behaviour data would afford a wealth of applications to designers of interactive systems of many different types. Novelty-seeking on shopping websites, social curiosity on dating platforms and social network sites, or cognitive and sensory curiosity on music and movie streaming services, are a few examples of different curiosity types that could be leveraged in non-gaming contexts.

Limitations and Future Research Directions

There are three main limitations to our study. First, we only collected data from one game, which limits generalizability and applicability of our results to other games and genres. However, many multiplayer games do feature a combination of competitive and cooperative actions in a shared world with the possibility of various rewards upon completion.

Second, while the correlation coefficients between behaviour metrics and self-reports may appear low at $\rho = .34$, statistically significant yet low effect sizes are not uncommon in correlational studies with large sample sizes involving psychological factors. Our correlation coefficients are not strikingly different from those found in previous work—some published at CHI—with similar research parameters [62, 64].

Third, we are aware that players experience and express multiple types of curiosity in a single play session. The low correlation in some parts of this study may be due to this multiplicity. These natural cycles in player emotion and engagement may correlate with the different activities we describe. Investigating temporal patterns in how profiles of player motivation and personality evolve over time would be a worthy research goal for future work. Unfortunately, our dataset did not allow us to obtain further insights on temporal patterns because all metrics were cumulative values, aggregated over the entire lifetime of a user account.

Other future research directions may address the limitations of cross-sectional approaches, which do not permit conclusions about the causality of the observed relationships between variables. For example, based on our results, we do not know whether explorative behaviour leads to strong performance in the game, or if strong performance is an outcome more likely to coincide with curiosity-driven exploration.

CONCLUSION

Our findings provide important empirical evidence of the differing aspects of curiosity that motivate the video game play in our chosen game. Additionally, we would argue that the robustness of our methodology represents a solid foundation for assessing self-reported measures of curiosity, which in turn may facilitate yet more granular player experience research in the future. In particular, we were able to predict all four curiosity factors from behaviour metrics. This points the way to a promising opportunity for game designers seeking to improve team-matching and recommender systems. It also opens up potentially very fruitful avenues for research into player well-being. Perhaps most significantly, our findings suggest a breadth of applicability. Curiosity, after all, is not a factor just in the playing of cooperative video games. It could be justly regarded as one of the core motivations animating people's online experiences as a whole. The ability to measure it, as we suggest we have been able to do in this paper, differentially and in a more detailed fashion than achieved thus far, might be leveraged in a host of non-game settings, including commercial and social websites.

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