Ethereum Crypto-Games: Mechanics, Prevalence and Gambling Similarities

Oliver James Scholten
University of York
York, UK
ojs524@york.ac.uk

Nathan Gerard Jayy Hughes
University of York
York, UK
sch538@york.ac.uk

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

Anders Drachen
University of York
York, UK
anders.drachen@york.ac.uk

James Alfred Walker
University of York
York, UK
james.walker@york.ac.uk

David Zendle
York St. John University
York, UK
d.zendle@yorksj.ac.uk

ABSTRACT
Ethereum crypto-games are a booming and relatively unexplored area of the games industry. While there is no consensus definition yet, 'crypto-games' commonly denotes games that store tokens, e.g. in-game items, on a distributed ledger atop a cryptocurrency network. This enables the trading of game items for cryptocurrency, which can then be exchanged for regular currency. Together with their chance-based mechanics, this makes crypto-games part of the recent convergence of digital gaming and gambling. In a first effort to scope the field, this paper surveys popular crypto-games, which use the Ethereum cryptocurrency, to tease out characteristic technical properties and gameplay. It then compares the games' features with criteria found in current legal and psychological definitions of gambling. We find that the popular crypto-games selected meet a combined legal and psychological definition of gambling, and conclude with ramifications for future research.

CCS Concepts
•**Applied computing** → *Electronic data interchange;*

Author Keywords
Distributed ledger; Ethereum; crypto-games; gambling; regulation; blockchain gaming

INTRODUCTION
Crypto-games are video games with a fully or partially distributed ledger architecture that operate atop a cryptocurrency network, giving players provable ownership over the virtual goods they contain. This also allows players to exchange virtual goods for cryptocurrency, which in turn can be exchanged into real currency. Crypto-games are thus an instance of *real-money gaming* [26] and, due to their chance-based mechanics, of the recent convergence of gaming and gambling [12, 20]. Similar phenomena, like loot boxes, or gacha games, have drawn the attention of regulators, whose concerns regard whether they pose risks similar to gambling and therefore require similar regulation [22]. Interestingly, this discussion has not yet reached crypto-games.

Examples of crypto-games include *CryptoKitties* and *Gods Unchained*, whose gameplay involves using these virtual goods to complete in-game objectives. They are growing in player popularity, with *CryptoKitties* generating over £26 million in sales since its creation in the last two years[1]. Perhaps more importantly, crypto-games draw enormous attention in the games industry, with events like the *Crypto Games Conference* attracting 1,500 delegates in 2019 [2]. In March 2019, the blockchain gaming startup Forte announced an investment of US$100 million to fund blockchain game development [3].

Despite the growing player popularity and industry interest in crypto-games, research on them has been limited. In this paper, we therefore provide an overview of current crypto-games, drawing on a sample of popular games on the Ethereum cryptocurrency. We begin by introducing distributed ledgers, blockchains, and cryptocurrencies, discussing some advantages and trade-offs of such decentralised architectures for games, followed by the contested distinction between gaming and gambling with respect to the underlying technology of crypto-games. We then describe the gameplay and mechanics of current crypto-games. Finally, we compare crypto-games to psychological and legal definitions of gambling to assess to what extent they warrant deeper scrutiny by player researchers and legal scholars. This will also assist designers in the de-

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

ACM ISBN 978-1-4503-6688-5/19/10.
https://doi.org/10.1145/3311350.3347178

[1] See developer website: https://www.dapperlabs.com/, accessed 05/07/2019.
[2] See event page: https://cryptogames.events, accessed 05/07/2019.
[3] See https://venturebeat.com/2019/03/12/forte-and-ripple-form-100-million-fund-for-mainstream-blockchain-games, accessed 05/07/2019.

Term	Definition
Distributed ledger	A system for recording and synchronising data across multiple identical copies at separate sites
Blockchain	One implementation of distributed ledgers storing records in a sequence of linked blocks
Blockchain gaming	Umbrella term for the use of distributed ledger technologies in digital games and gambling
Cryptocurrency	A decentralised digital currency using a distributed ledger to record and prove ownership
Crypto-game	A game whose in-game tokens are stored on a distributed ledger atop a cryptocurrency network
DApp	A decentralised application with code and data stored on a distributed ledger
Digital wallet	An alphanumeric key pair used to verify transactions on cryptocurrency networks
Ether (ETH)	The token used to 'purchase' compute power on the Ethereum network
Ethereum	A popular cryptocurrency network that can support DApps
Ethereum crypto-game	A crypto-game running as a DApp on the Ethereum cryptocurrency network
Gacha game	A game where players purchase 'lucky draws' to acquire virtual items of different rarities [22]
iGaming	Short hand for internet gambling e.g. online poker, roulette, etc.
Loot Box	Items in video games purchased with real-money which contain randomised contents [36].
Standard game	Any game not using distributed ledger technologies, for example *Hearthstone*, *Fortnite*, etc.

Table 1. Definitions of terms used throughout this paper.

velopment of crypto-games that don't replicate gambling services.

BACKGROUND

Distributed Ledger Technologies

In broadest terms, the technology underlying crypto-games are *distributed ledgers*. Distributed ledgers are identical copies of files recording transactions that are stored across several sites and kept aligned through a consensus mechanism [3]. Take a network game where players can trade virtual gold for virtual swords. The ownership of any virtual item must be recorded somewhere to ensure persistence of the item within the game. Traditionally, game provider C may store this information on their own central game server. When player A sells a sword to player B in-game, this triggers a request from player A's client computer to game provider C's server to update the sword's ownership entry in its database. Game provider C's server database here is a *central ledger* - a single authoritative record of transactions. While central ledgers can be efficient, they also constitute a single point of failure, and they require every player to trust the entity controlling them. If a network glitch corrupts the transfer of a transaction to the server, or a hacker manipulates its database, or the game provider decides one morning to wipe all swords off the in-game world, the players would lose their virtual swords. With a distributed ledger, all nodes of the network - here, players A, B, and game provider C - keep an identical copy of the ledger. Every time someone issues a change to the ledger, e.g. sells a sword to someone else, one or several nodes of the network then process this transaction and use some consensus mechanism among all nodes to establish the new correct entry, which is then copied onto all ledgers. Thus, participants don't have to trust any single node to not lose or corrupt or manipulate the ledger.

