Unpacking "Boardgames With Apps": The Hybrid Digital Boardgame Model

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Increasingly, modern boardgames incorporate digital apps and tools to deliver content in novel ways. Despite disparate approaches to incorporating digital tools in otherwise non-digital boardgames, there has to date been no detailed classification of the different roles that these tools play in supporting gameplay. In this paper, we present a model for understanding hybrid boardgame play as performing a set of discrete functions. Through a mixed-methods approach incorporating critical play sessions, a survey of 237 boardgame players, and interviews with 18 boardgame designers and publishers, we identified the key functions performed by the digital tools in these games. Using affinity mapping, we grouped these functions into eight core categories, which were tested and refined using a survey of 44 boardgame players and designers. This model defines and classifies the diverse functions that digital tools perform in hybrid digital boardgames, demonstrating their range and potential application for researchers and game designers.

CCS CONCEPTS •Human-centered computing~Interaction design~Empirical studies in interaction design •Applied computing~Computers in other domains~Personal computers and PC applications~Computer games

Additional Keywords and Phrases: boardgames, hybrid play, hybrid digital boardgames

ACM Reference Format:

1 INTRODUCTION

For over a century, there has been interest in combining boardgames with novel technologies. Lichtra [3], believed to be the first boardgame to incorporate electricity, was released in Leipzig in 1910 [85, 86]. Building on this more than 100-year-old history of boardgames which use electrical or electronic components, the past five years have seen a rapid increase in commercial boardgames that integrate smart digital technologies. This creates "hybrid" games that unite a physical game and digital tools – "boardgames with apps". In this paper, we explore these games and describe how digital tools are used to mediate, enhance or supplement tabletop boardgame play in novel ways that align with players' preferences and industry goals. Building on mixed-methods research with boardgame players, designers, developers and publishers, we present a model for Hybrid Digital Boardgames (HDBs) which identifies and categorises the functions which such digital elements perform in gameplay. These range from simple timers to thematic and game-specific content, complex calculations, and teaching and tutorial material.

Although HCI researchers have a long-standing interest in hybrid objects and interactions [40, 129], in hybrid forms of play [17, 76, 82, 126], and in the play of non-digital tabletop games [19, 31, 102, 105], there is no structured and codified description of the specific roles which hybridity can perform within a boardgame. Instead, the term 'hybridity' is broadly applied to a range of uses and settings which include hybridity of genre [8] and or other forms of hybridity that are not associated with the delivery of the game itself [42, 131]. Such research is useful in its exploration of technologies and settings but does not address the needs of researchers

or game developers working with HDBs that combine digital and non-digital components. Instead, we offer a technology-agnostic model that focuses on the role of digital elements rather than on the specific technologies used to deliver them and which responds to the call for "clarifying models and typologies on the subject" [66].

In this research, we define HDBs as **boardgames in which play is enacted through both physical components *and* a 'smart' digital element**. This definition requires that both the physical components and the digital element are necessary to play the game, that neither is sufficient on its own to play the game, and that neither the physical nor the digital element is optional, after-market, or third-party. This definition, which aligns most closely with the "Smart device tabletop games" discussed by [66], explicitly excludes a number of other interesting areas of research including non-game interactions [43, 46], smart toys [58, 87, 133], tangible objects as novel physical controllers for digital games [24, 27], fully digital games [30, 122], digital tools for design [23], boardgames which teach about technology but do not themselves utilise it [48, 50], pervasive or 'orchestrated' games [29, 51, 60] and even tools to enhance play in other forms of tabletop game [17]. This in no way suggests that research in these areas is not valuable but rather reflects the focus of this work on the combination – or merging [44] – of material and digital elements in boardgame play.

This paper contributes a long-overdue analysis of the use of digital tools to enhance and extend the play of boardgames, in the form of a model describing the different functions that such tools can play within an HDB. It examines notions of hybridity from the perspective of the affordances of hybrid artefacts. It is of value to researchers seeking to describe and develop such games as well as to the broader boardgame industry and can be used to inspire and broaden the use of digital elements to augment the tabletop play experiences.

2 RELATED WORK

We begin this section by considering the concept of affordance which is, we argue, critical to understanding HDBs as a novel medium. We then ground this work in the history of hybrid, electrical, or electronic games and in the study of game design. Hybrid boardgames may be novel, but the combination of a boardgame and electricity has a long history. We then examine research into hybrid forms of play before focusing on the use of digital tools as game boards and components.

2.1 Hybridity and its affordances

Although many scholars have been concerned with the design of hybrid games or the user experience of interacting with those tools [70, 96], our research engages specifically with design features of HDBs. We catalogue and describe the functions of digital elements in these hybrid artefacts, examining how these tools afford and mediate action [67].

The term *hybrid* has been contested in HCI literature recently [35, 44]. Some researchers have suggested that it may imply an implicit binary distinction between two mutually exclusive categories, and that alternate terms, such as coproduction, may be preferable [35]. Fuchsberger speculates that the notion of hybridity may become immaterial in the future as even "the processes and practices of crafts … are finding their way into our research as sites of investigation focusing on online and offline practices and meanings" [44]; this has been termed the "digital hinterland" of traditionally material pursuits [104]. Yet to boardgame hobbyists, there *is* an inherent and meaningful distinction between games which are wholly or partially digital and those which are purely material. Whether their opinions of HDBs are positive – "I'm a fan of tech either simplifying some of the general management or bookkeeping" – neutral – "I am interested in seeing how far games will go with digital technology, but I will still prefer a traditional board game overall" – or negative – "Idiocy. If you want to play a video game, do that. The joy of boardgames is exactly in keeping things tangible, but also run by people", they see HDBs as a novel media form which is distinct from boardgame or videogame play.

Elsewhere, scholars have used the language of augmentation in describing these games [16, 33, 98, 114]. This suggests that the digital element is *added on* to the boardgame, rather than that the game is designed *from the start* as a hybrid artefact [67]. Similarly, the language of virtualisation [39, 61] suggests a situation where elements of a physical game are replaced by digital elements. These terms echo the digital augmentation fallacy [20] by implying that the addition of digital elements somehow improves a game.

We see HDBs as a novel form of hybrid artefact that is an aggregation of distinct physical and digital elements [67]. The HDB does not simply accrue the affordances of those elements but rather affords new opportunities [64] for play and for game design that are not found in purely physical or purely digital games. Thus, HDBs are compound media which aggregate both physical and digital components; they are mediated by digital tools, by materials [123] and by humans [12]. In such physical-digital hybrids, "digital interaction is … woven in seamlessly with the action affordances of physical object forms" [119] through aggregation, to create a "larger-scale compound mediator … designed from the start to work in unison" [67, 89]. The digital component is not *added into* the material object; rather, the two *combine* to create a new compound mediated artefact which does not simply accrue the affordances of the physical and digital artefacts but gives rise to novel possibilities that the artefacts would not afford in isolation [64]. Such notions of relational materiality in interactions with hybrid media are further explored by [45] in the context of museum engagement.

