How Boardgame Players Imagine Interacting With Technology

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Modern digitally-augmented boardgames have, with few exceptions, relied primarily on mobile devices rather than taking advantage of other components such as microcontrollers, sensors, and actuators. What alternative shapes might such games take? And what types of player experiences might such games support? To begin to map out answers to these questions, we collected information about how 31 hobbyist boardgame players envision interacting with technology in future analogue-digital hybrid games, using a rapid idea generation activity. We employed a qualitative content analysis approach to identify their envisioned game components, player interactions with these components, and game effects triggered by these interactions. From this analysis, we constructed a taxonomy of analogue-digital hybrid board games as envisioned by players. This paper uses the taxonomy to organise a detailed discussion of players' imagined interactions. This work thus contributes a player-centric exploration of the design space of hybrid digital-analogue games, with the aim of inspiring new, alternative approaches to boardgame design. Based on the taxonomy, we have additionally released a free and open-source ideation card deck to support new avenues into the design of future hybrid games.

CCS Concepts: • **Human-centered computing → Interactive systems and tools**; **Interaction design**; • **Applied computing → Computer games**.

Additional Key Words and Phrases: Boardgames, Tabletop Games, Hybrid Games

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1 Introduction

Most contemporary boardgames that employ digital technology do so through mobile apps, where the "triggering" of technology elements come from players interacting with screens, such as phones or tablets. However, materiality and the analogue nature of games are important factors to players [40] and screens are not always appreciated as an addition to the analogue experience [29].

The aim of this research was to collect information about how boardgame players envision interacting with technology in future analogue-digital hybrid games, and to organise this information into a taxonomy that can serve as a valuable reference for boardgame designers and researchers.

In product design, discovery research [45] is often utilised to understand a problem space before committing to a design and building a product, and understanding users and their needs is a key step

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in the process, as they are the main beneficiaries of the resulting product. Thinking of boardgame players as end-users, and analogue-digital hybrid boardgames as products, the goal of discovery here was to understand players' desires in:

- How they imagine interacting with hybrid boardgames, ignoring the believed and real constraints of current technologies
- And, what outcomes players imagine the technology could enable and foster in these experiences.

Therefore, this work is meant to inspire new, alternative avenues in boardgame design on a conceptual level, based on players' own depictions of future boardgaming experiences with a technology component. It aims to explore the design space of hybrid digital-analogue games through a user-centric lens, explore the potential of regular boardgame pieces as connected input-devices, consider technology's potential in enabling these alternative interactions, and consider the potential effects these interactions can create on player experience.

The next section describes the context of this research, including commercial hybrid games, players' views and experiences of hybrid games, and the motivation for this research. We then present in Section 3 a description of our research method, which entailed running online ideation workshops in which 31 hobbyist boardgamers rapidly generated 242 new designs, followed by qualitative content analysis of the workshop data. In Section 4 we present a taxonomy organising the components of participants' designs into inputs (things that trigger an action), processes (computational processing of an input to decide on a response), and outputs (events)—with subcategories within each of these—drawing on examples of participants' designs to illustrate the design space represented by the taxonomy. We additionally present in Section 5 the Hybrid Board Game Ideation Deck, an open-source card deck intended to provide game designers with a complementary representation to the taxonomy, which can be used for exploring this design space. We conclude with discussions of the implications of this work for game design as well as its limitations.

2 Background

2.1 Hybrid Boardgames in Commercial and Research Contexts

Rogerson et al. [44] define hybrid boardgames as those "in which play is enacted through both physical components and a 'smart' digital element." Such games are also sometimes referred to as "augmented" [30, 38]. Amongst the first such games was *Stop Thief* [15], which gave aural cues to players with an electronic device—the "crime scanner". Following invention of the microprocessor, games like *Dark Tower* [10] and *Fireball Island* [26] employed miniature computers as game masters. Later games (e.g., [8]) used VHS tapes to offer interactivity through recorded footage, with multiple endings and randomness in gameplay.

Today, the most common mechanism for augmenting boardgames is through an accompanying mobile app. These may offer optional functionality that aims to be practically useful or enhance immersion, for instance offering digital timers, scanning ingredient cards to create potions [31], or providing instructions or thematic music and sound effects (e.g., [14]). Other games integrate apps more fully and require their use. For instance, an app may generate the game-space [51], or provide access to in-game information [12, 47].

A few contemporary games use technology beyond apps, sometimes in conjunction with apps. Some (e.g., [7]) are driven by smart speakers such as Alexa. In the new version of *Dark Tower* [9], many game interactions including the combat system and in-game events are carried out through an app, but players can also "drop" skulls into the game board's physical tower to trigger events in the app. *Beyond Humanity: Colonies*' [48] game components have built-in RFID, which interacts with a wireless game board; while an app is still used, players' focus remains on the game's physical components. *Beasts of Balance* [6] tightly links an in-app gameworld and physical, animal-shaped pieces. By stacking the animal components, new types of beasts are created in the app-world.