A popular distributed ledger technology is a *blockchain*, where the ledger is organised in a sequence of blocks of entries, and each block includes an encoded or cryptographic representation (a so-called 'hash') of all prior blocks. Hashes are unique - any set of encoded data will generate one and the same unique hash - and can be easily automatically verified. Thus, they ensure that none of the previously recorded blocks have be tampered with.

While there are many use cases for distributed ledgers, the most well-known application are *cryptocurrencies*, digital currencies that use a cryptographically secured distributed ledger like a blockchain [24]. Like distributed ledger technology more generally, cryptocurrencies have seen several waves of interest in recent years [17], with a combined market capitalisation of over US$130 billion as of March 22, 2019[4]. This value is especially noteworthy given state limitations on the exchange of cryptocurrencies into real currencies, with some nation states outright banning their exchange [19]. Although Bitcoin, the 'flag bearer' of cryptocurrencies, frequently experiences large fluctuations in price, the overall market of cryptocurrencies has grown approximately 620% in the last 3 years[4]. Bitcoin popularised the consensus mechanism of *proof of work*: to earn the right to add a new transaction to the block chain, as part of the transaction entry, nodes have to solve complicated mathematical puzzles that take a lot of computing time to solve but are again quick to verify. This prevents people from spamming the distributed ledger with entries. In Bitcoin and many other cryptocurrencies, the computing cost for generating such a new entry is rewarded with new Bitcoin that the system 'drops' at a random rate. Participating in the distributed ledger network is thus financially rewarded.

Next to cryptocurrencies, the second popular type of distributed ledger use case are *Decentralised Applications* (DApps) [33]. These are software applications whose data and processes are stored on a distributed ledger. The actual processing of the application code happens across the network of computers running the DApp in question. Most DApps operate on a cryptocurrency network which rewards nodes for running the application with small amounts of cryptocurrency. Again, this decentralised architecture means in principle that the DApp is not dependent on the functioning or trustworthiness of any particular node[5].

[4]See https://coinmarketcap.com/ for valuations, accessed 22/03/2019.

[5]For an accessible primer on these technologies, see [29].

Distributed Ledger Technologies in Games

The ongoing media and investment attention around distributed ledger technologies has led game developers to explore their potential for gaming and gambling, especially online gambling (also called *iGaming*). A recent empirical survey found that games constitute the single largest category of DApps, making up 47% of all DApps recorded [33]. The crypto-game *CryptoKitties* is currently the third largest DApp by number of transactions [33].

Industry observers hasten to emphasise that we are in the early days of exploring the intersection of distributed ledger technologies and games[6]. A substantial portion of current industry and, where existing, academic discourse is engaging in speculative conceptualisation of opportunities (see [10] for one example). This nascent state is reflected in the lack of defined terminology. Terms like 'blockchain gaming' or 'crypto-games' are used interchangeably without much clarity over what they refer to. For our purposes, we will here use the term '*blockchain gaming*' to refer to *any use of distributed ledger technologies like blockchains or cryptocurrencies in digital gaming and gambling*.

Given the speculative nature of the present discourse, we will in the following focus on one particular subset of blockchain gaming that has seen actual technical implementations and player uptake, namely games that are DApps built atop the Ethereum cryptocurrency. In the following, we will use the term '*crypto-games*' to refer to *games whose allocation of in-game tokens is stored on a distributed ledger atop a cryptocurrency network*, and '*Ethereum crypto-games*' to refer to *crypto-games that are DApps running on the Ethereum cryptocurrency*. Again, we emphasise that crypto-games in general and Ethereum crypto-games in particular may be the currently dominant form of distributed ledger technologies applied to games, but present only one possible instantiation.

Gaming and Gambling

Gambling and gaming have been traditionally considered as distinct activities supported by distinct kinds of games. However, with the rise of so-called free-to-play and service games, traditional 'gaming' games are increasingly integrating ongoing real money payments for in-game items, which have more recently been connected with chance-based mechanics. Real-money exchange and chance are the two traditionally defining features of gambling games [37]. Examples of this convergence of gaming and gambling include gacha games [22] and loot boxes [37]. Where gacha games may be described as a game where players purchase 'lucky draws' to acquire virtual items of different rarities, and loot boxes are items in video games purchased with real money which contain randomised contents, as in Table 1. These have raised concerns whether games integrating mechanics like loot boxes might carry the same potentially adverse psychological effects as gambling games, and therefore, whether they should be regulated alike [7].

Whilst some analysts find that e.g. loot boxes meet psychological definitions of gambling [7], national regulators differ in their classification [22] [31]. Notably, psychological and legal definitions focus on different aspects; the financial value of winnings in the legal instance, versus the nature of the activity itself in the psychological instance. For this reason, authors like Macey have called for more research on these topics in the context of video games [27].

On the surface, crypto-games share many similarities with free-to-play games that have come under scrutiny. Specifically, both involve virtual currency that can be purchased with real currency. Psychologically, both free-to-play games and crypto-games virtual currencies often compound what has been called the numerosity effect [18], where multiple currencies and uncommonly divisible quantities prevent players from making intuitive value estimations. This may lead to players spending more than intended given the obfuscation of real world value [18]. For example, in a free-to-play game, one in-game apple may cost 7 gems (an in-game currency). 40 gems may cost 0.155 coins (another in-game currency), and one coin costs £250. In this instance, calculating the cost of one in-game apple in real currency becomes non-trivial [7]. In crypto-games, in-game items and activities have similar fractional cryptocurrency costs, with one unit of a given cryptocurrency typically having a non-intuitive and fluctuating real money exchange rate.

Despite this and other similarities between crypto-games and other forms of video-gaming that approach gambling, to our knowledge, there has been no analysis as to whether crypto-games meet current definitions of gambling. Therefore, following descriptions of Ethereum crypto-games and their mechanics in the following section, we present and combine gambling definitions to assess whether the Ethereum crypto-games sampled meet gambling criteria.