2.2 The antecedents of modern HDBs

Boardgames that incorporate electrical or electronic components have existed for at least 110 years [3, 85, 86]. In fact, games which rely on simple electrical circuits, such as *Operation* [49], where the player performs 'surgery' to remove items from the human-shaped gameboard without bringing their instruments into contact with the board, are still available today. Through the mid twentieth century, these circuits were augmented with switches to recognise input from more than one player, most notably in the sports-themed games published by Jim Prentice's Electric Game Company between the 1930s and 1960s [124]. By the early 1980s, designers were experimenting with more elaborate electronic components in games like *Dark Tower* [15], which featured a battery-powered electronic tower that resolved player actions. Other games from the 1980s and 1990s such as *Assault of the Ogroids* [22] and *Nightmare* [112] incorporated computer programs and even VHS cassettes as essential elements of gameplay. The early 2000s saw the introduction of further electronics in games like *King Arthur* [68], which used conductive inks to deliver new forms of interaction. More recently, an increasing number of boardgames with smart digital elements have been released. For example, in 2015's *Alchemists* [71], players must deduce secret alchemical formulae that have been randomly generated by an app. Of 155 commercially published games that meet our definition of an HDB[1], 146 were published in the last ten years (see Figure 1).

[1] Figures current as at September 2020, based on data from Boardgamegeek.com. Titles exclude expansions which require the base game for play. Titles from 2020 may not yet be announced/released. Six 2021 titles have already been announced & are counted in the total. We started with a list of HDBs that were already known to us & extended it by searching BoardGameGeek using 'families', 'categories' and 'geeklists' as well as through broader online searches including eBay for older titles. We updated the list as new games were released. We attended game fairs & cons in 3 continents, engaged with publishers, and reviewed games named in the survey & interviews. We researched each new title & categorised it as an HDB, an electronic game, a game involving nondigital computation, or as a game released with an optional 'Helper' app.

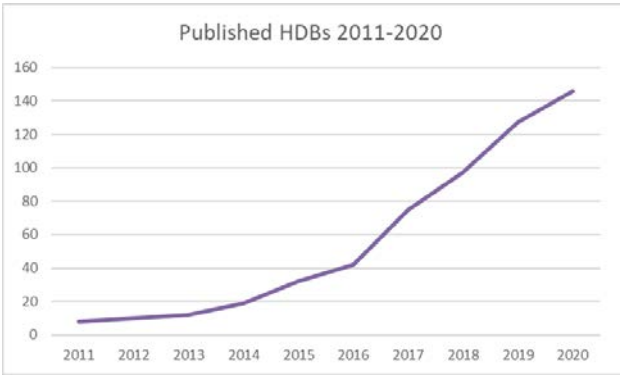

Figure 1 Cumulative Published Hybrid Digital Boardgames, 2011-2020

2.3 Hybridity in games and play

The most significant body of work examining hybrid games comes from Finland's Hybrid Social Play research project (2016-2017). The project's definition of hybrid play extended beyond hybrid digital boardgames to encompass toy-oriented play [58] as well as games that span multiple genres, for example, the hybrids of Eurogames and American-style boardgames [8, 128]. In prior work, [66] attempted to create "a loose typology" of what they termed "smart device tabletop games" (SDTGs), which they characterize as one of many forms of hybrid game. In this early classification, based on analysis of around 50 early hybrid games, they identified four categories of SDTG which, variously, used the smart device as the game board; a game pawn; a tabletop game helper; or as a tool for overseeing play. Their schema addressed the technologies used to implement the game (e.g. tablet computers, capacitive inks) and the effects afforded by those tools. Importantly, their paper presented a clear statement of what the authors understood to be a SDTG.

Subsequent work by the same group [93] extended this interest to examine social features which occur in marketing material associated with games that "contained digital elements which affect gameplay and board game like mechanics". The authors examined marketing material for 13 such games and proposed seven key social features which appear in such material. In another piece of work, the project team developed 17 design guidelines [65, 96] for hybrid boardgames. These aspirational design guidelines, which included *Accessibility*, *Automation*, *Sociability* and *Universality*, were deliberately generic "so that they can be utilized in a variety of other contexts and platforms". Although valuable as broad guidelines, they do not directly address the question of how hybridity is – or can be – used in games.

Earlier work in the early 2000s identified seven broad possibilities for 'augmentation' [33] of boardgames. This research focused on how boardgames could most usefully be augmented, and proposed a 'self-conscious gameboard' with electronic infrastructure to support play (configuration switches, LEDs, LCD displays). Although there have been significant developments in technical infrastructure since this work was published in 2004, the augmentation possibilities described here and by [79] remain highly relevant for this area of research.

Kultima [72] drew attention to the need for research into game design as well as into the play experience. She pointed to a disconnect between academic study of games and the practices of game design and development, noting that few videogame developers are connected to games research. She identified rapid change in emerging design areas as one feature that complicated academic research. Nevertheless, there are opportunities to engage with game designers who themselves study design practices. For example, [37] have catalogued the "building blocks" or mechanisms found in boardgames, although they do not engage with emerging practices around the design of HDBs. They see hybridity as a tool for implementing the mechanisms

already described in the book, rather than as a distinct mechanism or set of mechanisms (personal communication). They acknowledge, however, that hybridity may afford or enable novel mechanisms which have not yet been implemented in purely material form.

Bergström and Björk [12] discuss hybrid boardgames in the context of "the meeting of analog and digital games", extending their research from hybridity to the full digitisation of popular boardgames. Prior work in this space has examined the value of different levels of automation in digitised boardgames [122], as well as the tensions inherent in translating boardgames to digital form [103] and the 'chores' required for play [130]. Leveraging the idea of heteromation, which [36] present as "situations in which human labor, skill, and affect are brought to bear in order to make a broad array of technological systems work", [12] propose that heteromation may inform the digital play setting. They argue that an apolitical view of heteromation can provide "a way to think about what tasks players should have to do or not have to do when playing a game." [12]. They link this to the concept of excise [26], "a tax … of cognitive and physical effort … extra work that satisfies either the needs of our tools or those of outside agents as we try to achieve our objectives". Many scholars advocate the removal of "simple, mundane tasks such as the ones required for board setup" [61], although this work may be inherently satisfying to players. [65] contend that "the digital layer should not automate activities that are fun for the players - like handing out cards to each other." Elsewhere such tasks have been positioned as a form of articulation work [102, 109].

Like [12], Maurer and Fuchsberger [82] consider hybrid play in the broader context of digitised boardgames. Their interest is in remote gameplay, which is often enacted through smart devices, and which removes the essential tangibility of boardgames [105] from the interaction. Their interest in HDBs is therefore in their capacity to extend and facilitate remote tangible play between people who are not co-located. They argue that "we should focus on digitizing the "non-functional" (from the perspective of the game itself) aspects of co-located gameplay". Such activities include non-verbal body signals and epistemic player actions such as sorting and ordering cards or components, as well as the sound and spectacle of rolling dice [20, 82].

2.4 Digital game boards and components

A considerable body of the research on hybrid play forms has been concerned with the use of digital tabletops such as the Microsoft Surface [57, 80, 81] or novel projection interfaces [27, 127]. The CHI community has been excited by the possibilities of combining digital playing surfaces with tangible, material pieces; many see hybridity as an opportunity to leverage the best of digital and non-digital games [7, 9] or as a 'game-changer' for the design of traditional form boardgames [110]. These studies have investigated specific technologies used to implement hybridity and the novelty value offered by digital tools. Underexamined has been how the hybrid interactions support or extend the gameplay. In our investigation of HDB, we have adopted the view that HDBs provide an opportunity to explore the affordances of different media and tools [13, 67]. The ubiquity of smart devices, in particular, makes them ideally suited for delivering hybrid game elements as they can replace the need for costly custom components [10], although the appeal of the resulting hybrid interactions may arise from their novelty rather than for reasons of functionality and gameplay [73]. Like [20], we reject the "digital augmentation fallacy" that suggests that games with digital elements are inherently better or more interesting than those without.