Teburu [54] is a new hybrid gaming platform being funded through Kickstarter. Its materials aim to have the look and feel of analogue games, whilst building technology into all of its components (e.g., sensors beneath the cardboard surface, RFID-enabled dice and miniatures, tracking of components). Whilst the success of the product (and players' reception) is yet unknown, its Kickstarter successfully raised EUR 311,497 by 1174 backers [55].

Games and interaction researchers have also developed a number of experimental platforms for hybrid games. In 2004, the STARS project [35] utilised specialised "roomware" such as an interactive touch-screen table, a large vertical display, and room speakers to support hybrid versions of existing games. Undercurrents [3] was a computer-based system for supporting the use of alternative communication streams (e.g., player-player messaging and wikis) within tabletop role-playing games. WEARPG [11] is a platform, created using participatory design processes with players, which enables the integration of player movement (e.g., swinging a word) and novel tangibles (e.g., an augmented die), and wearables (e.g., a hybrid gauntlet) into tabletop role-playing games. Such research has further expanded the understanding of what the design space for hybrid games could look like.

2.2 Players' Views and Experiences of Hybrid Games

Players' views on contemporary boardgames with companion apps are divided. In a survey by Booth [4], just one third of boardgame players expressed a positive attitude towards games with apps. Kosa and Spronck [30] examined the different reasons for players' liking or disliking "augmented tabletop games," finding that the most common aversion was the fear of "obsolescence/incompatibility of technology" closely followed by the undesired "presence of electronics/screens" during board gaming. The most common attraction of technology was enhanced "enjoyment/experience/fun." As that work focused on app-augmented games, it remains unclear how players would receive technologies which did not require them to interact with digital devices or screens.

User tests of WEARPG [11] revealed that this technology led to increased player perceptions of immersiveness and supported new forms of gameplay which players enjoyed, for instance introducing mechanics from other genres of gaming such as Live Action Roleplay (LARP).

According to [50], game masters of tabletop role-playing games often use generative tools, including digital and online resources, to "design characters, treasures, monsters," and other game constructs. Through interviews with game masters, the authors also establish design guidelines for new generative tools, for instance finding that game masters would appreciate technology that provided inspiration, allowed for customisation, and was easy to use. While such tools do not constitute hybrid games according to the definition above, this research further highlights the potential of technology to support players' experiences, and analogue games players' willingness to engage with technology in the right circumstances.

One small study that compared purely analogue and purely digital versions of existing boardgames found that—while technology could sometimes slightly improve usability, e.g. by assisting with tile placement—players experienced analogue games as better overall, including in their experiences of social connectivity and engagement [32]. Such a finding further motivates research and development of hybrid games as forms of interaction which could enable new forms of play while ideally preserving the aspects of analogue games that players value.

2.3 Motivation for Further Research

Most existing commercial boardgames do relatively little to take advantage of the rich array of sensors, actuators, communications infrastructures, and microprocessor- and cloud-based computing capabilities that could be used to augment them. In principle, new games could incorporate the ability for game components to be tracked automatically with sensors or cameras (e.g., using the *Teburu* platform or its underlying technologies). Players' own behaviours and physiological states could be sensed: for instance, [41] found that eye tracking data can reveal aspects of both game and player state, and [25] present preliminary work to explore how eye-tracking data could be used to augment players' situational awareness and predict players' intended actions. Of course, players themselves could manually provide game state information to other digital components (e.g., *Chronicles of Crime* players use a mobile app to scan QR codes on game components [12]).

These facets of tracked game state could be used for myriad purposes; indeed, Rogerson et al.'s [44] *Hybrid Digital Boardgame Model* collects 41 functions—across 8 domains—that technology fulfils in existing boardgames with accompanying apps. Many of these offload tedious tasks—such as "housekeeping" and calculations—that players would normally do themselves. Additionally, though, they note the potential for technology to providing additional sensory stimuli, enhancing narrative and thematic elements. There is room for additional research exploring such potential, including in hybrid games not reliant on apps.

In a study on boardgame players' experiences of immersion, Farkas et al. [18] found that some players "did not feel board games were a medium able to facilitate immersion for them." Some players specifically noted that sensory input and narrative depth were lacking in boardgames; this raises the question whether particular approaches to hybrid game design might overcome these barriers to immersion.

Furthermore, augmenting technology could underpin novel game mechanics. For instance, work by Smit et al. [49] explores one novel approach, proposing what they call an "immersed character"—wherein miniatures in an existing boardgame are equipped with a camera able to livestream a feed from the perspective of the in-game character onto a player's VR display.

In 2019, Smit et al. [49] called for research to use hybrid boardgames to explore "how digital environments can add value to tactile, physical, or material experiences", and Wake [52] called for more research regarding the experience of immersion in augmented games. Since then there has been some published research on technologies for augmentation (e.g., [24] explored how electrochromic ink could be used to create game tiles to display information dynamically), and [17] conducted a player study that found that the music and sound effects of the hybrid game *Fuse* [27] increased players' enjoyment and tension, as well as sense of atmosphere. Yet there has still been little research conducted regarding the broader impact (real or potential) of hybrid games on player experience. In studying how players themselves conceptualise the space of possible hybrid games, we aim to inform future researchers and game designers in understanding how and why boardgames might be augmented with new technologies. Our work complements Rogerson et al.'s [44] Hybrid Digital Boardgame Model—which categorises the various functions and roles of technology as it is currently used in hybrid games—with an experiential model of potential implementations for future designs.