ETHEREUM CRYPTO-GAMES

With technical and definitional underpinnings considered, we now continue to describe current Ethereum crypto-games in their technical properties, gameplay, and mechanics. We base our description on a sample of the nine highest-ranked Ethereum DApp games listed on 'State of the Dapps', a website ranking DApps according to user numbers, transaction volume, developer activity, and user activity [8]. We chose 'State of the Dapps' as it is recognised as the leading public directory of DApps [33], which currently records seven DApp platforms, Ethereum, EOS, Steem, POA, xDai, Loom, and GoChain. We decided to limit our sample to Ethereum as it is the oldest DApp-supporting cryptocurrency and the most established as measured by market capitalisation, according to data of the popular multi-digital currency platform Coinbase[9]. Our sample of Ethereum crypto-games, presented in Table 2, is based on the top-ranked games on 'State of the Dapps' on March 6, 2019. As cryptocurrency valuations and user and developer statistics fluctuate, the 'State of the Dapps' ranking

[6] See https://venturebeat.com/2019/05/03/the-deanbeat-why-the-smart-kids-are-moving-into-blockchain-games/ and https://venturebeat.com/2018/04/05/gamesbeat-summit-2018-working-on-the-block-chain-gang/, accessed 05/07/2019.

[7] One apple = £6.78.

[8] See https://www.stateofthedapps.com/rankings/platform/ethereum/category/games, accessed 05/07/2019

[9] See https://www.coinbase.com/, accessed 05/07/2019.

	30 Day Transaction Statistics				Criteria Fulfilled				
Name	Accounts	Vol (ETH)	Vol (GBP)	GBP/Account	1	2	3	4	5
CryptoKitties	2,749	1,331.895	139,023.20	50.57	✓	✓	✓	✓	✓
MyCryptoHeroes	4,208	4,256.066	444,248.17	105.57	✓	✓	✓	✓	✓
HyperDragons	882	481.977	50,308.76	57.04	✓	✓	✓	✓	✓
Gods Unchained	914	1,228.185	128,197.95	140.26	✓	✓	✓	✓	✓
0xUniverse	1,366	720.428	75,198.27	55.05	✓	✓	✓	✓	✓
Evolution Land	140	106.236	11,088.91	79.21	✓	✓	✓	✓	✓
Axie Infinity	625	1,072.305	111,927.20	179.08	✓	✓	✓	✓	✓
Ethermon	876	54.209	5,658.34	6.44	✓	✓	✓	✓	✓
Blockchain Cuties	1,501	81.267	8,482.02	5.65	✓	✓	✓	✓	✓
Average	1,474	1,036.951	108,236.98	75.43	-	-	-	-	-

Table 2. Sample of popular Ethereum crypto-games covered in this paper. For each, we report (a) the number of active user accounts, trading volume in Ethereum (ETH) and Great British Pounds (GBP), and average spend per account in GBP over the past 30 days on the sampling date of March 6, 2019. We also report (b) which gambling criteria each game matches.

itself shows fluctuation. However, over the period of several months, we found our sample to be consistently in the top 20. On the date of sampling, the price of 1 Ether (the Ethereum cryptocurrency) was £104.38 per unit. When reporting monetary statistics as follows, this exchange rate has been used to convert values into real-world terms.

The average crypto-game in our sample has 1,474 active accounts, ranging from 140 to 4,208, with a mean transaction volume of £103,236.98 in the last 30 days. The mean transaction volume per account, per 30 days, comes to £75.43[10]. By comparison, the top 20 games on the game platform Steam in 2017 had between 500,000 and and 28 million owners, with a top-heavy distribution: the *median* for owners per game on Steam is 9,500, the median for so-called independent games is 5,000[11]. Add to this that Steam is only one of several marketplaces through which a given game is usually published, and you arrive at the assessment that in terms of player numbers, crypto-games are at most on par with typical independent games.

Technical Properties

By definition, all sampled Ethereum crypto-games are DApps that run on the Ethereum cryptocurrency. All sampled games involve a *digital wallet* - briefly, a piece of software that allows individuals to make electronic transactions on a network like a cryptocurrency. The wallet holds a public-private pair of cryptographic keys that serve as an address for sending and receiving transactions, and as a test to authenticate - much like an email-password combination where anyone can send emails to the public email address (public key), but only someone with the password (private key) can send emails from this address [2, 3, 28]. Unlike regular bank accounts, a wallet with a public-private key pair in principle requires no personal identifying information to set up, which provides a degree of anonymity that makes tracing accounts back to individuals problematic, but also means that once a person loses or loses control over their key pair, there is no principled way to retrieve it [13].

Once a player has created a digital wallet, cryptocurrency exchanges allow them to spend real currency to purchase cryptocurrency from other network users, which is then associated with the player's public key. Players can then spend this cryptocurrency to purchase in-game items like virtual goods or upgrades – much like many free-to-play games allow players to purchase an in-game currency like gold or gems which they can then spend on in-game items. As in many online games, crypto-games allow players to trade or auction such in-game items in exchange for in-game currency. Unlike most free-to-play games, in crypto-games, the in-game currency is often exchangeable and can be used to pay for other goods and services outside gameplay, and can be exchanged back for real currency.

Like the cryptocurrency itself, the ownership of in-game items is recorded on the game's distributed ledger, meaning that no single unilateral hack, glitch, or action on one database can tamper with them. Furthermore, not only the game item's ownership data, but all game data and code exists as a DApp stored on a distributed ledger with copies running on each machine that runs the game. Every action in the game – every game state change, such as a transaction between players – therefore requires *some* machine which is part of the underlying network to execute the DApp code, and generate a new entry in the game's distributed ledger to record the resulting game state change. This is then verified through consensus and copied onto the ledgers on all other machines. Since this processing consumes computational resources, Ethereum crypto-games games incentivize participation by charging a fractional amount of cryptocurrency (here: ETH) for each game action, some or all of which is then distributed back to the addresses of the owners of the machines that run the game code.

All of the sampled crypto-games are browser games with an HTML web interface and recommended browser extensions to

[10] When calculated independently, then averaged.