Although there has been considerable research interest to both understanding hybridity and to exploring its implementation in HDBs, to date there has been no detailed and systematic investigation of the specific functions that such implementations enable and support. This paper addresses this research gap.

3 METHOD

We adopted a mixed-methods qualitative approach to data generation and analysis. This combined a survey exploring players' knowledge of and attitudes towards hybrid digital boardgames (HDBs), a series of semi-structured interviews with people working within the boardgame industry, and critical play sessions where we explored different HDBs. The attitudinal material will be the subject of a future paper, but we describe the survey and interviews here as they also informed the development of the model. Finally, we conducted an online card sort activity to test our grouping of functions into broader categories. The key research goals, as shown in Table 1, were to identify the 'work' done by digital tools in HDBs, to group and classify these functions, and to explore and understand how they are used.

Table 1 Key project research goals and activities

Activity	Identify functions	Understand use & attitudes	Group and classify
Survey	X	X	
Interviews	X	X	
Critical play sessions	X	X	
Coding and analysis	X	X	X
Affinity mapping			X
Card sort activity			X

3.1 Survey

We surveyed 237 boardgame players about their attitudes towards and experience with HDBs. This was explicitly exploratory research [121, 132]; we wanted to see what people would tell us about HDBs, given the opportunity. Respondents were recruited via the project's and researchers' social media accounts, as well as at international gaming events, trade fairs and conventions in Europe, the US, and Australia, as well as through posts on hobbyist gaming websites. Respondents' ages ranged from 19 to 66, with a median age of 41. In total, 20 countries were represented. The majority were from the USA (111), followed by Australasia (53) and the United Kingdom (26). A total of 165 respondents identified as men and 65 as women, 6 respondents were non-binary, and 3 preferred not to disclose their gender [111]. Table 2 shows how respondents to this and the subsequent card sort self-describe their involvement with games. Through the survey, we collected examples of hybrid games as well as discussion surrounding them. Although this paper does not explicitly examine respondents' attitudes to HDBs, the survey informed the collation of the sample of games and assisted us to identify the functions performed by digital tools.

Table 2: Respondents' involvement with games – responses to Survey (n=237) and Card sort (n=44)

	Survey (n=237)		Card sort (n=44)	
	Frequency (n=237)	Percentage	Frequency (n=44)	Percentage
Hobbyist boardgamer	179	75.5%	32	72.7%
Hobbyist gamer	92	38.8%	19	43.2%
Casual boardgamer	43	18.1%	11	25%
Casual gamer	27	11.4%	11	25%
Boardgame designer	34	14.3%	9	20.5%
Boardgame publisher	6	2.5%	0	0%
I work in the boardgame industry	15	6.3%	4	9.1%
Other*	14	5.9%	3	6.8%

* 'Other' responses included educators using games for various purposes, podcaster/reviewer, hobbyist game designer, "Used to work in the industry", "Teach wargaming and run wargames for the military" and a small number of game scholars.

3.2 Interviews

We interviewed 18 boardgame designers and publishers. In explicitly including these professionals in our research, we recognise that "sometimes practitioners are superior sources … due to their better access to the internal design processes." [72]. The interviews explored the current state of HDBs, considering specific games as well as identifying trends, and discussed the types of value that digital functions can add to a game, particularly in the light of the interviewee's own design practice. Many of the people interviewed are significant figures in the international boardgame industry, with influence on the hobby game market through innovative design and development as well as publication practices. They include winners of and nominees for the prestigious *Spiel des Jahres* and other awards as well as designers and publishers of several boardgames in Boardgamegeek's top 20 as well as more niche titles.

3.3 Critical play sessions

Acknowledging that it would not be possible for us to play all of the HDBs available on the market, we set out to play a broad cross-section of available HDBs to inform our understanding of the hybrid play experience. We recruited colleagues with a range of boardgame experience to join us as players. Our goal was to critically understand the activities that constitute the play and how they are shared across digital and material spaces to make sense of and enact gameplay [78]. At the conclusion of each play session, we conducted a short group discussion about the role of the digital tools in the game. Notes from each session were collated.

We played five games[2] before the COVID-19 Coronavirus pandemic prevented further sessions. During the extended lockdown period[3], we continued to explore a number of different HDBs with our households and to discuss them with the project team. Although this is a different experience from playing together, it nevertheless contributed to the breadth of games that we were able to explore through this approach. In total, we played 24 hybrid games at least once.

We used publishers' sites as well as the games' reference pages, reviews, and discussions on BoardGameGeek to learn about other games that were mentioned by survey or interview participants. These provided access to game rules as well as to examples of and clarifications about gameplay. These activities deepened our understanding of the HDB play experience and design space.

Like many other games researchers [113, 128], we are not only researchers but also players. In selecting games to play and in analysing the experience of play, we bring not only our critical perspective as HCI researchers but our critical perspective as players, as well as our personal histories with games and gameplay, to the table. This helped us to analyse games and position them in the context of the development of hobbyist gaming, to expand on our historical overview of hybrid and electronic games, to amplify our call for survey participants to a broad pool of hobbyist boardgame players, and to access key people in the industry for interview. It grounds our research in understanding not only of HCI research but also of the games themselves, ensuring that this work is relevant not only for academic research but also to game designers and practitioners.

3.4 Coding

We coded the text responses from surveys, as well as the interview data and our own observations from critical play sessions. Although for this paper, the focus is on identifying and cataloguing the role of digital elements in gameplay, in future work we will explore respondents' attitudes towards HDBs. The coding was an exploratory

[2] Chronicles of Crime; Unlock! Tombstone Express; Mask of Anubis; Beasts of Balance; Woofy Whoops!

[3] At the time of writing, due to government and University regulations, the project team has been unable to meet in person since early March 2020.

and open process with the goal of identifying all of the digital functions raised by participants. These were then refined and grouped during the affinity mapping process.

3.5 Affinity mapping

Building on the coded survey responses and critical play sessions, as well as our review of related literature, we first identified functions performed by digital tools in HDBs and then grouped them into loose categories using MindManager software. This allowed us to create multi-level hierarchies within the maps and made it easy to move clusters of functions to different groupings as well as to create new clusters. Even at an early stage of this research, this created an artefact which we could show to interviewees for feedback and to which we could easily add new elements. The map (and, thus, the model) evolved over five iterations, with the third presented as a work-in-progress [100]. External feedback was explicitly sought during stage 1 (through the interview process), at stage 3 (through the work-in-progress presentation) and at stage 5 (through the card sort activity). At each stage, we refined the categories and checked the logical consistency of the model both through examination and by exploring how a particular game reflected the proposed categories. Following the card sort activity, a final model was prepared and is presented here. This process is outlined in Table 3.