[11] See https://www.gdcvault.com/play/1025472/Steam-in-2017-State-of, accessed 05/07/2019.

embed the player's digital wallet. Players are also free to use a non-integrated wallet to initiate transactions manually, should their local state limitations allow. Several of the games also integrate direct links to cryptocurrency exchanges into their interface to streamline the process of transferring real-world currency into the player's digital wallet.

Gameplay

The gameplay of *CryptoKitties* revolves around trading and breeding virtual cats. Players buy new cats from the game's market, or trade and auction cats among one another, all with Ethereum. Players also breed or create new cats by either mating two cats they own or mating a cat they own with a public cat. Depending on which cats are mated with one another, a new cat is produced with different properties, each with different rarities. These rarities are most comparable to attributes of cards found in trading card games. Owned kittens can serve to complete collections that unlock further rewards, but the main player aim suggested by the game's website are to simply collect cats, discover new cats, or breed and trade cats for a profit.

MyCryptoHeroes focuses on building teams of heroes to embark on quests, each costing a fee based on quality and likelihood of higher-rarity loot gathered. Gameplay involves choosing and modifying the team composition of a collection of heroes, then choosing missions to attempt, each of which costing an amount of 'energy' per team member to complete. This is currently the most popular crypto-game available with over £100,000 in weekly trading volume - see Table 2 for 30-day figure. Following the fictitious example of the numerosity effect in the introduction: *MyCryptoHeroes* uses *Crypto Energy* as one in-game currency, which can be purchased with *GUM*, another in-game currency, which can be purchased with Ether.

Gods Unchained can be described as the most unique in the selection, as it is a trading card game following a similar art style and gameplay as Blizzard's *Hearthstone* [1]. It does not include an intermediate currency for its virtual cards, and offers less idle-style gameplay than other titles presented. As in *Hearthstone*, players can create decks of virtual cards then combat each other in a turn-based style.

Given the similarities of several crypto-games in the ranking, we finally outline *Evolution Land*, which can be described as a peer-to-peer virtual land marketplace, where users manage virtual plots of land in one of several unique areas. Gameplay involves trading and modelling of these plots of land, with certain areas in higher demand given their central location on the map or other desirable characteristics.

The remaining crypto-games in Table 2 can be described as variations or combinations of the above gameplay elements so are not individually described. This can be confirmed individually through each of the games websites and promotional content as described in the previous subsection.

Mechanics

This section explores prevalent mechanics in the sampled crypto-games.

Generating Virtual Goods

The generation of new virtual goods is key to creating enjoyable virtual economies in video games, this is comprehensively discussed by Lehdonvirta and Castronova [26]. Several of the crypto-games in Table 2 use breeding mechanics to achieve this generation whereby two existing goods can be combined to create a third. The breeding mechanics found in *CryptoKitties*, *HyperDragons*, *Axie Infinity*, and *Blockchain Cuties* all feature some chance mechanic, such that the desirable traits carried over to the next generation cannot be specified, making repeated attempts essential in long term play. In these examples, the value of the resulting virtual creature is variable, as successful breeding may result in a more (or less) desirable trait set meaning an overall increase (or decrease) in the value of the player's collection (if the value of their digital wallet is included). Parallels can be drawn here with the chance based mechanics found in loot boxes/gacha games [22], which echo similar variability in outcome. This aligns with consensus in the virtual economics literature that, generally speaking, rarity implies value; the more difficult an item is to create, the more valuable it becomes [26]. This means that although the chances of creating rarer, more valuable virtual goods are lower than more common goods, there is still an incentive to make these repeated attempts.

Multiplayer Gameplay

Multiplayer mechanics in the form of direct interactions between players specific to completion of in-game objectives are commonly found in standard games, especially those in the battle royale genre [5] such as *Apex Legends* [30] and *Fortnite* [8]. We may infer that crypto-games suit particular genres of game more than others. For example, single-player games are non-existent in the selection given the non-equivalence of the virtual goods they contain - it would therefore be fruitless decentralising their storage to facilitate player ownership. The multiplayer components of the games presented here also vary in terms of the depth of their effect on gameplay. Polarised examples include *CryptoKitties*, where user-user interaction occurs solely in the marketplace, and *Gods Unchained*, where players directly compete with one another in turn-based combat. The first example varies significantly from comparative standard games like *Hearthstone*[12], in that the game relies only on the attributes of the virtual goods in the player's collection. The second example contains an element of skill in the form of player interactions with their card deck and their opponent, so sits closer to the type of direct multiplayer interaction found in standard games.

Micro-transactions

As mentioned previously, the decentralised nature of crypto-games means each in-game action incurs a cost specific to the design of the game in question. This manifests in the form of micro-transactions in either the underlying cryptocurrency, or in some sub-currency which can be purchased with the underlying cryptocurrency. Examples include *CryptoKitties* breeding mechanic where the player may combine two kitties for a set amount of Ether, and *MyCryptoHeroes* mission mechanic, where the player may send their team on a mission for

[12]Gameplay in *Hearthstone* has a card collection element, it is this element with which we draw comparisons.

Crypto Energy. These two examples are typical of costs baked into the design of the games themselves, where in-game activities require a *usually small* monetary investment. It should be noted that this monetary investment may go completely to those operating machines which process the underlying network's transactions, or some may go to the developers of the crypto-game in question. This decision is made at the game design level and varies between those in the selection. For the crypto-games described in this work, a portion must always go to those verifying transactions on the Ethereum network.

Trading Virtual Goods

The final mechanic underpinning all of the games selected is the trading of virtual goods on an in-game marketplace. Players, through completing in-game activities, may receive generated virtual goods as described above which can then be sold for cryptocurrency or in-game currency. Each game in Table 2 includes its own marketplace operating limit-order mechanisms, i.e. players issue sell orders for goods at a set price, and upon creation of an equivalent buy order both are resolved and the goods are transferred. These marketplaces are freely accessible to all players, with no restrictions on the number of virtual goods a player may purchase, other than the funds available in their digital wallet. The transaction costs inherent to the Ethereum network, as described in the 'Technical Properties' subsection, also apply to each of the transactions in the marketplace(s) of these games.

CRYPTO-GAMES AND GAMBLING

This section introduces the psychological and legal definitions of gambling, and key differences in their application to game mechanics and crypto-games. Existing definitions are then combined, yielding a single set of criteria whose application distinguishes typical risk taking activities in such games from gambling. We then apply these combined criteria to our sample of crypto-games, discussing their interpretation from both legal and psychological perspectives as appropriate. Recent work on loot boxes and gacha games, as defined in Table 1, are included as naturally parallel discussion points between these currently distinct topics.

Definitions of Gambling

The psychological and legal definitions of gambling each focus on different aspects of chance based games. In the psychological case, the emphasis lies on the behaviour enabled by the activity, whereas the legal definition focuses on the financial components of outcomes.

Furthermore, both definitions are subject to interpretation so may yield opposing conclusions in their application to video games, as discussed in the following section. We begin by describing historically influential definitions of gambling, with recent additions specific to mechanics found in video games.

Psychological Definitions

Psychological interest in gambling typically concerns the ability of an activity to influence behaviours such as spending and frequency of participation [9, 27]. These activities require differentiation from simple risk-taking or chance-based play, in that *some* may foster potentially adverse behaviours [4]. To this end, Griffiths developed four criteria to distinguish gambling from simple risk-taking behaviours [15], revised from his seminal work on gambling classification [14][13]. These revised criteria are as follows;

1. The exchange is determined by the outcome of a future event, which is unknown at the time of betting
2. The outcome of the future event is at least partly due to chance
3. An exchange of money/objects of financial value occurs, typically without productive work from either side
4. Losses can be avoided by not taking part in the activity

These four criteria naturally fit traditional casino games. Take roulette as an example: A player must place bets on where the roulette ball will land, without knowing where it will land (1). The landing position of the ball is due to chance (2). A player places bets with chips exchangeable for money, and loses or gains chips based on the ball's landing position, with no further work involved (3). Finally, the player would not lose money if they were to not play (4). As expected, roulette meets this psychological definition of gambling as it fulfils all four criteria.

Griffiths' criteria have been usefully applied outside of traditional casino games. Specifically, Drummond and Sauer have used them to assess whether loot boxes are psychologically akin to gambling [7]. In trying to distinguish gambling-like from non-gambling like mechanics, Drummond and Sauer retained Griffith's original fifth criterion (winners gain at the expense of losers) and found it necessary to add a sixth criterion, namely the ability to 'cash out' winnings. In this, they followed the legal definition of gambling used by regulatory bodies (see below). Applying these six criteria, Drummond and Sauer [7] concluded that loot boxes in several popular video games "appear to meet both the psychological and legal definitions of gambling". To give an example from their work, players in the game *FIFA 18* can open packs which contain new players. The content of these packs is not known at the time of purchase (1), the content is based on chance (2), packs can be purchased using virtual currency which can be purchased for real money (3), and losses can be avoided by non-participation (4). Finally, the winnings of these packs can give a direct competitive in-game advantage to the player (5). In the case of *FIFA 18*, the resulting in-game items can also be 'cashed out' for real money[14] (6) satisfying their final criteria.

This extension of Griffith's criteria partially coincides with Koeder and colleagues' recent analysis of gacha games, where again exchange for real money is a core criterion to classification of an activity as gambling [22]. Unlike Drummond and Sauer, Koeder et al. take a design-focused taxonomy of gambling games as their starting point of definition [11]. Interestingly, they inversely conclude that loot boxes and gacha games 'would not qualify as gambling' as no items of real

[13]This revision removed one criterion from his original five: Winners gain at the sole expense of losers.

[14]Irrespective of whether this cashing out is actively supported or suppressed by the game company [38].

monetary value can be won. The two conclusions here complement one another in that the first argues that they may be considered gambling should real-value exchange be possible, whereas the other argues that they may not, should such exchange not be possible. This means similar conclusions may be drawn as to whether chance based mechanics in games meet definitions of gambling, even when using different criteria, a point discussed further in Section 5.

Legal Definitions

Legal definitions of gambling are by nature specific to the legislative entity (nation state or federation) in question; legal scholarship on the matter is therefore either grounded in a particular (typically national) legislation or engages in cross-national comparison. That said, there is significant overlap between national legislations. In the following, we focus on legal definitions in the United Kingdom. Here, the UK Gambling Act defines gambling as 'playing a game of chance for a prize', where a game of chance is 'a game that is presented as involving an element of chance'[15]. The prize is defined as 'money or money's worth'. This definition has recently been considered to be expanded by the UK Gambling Commission's position paper on virtual currencies, esports, and social casino gaming [6]. This defines prize as 'in-game items or currencies which can be won, traded or sold [and] can be converted into cash or exchanged for items of value'. As can be seen, this definition places emphasis on the financial value of winnings in relation to chance exclusively, irrespective of any psychological repercussions of such activities.

As with psychological definitions, legal definitions find application outside of traditional casino games, specifically with respect to loot boxes and gacha-style mechanics, whose legal classification as gambling or gaming is currently a point of contention across national regulators [22] [21]. This contention hinges on the exchange of items for real world value as above. Notably, to what extent the purchasing and trading of in-game items constitutes real-world value exchange has long been and continues to be a divisive issue in the field of virtual economics [25, 32]. We argue that this contention expressly does not apply to crypto-games given the directly exchangeable nature of in-game tokens to cryptocurrencies and cryptocurrencies to real currency, as described in 'Technical Properties' above. This key difference is further expanded in the following subsection.

Combined Definition

For the purposes of assessing crypto-games, we will in the following use a set of psychologically-oriented criteria. We take Griffiths' four revised criteria, repeated below for convenience, to meet the psychological definition, plus the sixth suggested by Drummond and Sauer, which mirrors the relevance of monetary exchange of value in legal definitions:

1. The exchange is determined by the outcome of a future event, which is unknown at the time of betting
2. The outcome of the future event is at least partly due to chance
3. An exchange of money/objects of financial value occurs, typically without productive work from either side
4. Losses can be avoided by not taking part in the activity
5. Real-world money can be obtained by 'cashing out' winnings

In the following, we will use these criteria to assess whether playing the crypto-games in our sample (Table 2) meet the combined definition of gambling, specifically focusing on how their shared and individual mechanics contribute to the fulfilment of each criteria.