Table 3 Affinity mapping stages

Version	How the model was updated	Review method
0.1	Initial brainstorming	Discussed in interviews
0.2	Updated with data from interviews and survey	Reviewed by project team
0.3	Presented as WIP	Feedback from conference attendees
0.4	Critical play sessions	Reviewed by project team
0.5	Revised & checked for consistency	Card sort activity
1	Revised & checked for consistency	

3.6 Card sort activity

We tested the model using an online closed card sort activity in the OptimalSort tool[4]. Participants were presented with a list of 38 functions, represented as 'cards', which they were invited to sort into one of 12 pre-named categories. These included two categories designed to identify cards which did not easily fit our hierarchy, or which confused participants. Each participant's response was saved individually.

We advertised this activity on the project's website and social media account and amplified these messages by sharing them on our personal accounts, encouraging others to share. Game-in-Lab also shared the call for participants on Twitter. Further, we emailed survey participants who had indicated possible interest in further work on this project to invite them to participate. As in the survey, we asked participants to tell us about their gaming preferences (see Table 2). At the conclusion of the activity, participants were asked whether there were any functions of digital tools in hybrid boardgames that appeared to be missing from the cards provided, and whether they had anything further to add.

4 MODEL DESCRIPTION

The model comprises eight domains, which reflect the 41 functions of digital elements in HDBs. It focuses on the way that these are already used, although several people identified potential uses that have not yet, to our knowledge, been implemented in any commercial HDBs. Figure 2 shows an overview of these domains, which are discussed in more detail below.

[4] www.optimalworkshop.com August 2020

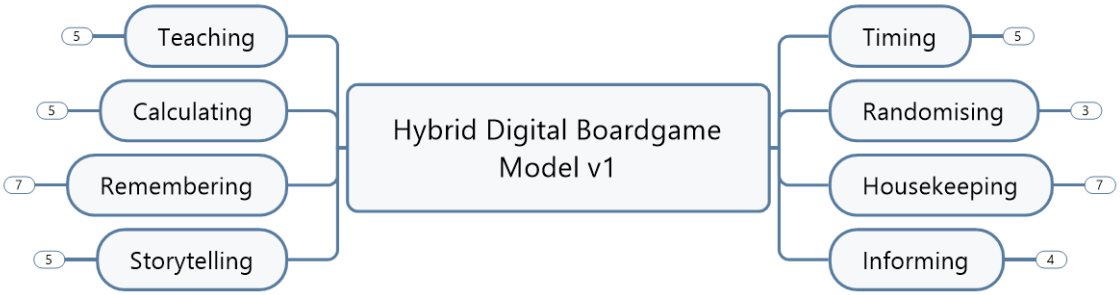

Figure 2 The Hybrid Digital Boardgame Model. Numbers indicate the number of functions within each domain.

4.1 Timing

The timing domain incorporated functions associated with timing and scheduling of gameplay. These timing functions were frequently mentioned dismissively by players, who suggested that an app that is 'merely' a timer adds little to the game. Yet in interviews, designers and others identified a rich range of uses of timing functions, including the delivery of scripted or random content and orchestration of the game. They also discussed the difference in player experience between a sand timer or hourglass which players must monitor themselves, splitting their attention between it and other game activities, and a digital timer which alerts players when time is up and therefore does not generate this divided attention. Table 4 shows the detailed timing and scheduling functions that make up this domain.

Table 4 Functions in the Timing domain

4.1.1 Countdown	Timers are used to count down time until a particular event occurs or until the end of the game. In the *Unlock!* series of Escape Room-themed games (e.g. [34]), players have a limited amount of time to complete the game. In *St Noire* [18], where the digital element is implemented through an Alexa skill, 'game time' is measured in the limited number of actions that players can take before a second murder occurs (4 days of 3 actions) or the game is lost (7 days).
4.1.2 Time rounds	Timers are used to limit the time that is available for a particular action or to a particular player. In *XCOM* [74], where players work together to repel an alien invasion, actions must be completed within a strictly limited time. In the dexterity game *Meeple Circus* [83], peppy circus music is used to dictate the duration of a round.
4.1.3 Track game time	Timers are used to track the overall duration of a game. Although players can pause the round timer in *XCOM*, the game also tracks the duration of those pauses. In *Unlock!*, the game tracks the total playing time.
4.1.4 Initiate game events	Timers trigger certain game events. These events may be randomly generated or selected (see 4.2.3) or may be scripted and static (see 4.5.3). In *Unlock!*, events appear to be timed to occur after a defined time, or some number of minutes before the game's end. In the real-time game *Escape: The Curse of the Temple* [95], countdowns require players to return to a safe area or suffer a penalty. A survey respondent noted that such triggers "keep you on your toes and change up game play".
4.1.5 Sequence game	Digital tools can coordinate in-game events. This can include managing player order and notifying players when it is their turn to act. In the *One Night* game series (e.g. [6]), the app acts as a moderator, telling participants when it is time for particular (recurring) activities. These tools are particularly helpful for players who prefer to play solo games, but also allow the players to play one 'side' together rather than competing one-vs-many (as in the story-driven adventure game *Descent: The Road to Legend* [54]).

4.2 Randomising

Randomisation was identified by both players and designers as a key benefit of hybrid technology. The ability to generate random numbers in more nuanced ways appears to be a key benefit of digital technology. Although [20] found that players of *Warhammer 40,000* preferred to use physical dice rather than die-rolling apps, [73] found that players of their mixed reality game *Mensch ARgere Dich Nicht* preferred the virtual dice to physical dice, although they note that this may have been a reaction to their novelty. In particular, the game's AR environment allowed players to safely throw dice at one another as well as at the walls and furniture of the room. The functions related to the Randomising domain are shown in Table 5.

Table 5 Functions in the Randomising domain

4.2.1 Roll dice	Rolling dice and generating random numbers was clearly a means to implement randomization, although it is not overt in any of the hybrid games that we reviewed in detail.
4.2.2 Order components	Random components may be drawn (e.g. to form a tableau) or cards shuffled. A survey respondent noted that they "really like how *Mansions of Madness* [118] randomizes elements so a game will feel fresh."
4.2.3 Generate or select random events	Random events covered by the model include selection of random encounters (as in *Assault of the Ogroids* [22], a computer-moderated solo boardgame for users of the Sinclair ZX Spectrum) and simply triggering a random event. In the family game *Woofy Whoops!* [4] the dog pees at what appear to be random intervals.

4.3 Housekeeping

Significant 'housekeeping' is often required to play a boardgame [103, 130]. This domain describes how the digital element in a HDB takes responsibility for managing the board and in-game items. Custom digital game boards, such as *The Last Gameboard* and the *Teburu* system[5], replace the traditional cardboard board with a digital platform that links a board display with smartphones or other handheld devices. These promise to simplify housekeeping and board management activities and are expected to be commercially available within the next twelve months. Both digital and modular boards provide an interface that is similar to videogame maps, which "foster exploration and aid navigation" [113]. Beyond the board, game designers also pointed to the potential for HDBs to combine card decks in novel ways, to generate or select among card decks and maps or playing boards, and to create or generate updates to the game. Table 6 introduces the functions in this domain.

[5] https://lastgameboard.com/ and https://www.cmon.com/news/teburu-a-new-evolution-in-board-games

Table 6 Functions in the Housekeeping domain

4.3.1 Include or exclude particular items or objects	Designers can prevent or force particular combinations of objects, cards or boards, for example, to allow for parameters, or to update available materials as a game progresses.
4.3.2 Track in-game resources	HDBs can track not only what resources are available in a game but also what resources a player has available to them (their "inventory"). Respondents noted that the complex game *First Martians* [116] does "a very good job at keeping track of bookkeeping details" and that *Descent: Road to Legend* "improved the standard campaign play experience of *Descent* by cutting down on book-keeping".
4.3.3 Generate or select a board or configuration	The smart tool may create or select a particular board or configuration of items to be included in the game. This function also encompasses level design – the ability for players to design their own configuration of boards and components within the game. In the story-driven adventure games *The Lord of the Rings: Journeys in Middle-Earth* [53] and *Descent: The Road to Legend*, the map is revealed to players as they proceed.
4.3.4 Control AI players and NPCs	The HDB can control AI players and non-player characters, removing the need for a "game master" to run the game or for complex work-around solutions. In *Stop Thief!* [32], the app tracks the thief's location and can be interrogated by the players. The app for *Descent: The Road to Legend* acts as the evil Overlord, sequencing the game and placing and moving monsters on the board to endanger and disrupt the players' plans.
4.3.5 'Know' the players' location	Digital tools are used to maintain awareness of the players' location, reducing the need to ask questions or provide extraneous information. In *St Noire*, the app remembers which suspect is being interrogated; in the story-driven *Mansions of Madness*, the app tracks the location of game pieces.
4.3.6 Show or obscure parts of the board or components	Unlike a traditional boardgame with designated playing space, hybrid boardgames can selectively reveal sections of the game board, cards, or other tokens. This is similar to the "fog of war" effect [80] and is used in *Mansions of Madness* where map tiles are added gradually as the scenario progresses.
4.3.7 Update the game with new or revised content	The design of some games allows existing components to be re-used to create new scenarios or stories. The detective-themed *Chronicles of Crime* [25] app allows for new stories to be released without requiring additional physical components.

4.4 Informing

Both players and designers pointed to the value of digital tools for controlling the flow of information to and between players. The functions that deliver this are shown in Table 7. Both designers and players noted that they would like to see more tools that enable different forms of in-game communication. For example, information and functions may be 'blocked' or 'gated', requiring players to complete a certain task or acquire a particular artefact before they become available. Designers noted that revealed information can be partial or incomplete, or may be directed to one player or a group of players. This issue has also been raised in HCI literature, where scholars have discussed dimensions of communication visibility [115].

Table 7 Functions in the Informing domain

4.4.1 Tell players about a situation or setting	Many games use digital tools to tell players about a situation or setting or allow players to interrogate them for details. In *Detective: A Modern Crime Board Game* [106], players query the game's database to learn more about a particular location or character.
4.4.2 Know secret information	Digital tools can know information about the game that is not available to players. In Alchemists [71], the app knows the secret rules of alchemy that are different in each game. Similarly, the app for The Search for Planet X [94] knows the secret location of all the objects in the game's solar system (see Figure 3).  Figure 3 In *The Search for Planet X*, the digital tool knows the location of all the objects in the randomly generated solar system and gives clues. In this image, the clue specifies that "No asteroid is directly opposite a gas cloud." A survey respondent noted that the cooperative real-time UBOOT: The Board Game [99] "handles all the world-state info the crew should not know". Another pointed out that an effect of digitising this function in the deduction-based Awkward Guests [47] is that "it allowed you to make your guess without eliminating you from the game if you were incorrect."
4.4.3 Prevent players from accessing particular information until a specific condition has been met	Digital tools can check whether players are eligible to receive certain pieces of information – for example, whether they have fulfilled a criterion, completed a prerequisite task, or acquired an object or skill. Players often refer to this as "blocking" or "gating".
4.4.4 Communication with and between players	Digital tools have the capacity to enable communication with and between players. This may be targeted, anonymous or random, and could be true or false/misleading. Additionally, several participants noted the potential for digital tools to address social distancing rules and support remote play amongst players or groups of players who are not co-located.

4.5 Storytelling

Digital tools can enhance and represent the game's theme and story. This is often achieved through use of sound, video, animation and other mechanisms afforded by the digital medium. Table 8 details the functions that are used within this domain.

Figure 4 In *Stop Thief!*, the digital tool indicates the location of the thief (here: at an unknown crime scene in the Trust U.S. Bank) by playing a sound effect, while the players try to deduce their location and move to it on the physical board

Participants noted that these tools are often used to increase the user's sense of immersion and tension and their engagement with the game. Sounds may be used to provide thematic background music and sound effects or to provide explicit, character-acted content (*St Noire*), or the app may 'listen' to sounds created by the players (*Unlock!*). Video provides a sense of place and immersion, for example through the 3D glasses available with *Chronicles of Crime*.

Table 8 Functions in the Storytelling domain

4.5.1 Play background effects	A game's theme can be enhanced through background effects. A Russian folk music arrangement "theme song" plays in the background when players start *Soviet Kitchen Unleashed* [125]. In *Stop Thief!* (see Figure 3), players must listen carefully to hear the sounds made by an invisible suspect who moves around the board, opening doors and breaking windows. Survey respondents note the importance of the background sound in the *One Night* games in covering up incidental sounds of other players' movement.
4.5.2 Sense what the players are doing	The digital tool may sense what the players are doing. At least one *Unlock!* game measures the volume of noise that players create. Other uses of sensing tools include measuring movement using an accelerometer (*Ninja Catfoot and the Covert Action* [108]), recognising die rolls (*King Arthur* [69]), or measuring how dark or bright a playing space is using light sensors.
4.5.3 Play scripted events	Several games offered scripted events which ranged from recorded dialogue to full 'cut scene' style presentations or videos and even mini-games or puzzles that must be completed. In *King Arthur*, characters at different locations 'speak' to players to give them quests or reward them for completing them. A survey respondent praised the voice actor in *Fireteam Zero* [75], noting that "it really sets the atmosphere." Another commented on how much they enjoy the mini-games in the *Unlock!* series.
4.5.4 Customise playing pieces or characters	Digital tools may offer players the opportunity to customise their 'character' or playing piece. In *Golem Arcana* [63], the player could customise their army; in *World of Yo-Ho* [107], the player's phone is itself a game piece.
4.5.5 Visualise an in-game space or element	Digital tools can be used to provide players with a view of an in-game space. In *Mask of the Pharaoh* [55], the incomplete 3D map becomes the focus of players' attention as they attempt to replicate it using 2D game components. [10] describe a tool that shows a player's *Munchkin* [62] character carrying the various items in their inventory.

4.6 Remembering

Digital tools can record players' progress and actions, providing a form of 'digital remembering' of game states and events that extends across a session or may even extend across multiple sessions. These are detailed in Table 9. Both survey respondents and interviewees commented at length on the frustration and anger that are experienced when this information is lost, showing the very strong emotions that persist even many years after.

> There are games that I really cared about ... And those companies decided to stop producing the game, and all my time and effort that I put into those games are gone. There's no way to play them. … It's just gone. You're at the whim of the carrier and the format, and you're at the whim of the IP owners. If they go out of business without support, you can't play anymore. …. (Vaughn, interview)

A survey respondent phrased this more succinctly: "Good luck playing *Golem Arcana* now that the servers are gone."