Crypto-Game Mechanics as Gambling

The generation of virtual goods, micro-transactions, and chance-based mechanics found in crypto-games, as described in 'Ethereum Crypto-Games' above, each contribute in different ways to meeting our definition of gambling above. The right side of Table 2 contains which of the sampled games meet which criteria.

Criterion 1: The exchange is determined by the outcome of a future event, which is unknown at the time of betting

In applying this criterion, we consider the term 'betting' to mean any payment made before an in-game activity occurs, where payment is required by the activity. In the context of crypto-games such as *CryptoKitties*, this activity may be the breeding of two existing kitties, which results in a new kitty with attributes derived from the original two. Other examples include entering dragons into arena competitions in *HyperDragons*, or sending 'mon' on adventures for treasure in *Ethermon*.

In all these examples, the future event - the newly bred kitty, the outcome of the arena competition, or the treasure gained from adventuring, is unknown at the time of payment. This results in the exchange being determined by the outcome of a future event, in that a player may make payment of higher or lower value than the virtual goods received as a result of their activity. Notably, the future events considered are not solely the generation of new virtual goods, e.g. via breeding mechanics; participation in chance-based adventures and competitions is a core element satisfying this criterion across all games in Table 2.

Criterion 2: The outcome of the future event is at least partly due to chance

In each of the examples above, a chance-based mechanic governs the outcome of the in-game activity. For example, the breeding mechanic may favourably combine two existing kitties in *CryptoKitties* such that a high value kitty is created, however it may be equally (if not more) likely that a lower value kitty is created. Similarly, *Axie Infinity's* breeding mechanic is functionally comparable to that of *CryptoKitties*: players can choose what to breed, affecting the odds somewhat, but the ultimate result of each breeding is chance-based. This equally applies to arena outcomes in *HyperDragons*, adventuring in *Ethermon*, and raid boss mechanics in *Blockchain Cuties*: players somewhat affect probability distributions of an ultimately stochastic outcome. As shown in Table 2, this criterion is fulfilled by all crypto-games presented.

[15] This is one of three definitions of 'game of chance' - see the UK Gambling Act 2005 section 6.2(a).

Criterion 3: An exchange of money/objects of financial value occurs, typically without productive work from either side

Under this criterion, the fact that Ethereum crypto-games are DApps introduces an interesting complexity. Principally, any activity across the Ethereum network paid in Ether constitutes financial value exchange. For example, the breeding of any two virtual creatures in *CryptoKitties*, *Axie Infinity*, *Ethermon*, *HyperDragons*, and *Blockchain Cuties*, requires a transaction cost be paid irrespective of any additional charges included in the design of the game. Similarly, in *0xUniverse*, planetary exploration using spaceships requires a transaction cost be paid. This cost is the minimum required payment for any of the above activities to be completed, more specifically for their outcome or initiation to be stored on the Ethereum blockchain. Arguably, the computers executing the games' code do some work, in the same sense that a slot machine or croupier does productive work which is enabling the game to exist and run in the first place. However, classic gambling definitions do not consider this kind of game-constitutive work as *productive* work. Thus, by definition, this criterion is fulfilled by all Ethereum crypto-games, as a direct result of the transaction cost mechanism used in the Ethereum network and its inseparability from performing actions in crypto-games. Conversely, were crypto-games run without an architectural dependence on transaction costs, only those which incur a fee by design would fulfil this criterion. In addition to the basic transaction fee for executing any in-game action, all sampled Ethereum crypto-games also charge cryptocurrency for purchasing in-game tokens that is in excess on the code execution fee or cost. This alone fulfils this criterion for all games selected.

Criterion 4: Losses can be avoided by not taking part in the activity

We consider fulfilment of this criteria to include the investment of some amount of real world monetary value on typical activities within each of the crypto-games presented. Each of the activities described so far appear typical to the games in which they exist. Given the fulfilment of each of these games of the previous criteria, we may conclude that the simple act of not playing any of the crypto-games presented would result in the avoidance of losses. Whilst we acknowledge that several of the activities across the crypto-games may not result in an overall loss of value all of the time, the transaction cost used to perform such activities is irrecoverable so is lost for every activity performed. For this reason all of the crypto-games presented fulfil this criterion, also due in part to the collectable nature of in-game items promoted by their mechanics. As with the previous criterion, negation of transaction costs would mean only those with fees by design would fulfil this criterion.

Criterion 5: Real-world money can be obtained by 'cashing out' winnings

In the context of the crypto-games presented, we consider 'cashing out' as the exchange of tokens for cryptocurrency, which can in turn be exchanged for real-world currency. This is supported by the existence of cryptocurrency exchanges, where they can be readily exchanged for legal tender [10] in states where such exchanges are available. This criterion is fulfilled by all of the crypto-games presented. For example, *Evolution Land's* tokens can be directly exchanged for cryptocurrency, given the nature of their storage on the distributed ledger. Similarly, in each of the crypto-games featuring breeding mechanics, an in-game marketplace is implemented where users can exchange their virtual creatures for cryptocurrency. Given the collectable nature of these creatures, this is considered a typical part of gameplay, with each such game fulfilling this criterion by design.

In summary, we find that all sampled crypto-games currently operating atop the Ethereum network meet our combined definition of gambling. We now consider the limitations of our approach, with specific focus on the subjectivity of definitions, and their interpretations.

LIMITATIONS

Discussion so far surrounding the convergence of gaming, specifically mechanics in games, and gambling have been limited to loot boxes and gacha games. Discussions include, but are not limited to, their relation to problematic gambling severity [34], and impact on adolescent behaviours [36]. Our initial *definitional* analysis notably cannot speak to the actual psychological and behavioural effects of crypto-game play, and to what extent it approximates problem gambling. This is an important area for future work.

Second, different legal and psychological definitions exist to classify activities as gambling, and prior work applying them to gaming uses different definitions [15] [11] [22]. We transparently chose one particular combination of these definitional criteria, but others are possible and defensible. In addition, different interpretations of each criterion are possible and can be found in the literature. An example is the 'exchange of money/objects of financial value' criterion, with the real financial value of virtual goods being a heavily contested debate [16]. Methodologically, this limitation could be overcome through the development of a coding handbook as used in quantitative content analysis [23], or through the systematic application of a collection of definitions found throughout current literature.

Given the rapidly changing landscape of blockchain gaming, our paper relied on a discrete sample of Ethereum crypto-games that were top-ranking on a particular platform at the time of writing. As such, it is not necessarily fully representative of all currently existing crypto-games or blockchain gaming more generally. One can also expect the landscape to change over time, so that our findings may be outmoded by game innovation. Future work should therefore assess a broader sample of crypto-games, including those operating on other cryptocurrency networks, and assessing the evolution of the form over time. Our selection has also depended on an external ranking system; a stricter academically-grounded ranking system presents an interesting area of future work, on which very little literature exists [33].

Finally, whilst this work has aimed to identify characteristics of crypto-games and their similarities with gambling, not all countries allow cryptocurrency to be exchanged for legal tender, making playing such games (and importantly, the 'cashing out' of in-game items) legally impossible. For instance,

cryptocurrency exchange is legal in the UK, but prohibited or implicitly banned in countries such as Pakistan and China[16]. This means that any conclusions drawn from this work only apply to countries where the financial means to play such games are legal.

DISCUSSION

We find that several of the highest ranking crypto-games currently operating on the Ethereum network meet a combined definition of gambling. This definition builds on existing sets of criteria in the gambling literature, taking a psychological basis, and adding a final criterion on 'cashing out winnings' that previous authors found necessary for the analysis of comparable phenomena like loot boxes, and mirrors legal gambling definitions.

Specifically, we found that several mechanical similarities exist between current implementations of crypto-games, specifically breeding mechanics, and chance-based rewards found in standard games such as loot boxes. However, unlike games with loot boxes or gacha mechanics, all crypto-games discussed in this paper allow the direct or indirect exchange of in-game items for real world money. This makes them more readily fit current criteria of gambling. That said, we hasten to add that not all crypto-games *necessarily* follow this finding, given the immense variability of underlying cryptocurrency technologies, fee structures, and design decisions.

Although those presented here meet our combined definition of gambling, crypto-games offer a new gaming paradigm under which players may exercise cryptographically-secured ownership of the virtual goods they earn and trade. This new paradigm has the potential to give more control to users, and presents an interesting future direction of game development and design. When combined with the numerosity effect - that the perceived value of goods changes with the numerosity of the currency they are purchased with [18] - another dimension to the issues presented emerges, as the effects described above may be amplified or suppressed depending on the design of the game. This interaction of effects represents a valuable area of future work.

We conclude this discussion with a list of key points:

- Current crypto-games design focuses on the generation and ownership of virtual goods
- Payment for in-game actions, paired with some chance mechanic, is core to activities in crypto-games
- By design, decentralised in-game items in crypto-games can be exchanged for other currencies/items
- Popular crypto-games on the Ethereum network meet our combined definition of gambling specific to video games

FUTURE WORK

The mechanisms outlined in this work, and corresponding unexplored psychological effects, leave a rich landscape in which to pursue further work. This work has only investigated crypto-games found using the Ethereum cryptocurrency network, leaving much room for exploration and mapping of other DApp ecosystems such as the EOS and TRON networks [2]. Given the decentralised nature of the DApps in question, a comprehensive computational exploration of the blockchains of relevant cryptocurrencies would provide valuable insight into player behaviours, both from a gameplay and financial perspective.

Survey style studies such as those conducted by Zendle and Cairns [35] may more accurately inform conclusions regarding regulation and effects on player behaviour. Further studies in this vein may investigate the financial and/or psychological profiles of those who play standard games versus those who play crypto-games. Such comparative work would inform likely directions of industry development and highlight more fruitful avenues of further study.

Finally, the development of a set of design-specific criteria, based on the five point criteria set presented here, may aid crypto-game developers such that they do not inadvertently create gambling platforms from the original goal of making non-gambling games. These criteria may be integrated into the design process to identify any gameplay conditions, which may meet the criteria of gambling discussed above, to be avoided as/if required.

CONCLUSION

This paper has presented the gameplay style, underlying mechanics, and macroscopic user spending profiles of several popular crypto-games. Parallels have been drawn with chance based mechanics in standard games, presenting a means by which existing work on related topics such as loot boxes may be applied to this emerging domain. We have presented connections in recent literature regarding the similarity between the architecture of crypto-games and traditional gambling systems, specifically around their chance based mechanics and the payment for completion of tasks that underpin these games. The effect of this combination means high ranking crypto-games, when classified using well defined criteria for simple risk taking versus gambling, meet our combined definition of gambling.

ACKNOWLEDGEMENTS

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/M023265/1.

REFERENCES

[1] Blizzard Entertainment. 2014. *Hearthstone*. Game [PC]. (11 March 2014).

[2] Block One. 2018. EOS.IO Technical White Paper v2. (2018). https://github.com/EOSIO/Documentation/blob/master/TechnicalWhitePaper.md

[3] Vitalik Buterin and others. 2014. A next-generation smart contract and decentralized application platform. *white paper* (2014).

[16] Retrieved from https://www.loc.gov/law/help/cryptocurrency/world-survey.php, accessed 05/07/2019

[4] Filipa Calado and Mark D Griffiths. 2016. Problem gambling worldwide: An update and systematic review of empirical research (2000–2015). *Journal of behavioral addictions* 5, 4 (2016), 592–613.

[5] GyuHyeok Choi and Mijin Kim. 2018. Gameplay of Battle Royale Game by Rules and Actions of Play. In *2018 IEEE 7th Global Conference on Consumer Electronics (GCCE)*. IEEE, 599–600.

[6] Gambling Commission and others. 2017. Virtual currencies, eSports and social casino gaming - Position paper. *Gambling Commission, Birmingham, UK* (2017).

[7] Aaron Drummond and James D Sauer. 2018. Video game loot boxes are psychologically akin to gambling. *Nature Human Behaviour* 2, 8 (2018), 530.