Table 9 Functions in the Remembering domain

4.6.1 Register players	Digital tools can register players or groups of players, recording that they have chosen to play the game. This is seen in at least one popular Legacy-style game.[6]
4.6.2 Remember players' progress, actions, or choices within a session	Digital tools can remember players' activities during the game and apply appropriate consequences. Once a *King Arthur* player is given a quest by an NPC, they are unable to receive a new quest from that character until it has been completed. Similarly, in *Stop Thief!*, players can see a replay of the invisible thief's movement across the gameboard.
4.6.3 Remember players' progress, actions, or choices from session to session	Players' actions may not only be meaningful for a single play but across sessions. In story mode, *Soviet Kitchen Unleashed* tracks players' progress across multiple plays that take them from kitchen duty on the Russian Front to the gourmet kitchen of the Kremlin. *The Lord of the Rings: Journeys in Middle-Earth* remembers character progression and past game results, as well as some specific in-game decisions, within a 'campaign' comprising multiple games.
4.6.4 Produce shareable artefacts	Games may not only observe and track players' activity, they may also create artefacts which document the play. In *Woofy Whoops!*, a model dog randomly 'pees' on a player while the associated app records a shareable video of the event.
4.6.5 Compare scores or results with other groups playing the same game	Digital tools offer players the ability to compare their scores not only with one another but with all other players of the same game. Registered *Soviet Kitchen Unleashed* players can have their results registered on the game's Global Highscore table; players of the Legacy game described at 4.6.1 can compare their scores with other groups playing the same game.
4.6.6 Take notes as a group	Digital tools allow players to take notes as a group, exploring ideas. We have not seen examples of this technique in commercial boardgames, but it has been noted in research literature [57, 113].
4.6.7 Unlock achievements	Digital tools can unlock achievements and new content or abilities for players. In *The Lord of the Rings: Journeys in Middle-Earth*, characters increase their 'level' as they progress through the story, unlocking abilities tied to progression.

4.7 Calculating

Several participants pointed to the use of digital tools to perform calculations, as detailed in Table 10. This domain was seen principally as a way to use the app to overcome tasks that are "tedious" to do in physical space. Importantly, however, the calculations that a digital tool can perform may be novel and impossible (or at least extremely difficult) for humans. For example, in *Soviet Kitchen Unleashed*, the players each contribute an ingredient card with the aim of collaboratively matching the desired colour of a meal component. The app registers the played cards via a QR code and combines their colours, assessing how close the result is to the desired outcome.

The use of digital tools to perform calculations saves users time and reduces complexity, although, as [122] note, it may also reduce the players' awareness of the internal workings and structures of the game.

[6] This is a surprise to players when it occurs; to avoid any spoilers, we have chosen not to name the game that does this.

Table 10 Functions in the Calculating domain

4.7.1 Do maths	Digital tools are used to perform mathematical calculations, which range from simple to complex. This includes calculating players' scores. In *The Search for Planet X*, the calculation of action costs is relatively simple, but is streamlined through the app.
4.7.2 Resolve an outcome	Digital tools are seen as a reliable platform for resolving an outcome of an action. The stacking game *Beasts of Balance* [14]creates an in-app story world based on the physical pieces that players stack on a physical plinth. In the music-mixing game *Dropmix* [1], players' cards correspond to musical elements.
4.7.3 Judge who did something first or best	Digital tools can potentially judge which player was the first to perform an action, or which player did something best.
4.7.4 Use statistics to see which cards, pieces, or actions are better	Survey respondents noted that digital tools allow the collection of gameplay statistics on a wide scale. These allow insight into the play of the game. For players, they build on the experience of theorycrafting [97, 103]; for designers, they assist in playtesting and balancing a game.
4.7.5 Determine whether the players have completed a task	Digital tools may include a function to determine whether players have completed a task successfully. *Detective: A Modern Crime Board Game* considers not only whether players have solved a crime successfully but also whether they have collected and logged sufficient evidence to prove their case.

4.8 Teaching

Our interviews were conducted shortly after the announcement of an Alexa skill to teach the game *Ticket to Ride* [84] and following the announcement of the *Teburu* platform. Several interviewees commented on these, noting the potential for digital tools to teach games and, potentially, to make them more accessible to the general public – both by explaining rules, as the Alexa skill and various online videos offer, and by supporting specific questions about how to perform a particular action or use a particular piece (one interviewee called this "an almanac function"). Vaughn, however, was sceptical, and noted that one in-game item may be called many different things by players. Nevertheless, we speculate that this domain in particular may improve access to games for newer players, noting that reading and understanding rules is something that novice players may find particularly difficult [78].

Table 11 Functions in the Teaching domain

4.8.1 Know the rules of a game	The rules of a game are embedded in the digital tool; players need not question whether the app's interpretation is correct. This was common to many but not all of the tools we examined and is essential for successful completion of many in-game functions. As with fully digitised games, by knowing the rules of the game, the digital tool can prevent errors. The rulebook for *Soviet Kitchen Unleashed*, for example, advises players to "just GO! No rule book needed! Just play! The app will help you."
4.8.2 Provide setup instructions	Many HDBs provide setup instructions within the digital tool. This helps players to get started playing the game and may be particularly useful when they must select from a number of different possible configurations. *Mansions of Madness* was named by respondents as a game where the digital app streamlines the setup.
4.8.3 Explain the rules of the game	Digital tools that explain the rules of the game offer the benefits of 'tutorial' modes (*XCOM*) and ensure that important rules are not missed or overlooked. Additionally, digital formats allow for updates or clarifications to the game rules. *50 Clues!* [91] does not include any rulebook; instead, players are directed to the game's website which plays an explanatory video. Similarly, *XCOM* provides a brief brochure which explains setup but does not include full game rules, which are available through the app and can be downloaded through the game's website: LEARN TO PLAY This insert lists the components and takes you through the setup steps necessary before loading up the app. It is not a full rules document. To learn how to play the game, go to the app and select the "Tutorial" difficulty in the menu. You can also find the full rules at xcomtheboardgame.com. [74] A player who had tried playing *Zombicide* [52] on the Teburu console commented that "the device taught me without having to go through a lengthy rules explanation."
4.8.4 Answer specific rules questions	Digital tools may be able to answer specific rule questions – for example, "What does this piece do?" or "How do I build X?" In the word game *Werewords*, [5] the app holds a number of custom lists of words for use in the game.
4.8.5 Give the players prompts or hints	Digital tools can provide hints or tips to players who are unsure of what to do next. This feature is currently very common in Escape room-style games but could be integrated into other types of game in future.

5 DISCUSSION

5.1 Value of this model

This model responds to the ubiquitous term "boardgame with an app" by unpacking it to reveal the diverse functions which digital tools deliver in HDBs. It represents the current state of the art of these games, describing the use of hybrid digital elements in commercial boardgames as well as those designed for research settings.

Whereas [66] attempted to classify "kinship" structures by relating entire hybrid tabletop games to one another, the diversity of functions found in HDBs makes such a structure problematic. Belgium's Flemish Games Archives [92] found a similar problem when they attempted to build a classification system for their boardgame archive, finding that "many games could be listed into different categories at the same time" and bluntly dismissing other classification systems as "not very useful.". Their solution was to allow games to be classified in multiple categories, to apply a controlled vocabulary ("thesaurus") for description, and to create project based collections of games; a structure requiring a single classification was insufficient.