[8] Epic Games. 2017. Fortnite. Game [PC, Android, PlayStation 4, Nintendo Switch, Xbox One, iOS, PC, Mac]. (July 2017).

[9] Ingo Fiedler, Sylvia Kairouz, Jean-Michel Costes, and Kristina S Weißmüller. 2019. Gambling spending and its concentration on problem gamblers. *Journal of Business Research* 98 (2019), 82–91.

[10] Sally M Gainsbury and Alex Blaszczynski. 2017. How blockchain and cryptocurrency technology could revolutionize online gambling. *Gaming Law Review* 21, 7 (2017), 482–492.

[11] Sally M Gainsbury, Nerilee Hing, Paul H Delfabbro, and Daniel L King. 2014. A taxonomy of gambling and casino games via social media and online technologies. *International Gambling Studies* 14, 2 (2014), 196–213.

[12] Sally M Gainsbury, D King, Brett Abarbanel, Paul H Delfabbro, and Nerilee Hing. 2015. Convergence of gambling and gaming in digital media. *Melbourne, VIC: Victorian Responsible Gambling Foundation* (2015).

[13] Steven Goldfeder, Harry Kalodner, Dillon Reisman, and Arvind Narayanan. 2018. When the cookie meets the blockchain: Privacy risks of web payments via cryptocurrencies. *Proceedings on Privacy Enhancing Technologies* 2018, 4 (2018), 179–199.

[14] Mark Griffiths. 1995. *Adolescent gambling*. Psychology Press.

[15] Mark D Griffiths. 2018. Is the buying of loot boxes in video games a form of gambling or gaming? *Gaming Law Review* 22, 1 (2018), 52–54.

[16] Richard Heeks. 2009. Understanding "gold farming" and real-money trading as the intersection of real and virtual economies. *Journal For Virtual Worlds Research* 2, 4 (2009).

[17] Garrick Hileman and Michel Rauchs. 2017. Global cryptocurrency benchmarking study. *Cambridge Centre for Alternative Finance* 33 (2017).

[18] Yunhui Huang and Zhijie Lin. 2017. Increasing the Sales of Virtual Goods: Leveraging the Numerosity Effect in Virtual Worlds. (2017).

[19] Mykola Inshyn, Leonid Mohilevskyi, and Oleksii Drozd. 2018. The issue of cryptocurrency legal regulation in Ukraine and all over the world: a comparative analysis. *Baltic Journal of Economic Studies* 4, 1 (2018), 169–174.

[20] Daniel King, Paul H Delfabbro, and Mark Griffiths. 2010. The convergence of gambling and digital media: Implications for gambling in young people. *Journal of Gambling Studies* 26, 2 (2010), 175–187.

[21] Marco Josef Koeder and Ema Tanaka. 2017. Game of chance elements in free-to-play mobile games. A freemium business model monetization tool in need of self-regulation? (2017).

[22] Marco Josef Koeder, Ema Tanaka, and Hitoshi Mitomo. 2018. " Lootboxes" in digital games-A gamble with consumers in need of regulation? An evaluation based on learnings from Japan. (2018).

[23] Klaus Krippendorff. 2018. *Content analysis: An introduction to its methodology*. Sage publications.

[24] Jan Lansky. 2018. Possible state approaches to cryptocurrencies. *Journal of Systems Integration* 9, 1 (2018), 19–31.

[25] Eunjo Lee, Jiyoung Woo, Hyoungshick Kim, and Huy Kang Kim. 2018. No Silk Road for Online Gamers!: Using Social Network Analysis to Unveil Black Markets in Online Games. In *Proceedings of the 2018 World Wide Web Conference on World Wide Web*. International World Wide Web Conferences Steering Committee, 1825–1834.

[26] Vili Lehdonvirta and Edward Castronova. 2014. *Virtual economies: Design and analysis*. MIT Press.

[27] Joseph Macey and Juho Hamari. 2019. eSports, skins and loot boxes: Participants, practices and problematic behaviour associated with emergent forms of gambling. *new media & society* 21, 1 (2019), 20–41.

[28] Satoshi Nakamoto and others. 2008. Bitcoin: A peer-to-peer electronic cash system. (2008).

[29] Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, and Steven Goldfeder. 2016. *Bitcoin and cryptocurrency technologies: A comprehensive introduction*. Princeton University Press.

[30] Respawn Entertainment. 2019. Apex Legends. Game [PC, PlayStation 4, Xbox One]. (February 2019).

[31] Sebastian Schwiddessen and Philipp Karius. 2018. Watch your loot boxes!–Recent developments and legal assessment in selected key jurisdictions from a gambling law perspective. *Interactive Entertainment Law Review* 1, 1 (2018), 17–43.

[32] Meng Wang. 2018. Online Games Virtual Products-Transaction and Value. In *2018 International Conference on Management, Economics, Education and Social Sciences (MEESS 2018)*. Atlantis Press.

[33] Kaidong Wu. 2019. An Empirical Study of Blockchain-based Decentralized Applications. *arXiv preprint arXiv:1902.04969* (2019).

[34] David Zendle and Paul Cairns. 2018a. Loot box spending in video games is linked to problem gambling severity. (2018).

[35] David Zendle and Paul Cairns. 2018b. Video game loot boxes are linked to problem gambling: Results of a large-scale survey. *PloS one* 13, 11 (2018), e0206767.

[36] David Zendle, Rachel Meyer, and Harriet Over. 2019a. Adolescents and loot boxes: Links with problem gambling and motivations for purchase. *Royal Society Open Science* 6, 6 (2019), 190049.

[37] David Zendle, Rachel Meyer, Stuart Waters, and Paul Cairns. 2019b. The prevalence of loot boxes in mobile and desktop games. (2019).

[38] Z. Zhang, H. Anada, J. Kawamoto, and K. Sakurai. 2015. Detection of Illegal Players in Massively Multiplayer Online Role Playing Game by Classification Algorithms. In *2015 IEEE 29th International Conference on Advanced Information Networking and Applications*. 406–413. DOI: **http://dx.doi.org/10.1109/AINA.2015.214**