Rather than reimplementing a single game system, HDBs routinely draw on the features of several others and introduce their own novel elements. Our hybrid digital boardgame model describes the functions found in these games, considering how they control and enact the game for players and presenting a structure for relationships between features. Like [92], a single game may have multiple properties, even within a single domain, that reflect the ways in which digital tools are used in the game. This removes the difficulties associated with attempts to develop a "kinship" model. Moreover, it can inspire game designers and researchers to consider the opportunities that hybridity can offer not as a gimmick but as a meaningful, novel, and distinct form of tabletop play.

Our model complements recent interest in hybrid play [12, 65, 70, 82, 93] by presenting a detailed overview of the functions that are delivered by the digital elements in HDBs. It highlights conceptual similarities across games that on the surface appear quite diverse, for example, the digital remembering functions seen in games as diverse as *Woofy Whoops!*, *Soviet Kitchen Unleashed* and *The Lord of the Rings: Journeys in Middle-Earth.* Although these are realized very differently – through video of a player's reaction, carryover of scores, and detailed remembering of a player character's attributes – they nevertheless are clearly related functions. Similarly, echoing the games' diverse themes and player experiences, the digital elements in *The Search for Planet X*, *Alchemists*, and *UBOOT* manage secret information quite differently.

5.2 HDBs and affordances

Earlier, we identified affordances – and, in particular, the mediated action perspective on affordances [67] – as a key theoretical foundation for this work. We noted that the combination of app and physical boardgame components creates a new "compound mediator", or hybrid artefact. But this new artefact does not negate the affordances of its individual components; its affordances are multi-layered. Thus, the affordances of an HDB must consider the affordances of both the physical and digital artefacts as well as the perceived affordances signified by the digital element and by the hybrid artefact [90]. A smartphone may therefore itself become a physical game board or piece as well as a tool which mediates in-game activity through the perceived affordances of an app [66]. Furthermore, the in-built tools that the smartphone contains, such as a camera, microphone, or accelerometer, can themselves be leveraged for gameplay just as the computer in *Detective: A Modern Crime Board Game* affords access to both the Internet and in-game research tools. We illustrate this in Table 12 using the game *Stop Thief!*, where players take the role of investigators chasing an invisible thief through four locations. The associated app controls the movement of the thief, giving audio clues to players at each turn. When a player is satisfied that they know the thief's location, they enter it into the app to either apprehend the thief and receive a reward or pay a fine for wasting police time. The table highlights selected affordances and how they relate to the aggregated game artefact.

Figure 5 In *Stop Thief!* the digital tool provides clues to the thief's location. In this image, the app indicates that the thief is walking through the Swinnerton's Department Store location.

Table 12 Key affordances in the HDB Stop Thief!

Game artefact element	Key affordances
Affordances of the physical game material: board, playing pieces, thief and investigator cards, paper 'money' and movement cards	These afford on-board movement, as well as epistemic tasks associated with planning [102]. Players can arrange and rearrange cards to plan their movement. Additionally, the physical board affords a level of gaze awareness [88] as players may attempt to see where another player is looking.
Affordances of the smartphone as artefact	The physical form of the smartphone affords passing from player to player, enabling it to be shared by all the players. It also allows players to look at the screen privately, without sharing information with others.
Hardware affordances of the smartphone, including its ability to play sounds and display images	The sounds allow all players to hear the clues to the thief's location. Further, when a player attempts to apprehend the thief, the sound played indicates whether they were successful without revealing their location guess to other players. Thus, sound is used to reveal the outcome of an otherwise private interaction without revealing the guessed location.
Software affordances of the smartphone app, which allows players to take a number of in-game 'actions'	The app allows players to begin and end their turn as well as to select an action. It can play the 'clue' or history of clues to date in the game, although both are meaningless without the additional context provided by the gameboard. Further, it sequences the game, removing the need for a player to take the role of the thief.
Novel affordances of the hybrid artefact	The interaction between on-board movement and the associated app is integral to the game (see Figure 4). A player can only search for the thief in the areas immediately adjacent to their playing piece. Moreover, certain actions in the app such as the 'private tip' which reveals the thief's current location may only be taken when the player's selected movement card allows.

5.3 What the model is not

We stress that the model is not a 'cookbook' or guide to adding these functions. Our definition of an HDB encompasses games that include just one of the functions we describe as well as those that include many. The value of the model is in describing, defining, and categorising the functions that digital tools can offer to HDBs,

rather than as a checklist enabling designers to cram increasing numbers of functions into a game. Indeed, our research shows that both players and designers offer strong – although not universal – resistance to digital 'gimmicks'. Moreover, they share the concern that poorly-chosen digital tools may unnecessarily distract players from important gameplay decisions; echoing concerns about the 'digital augmentation fallacy' [20], our participants stress the importance of getting the right balance between digital and non-digital elements in a HDB. Nevertheless, our model can provide inspiration and draw attention to areas where designers could consider the use of digital tools.

5.4 Limitations

5.4.1 Types of game

This work is narrowly focused on HDBs which, as [8] note, are just one of many forms of hybrid game. In particular, we have not investigated 'non-smart' hybrids such as the 1991 game *Nightmare* (*Atmosfear*)[7] [112]. Nor do we examine boardgames which incorporate electrical or electronic components, such as *Lichtra* [3]. We see these as distinct types of game which offer a different, albeit related, set of features.

Further, we note that we were unable to critically play all of the HDBs that we would have liked, although we were able to review their components, rules, objectives and, in some cases, to examine the associated app. This is a function both of the growing interest in the genre (and therefore the number of titles currently available) and of the effects of restrictions linked to the COVID-19 pandemic.

Moreover, we did not investigate **optional** apps designed to expedite game setup, as seen for *Dominion* [117] and *Favor of the Pharaoh* [77]; **third party or after-market** apps such as the *Gloomhaven Helper* [38] which was widely mentioned in our survey; or **generic 'helper'** apps designed to assist with specific elements of gameplay in unspecified games. Examples of these include the *Chwazi Finger Chooser* app for determining a starting player and *BoardGameStats* [120] for logging and tracking game play.

5.4.2 Participation

Women and non-binary people are under-represented in boardgame design, as they were in our study. We note that only one of 18 interviewees and 65 of 237 survey respondents identified as women, and six survey respondents as non-binary. We did not collect gender data for the card sort activity.

We actively attempted to seek out women and non-binary people to interview, through email, social media groups for women and non-binary people in boardgame design, personal contacts, and direct introductions, but were not successful in persuading them to participate. We speculate that one possible reason for this reluctance to participate is that attempts to include women and non-binary people may impose a higher service obligation on them than on their male counterparts, due to their disproportionate representation in boardgame design. Additionally, our survey data suggests that women in general may be less positive in their attitudes towards hybrid games. We present these results noting this limitation.

5.4.3 Available games and new releases

This model was developed during 2020 and the latter part of 2019; it represents the current state of the HDB market, although this area is developing rapidly. Discussion of functions provided by games and specific examples of how games use and implement these functions is limited by the games currently available. We anticipate that HDBs in the future may offer novel functions that are not covered by the current model.

[7] We note that this game was reissued in 2019 as an HDB; references in this paper are to the 1991 release which used a VHS tape to provide atmospheric effects.

Nevertheless, as we have discussed, we have tried to present a technology-independent model that allows for future developments. For example, rather than using 'hear the players' as a descriptor (function 4.5.2) we chose to use 'sense what the players are doing'. The subsequent announcement of the game *Ninja Catfoot and the Covert Action* which uses a smartphone's accelerometer to measure the stealth of a player's movement was clearly accommodated within this function. We anticipate that the model may be updated in future to accommodate further developments in this space.

5.5 Future work

There are several key areas of future work that arise from this research and, in particular, from the limitations that we have identified. These include analysis of the electric and electronic antecedents to modern HDBs as well as 'unofficial' gaming tools like the *Chwazi Finger Chooser*, further exploration of the potential of HDBs for distributed play, analysis of players' and industry professionals' attitudes to HDBs, and exploration of axial analysis of game data both to further understand the domains and to represent them to players and designers. There is also a body of work to understand the player experience of HDBs, including whether or how they contribute to addressing accessibility in boardgames.

5.5.1 Novel types of game

The first is to explore 'non-smart' games with electrical or electronic components. These include circuit-completion games such as *Lichtra* and *Operation*, as well as games with logic such as the range of sports-themed electrical games designed by Jim Prentice between the 1920s and 1950s [101]. Additionally, they include games such as *Nightmare* (*Atmosfear*) which use VCR or DVD technology to deliver in-game content on schedule or when referenced. Games that incorporate other types of computation tools, such as *Test Match* [56] and *King Oil* [2], are also of interest.

5.5.2 Unofficial hybrids

A further unexplored area is that of 'unofficial' hybrids and tools that more broadly support play. We earlier mentioned the *Gloomhaven Helper* app, which has become so ubiquitous that many respondents consider *Gloomhaven* to be a hybrid game. Another popular app, which many interviewees mentioned by name, is the *Chwazi Finger Chooser* app which is used to determine a starting player. Although not HDBs, apps like this form part of a hybrid ecosystem of boardgame play that encompasses both tabletops and devices. Inspired by [13], we connect the appropriation of digital tools for boardgame play to the appropriation of the postal (and later telegraph) system to enable games such as Correspondence and Telegraphic Chess [11].

5.5.3 HDBs for distributed play

Like [82], many participants point to the potential for digital technologies to facilitate remote play across multiple physical sites. Despite an abundance of tools that enable fully-digital boardgame play [28], we have not identified any HDBs that are specifically designed for distributed play. Exploration of this design space is not only timely but will further validate and extend this model.

5.5.4 HDBs and accessibility

We understand the notion of 'accessibility' in two ways, each of which offers extensive scope for further research. First, there is the context of "making games more easy to access". Liberman [78], among others, has shown that players struggle to interpret and apply the rules of a game. This type of 'accessibility' is not a separate function but is something that may be enabled by other functions in our model. In particular, we suggest that Teaching functions (particularly 4.8.2 to 4.8.5) as well as Sequencing (4.1.5) may be beneficial in

reducing entry barriers for new players, however further work is required to understand the effects of digital tools in these spaces.

Accessibility also, importantly, means accommodating individual differences. We have not explicitly worked with people with disabilities on this project, so are hesitant to comment on how specific functions support or exclude different groups at this time. Related prior work has examined the use of tangible interfaces in digital games for children with special needs [21] and the accessibility of boardgames from a physical, cognitive or sociological standpoint [59]. [41], in developing guidelines for adapting boardgames for people with visual impairment, note the potential for assistive technologies including apps "to identify and read aloud game elements" as well as for computerization of components and/or game actions including dice rolling and the tracking of scores.

5.5.5 Player experience

A further question, beyond accessibility, is how these hybrid tools affect player experience. In the survey and interviews, both players and game industry professionals raised concerns about digital tools dividing players' attention and distracting them from the game. Joe, a prominent designer, suggested that "when a phone comes out, it's a really bad sign for engagement". Further research in this area could explore how – and whether – HDBs affect the experience of play. In particular, we see the use of shared or personal devices as a fruitful avenue to explore – both in terms of interruptions during play (e.g. social media notifications) and – based on our personal experience playing games with students – willingness and reticence to touch and use someone else's shared personal device. There is a further question of whether and to what extent the integration of personal smart devices may support COVID-safe play (e.g. by reducing the need to touch shared components).

5.5.6 Attitudes to HDBs

As we noted earlier, this paper focuses on the development and presentation of the model rather than on understanding players' attitudes to HDBs (see, for example, [70]). Our experience is that both players and professionals have strong views on the use of digital tools in boardgames. We have analysed the survey and interview results to identify key issues and plan to present these in a future paper.

5.5.7 Axial analysis of game functions

Finally, we propose that future uses of the model could go beyond its use in describing HDBs and as a design prompt. In particular, we see potential for axial analysis of the properties of HDBs to identify clusters of functions which occur together or which appear to be mutually exclusive. This analysis could also examine the value of such axial description for players – particularly when combined with a visualisation indicating the domains or functions addressed in the game. Figure 9 shows one potential format for such visualisations.

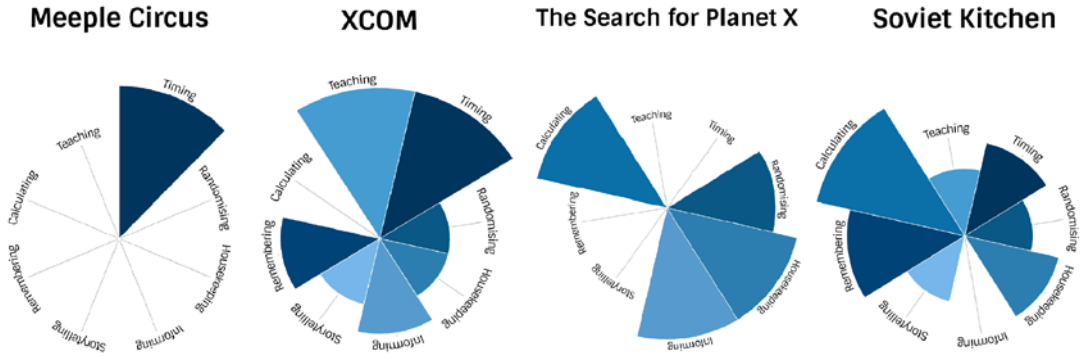

Figure 6 Nightingale's Rose chart visualisations of domain use in four HDBs

6 CONCLUSION

This model, which is both systematic and empirical, identifies and names functions of digital technology in HDBs. More granular than previous studies, it focuses on the specific activities that are performed by digital tools. Unlike generic guidelines, this work presents a detailed overview of current practices and future possibilities, with a broad range of specific examples that show how these strategies are already being adopted and implemented. The model is principally of use to researchers in analysing HDBs but is also valuable for those who seek to develop HDBs or other hybrid digital tools to supplement non-digital activities. Moreover, it is a welcome resource for game designers, developers and publishers in further exploring commercial activity in this space. As a respondent to the card sort activity observed, "I continue to be glad and excited that this project exists and is moving forward. As a designer of hybrid board games, I would love to see more work done in this niche".

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