We are especially interested in exploring how the affordances of technology noted above can enhance players' experience of a game's theme or world-building. According to Arnaudo [2], boardgames are a medium in which narrative and storytelling have increasing importance. He writes that, in games, stories emerge as a result of a combination of "strong theme, dynamic interaction of rules, and players' input" (p.17). He sees the experience of boardgame narrative as similar to that of narrative in film or literature, for instance viewing boardgames as a medium enabling fans of fantasy literature to step into these storyworlds. In the boardgame industry, the importance of theme to players is becoming well recognised; for instance, many Kickstarter boardgame projects provide incentives to donors in the form of game add-ons that enhance the theme (e.g., meeples and playmats with custom artwork [16, 37]). Recent academic research has found that players described theme as a contributing factor to immersion [18], and that players regularly modify or purchase (unofficial) game components that "contribute thematic detail" [40].

3 Method

3.1 Participants

Following approval of the study by our institutional ethics process, participants were sampled through open calls in specialist boardgaming interest groups on social media sites. All respondents filled a pre-screening survey for suitability, determining their habits and experience playing board games. A total of 31 hobbyist boardgamers—as defined by [39]—were selected, from participants identifying with any of the following statements: "I strive to play boardgames frequently and I consider it as a hobby," "I collect boardgames," "I work in the boardgames industry," "I participate in online and in-person boardgame discussions." Additional criteria for participation were access to a computer with a webcam, speakers and microphone, alongside pen and paper.

17 participants identified as male, 14 as female and 1 as non-binary. The majority, 23 players, were residing in the UK, with 4 from the US, 1 from Mexico, 1 from Thailand, 1 from Ireland and 1 from the Czech Republic. Ages ranged from 27 to 52, with a median age of 34. Most participants had also previously played boardgames with a technology element.

All participants were briefed about the study format and objectives in advance and were given an opportunity to ask questions before giving their informed consent. The consent form included consent for their data to be stored on a university server and used for research and publication, and advised participants that no personal data would be shared beyond the study team.

3.2 Participatory Approach

Participatory approaches to design and research have been gaining popularity in the last 30 years or so, with a significant increase in number of publications in the last decade [23]. We took a participatory approach where the end-user's point of view formed the main concern of enquiry, as defined by [22], with the goal to generate new knowledge about how users envision interacting with new technologies in a setting where they can shape the future outcomes of their own experiences. The resulting design concepts by participants are secondary in importance to the categorisation that grew out of them through analysis, serving as means, rather than the end results of the research.

To collect design ideas from participants, we utilised a rapid idea-generation method called *Crazy 8s*. The method was popularised by [28] as part of the Design Sprint system—a 5 day process aimed at solving design problems quickly in product development—and is now recognised as part of Google's Design Sprint Toolkit [20]. The goal is to create 8 individual design ideas in 8 minutes, spending 1 minute on each before moving onto the next. The one-minute limitation is used to prevent overthinking, and getting "stuck" with the first idea. Instead, it encourages considering refinements or alternatives by starting a new design each minute.

We chose Crazy 8s as we needed an ideation method that is:

- Accessible to non-designers, as most players have no experience designing boardgames.
- Fast, to minimise overthinking (or the surfacing of the "inner critic").
- Capable of generating multiple ideas within a short time.

The Crazy 8s method fulfilled all three requirements due to its simple rules, and its potential to result in 8 ideas per participant in under 10 minutes.

3.3 Workshops

Whilst Crazy 8s is an individual activity, we organised participants into small groups of maximum 5 members each to conduct workshops more efficiently. Groups were formed based on availability and location, with time-zone differences being accounted for. All workshops were conducted remotely through a Teams call. Participants supplied their own paper and pen, and worked individually in their own homes. In the end, there were a total of 10 remote workshops.

Participants were briefed about the goals and process of the workshop, asking them to think about board games with technology components, but to imagine capabilities beyond what is currently thought possible, and beyond the exclusive use of screens. They were also asked to think of interacting with regular board game components in such ways that they could trigger technology, which in turn could invoke thematicness. *Thematicness* is a term introduced in Farkas et al.'s investigation of the effects of a soundtrack on boardgame players [17], where it is defined as: *"The degree to which the game-world feels realised to the player"*. This definition was explained to participants as well, to ensure a common understanding.

Afterwards, the following instructions were given:

- Fold a paper sheet into 8 rectangles
- Draw 8 designs in 8 minutes

For each idea (1 minute):

- Choose a board game piece
- Think of a way of interacting with it
- Which then triggers something in the game
- Which makes the game more thematic

Participants were shown a compilation of common boardgame components, such as various dice, cards, meeples, tokens, miniatures and so on, for inspiration. They were told, however, that they can use any piece they have seen, or not seen, in any boardgame before, to their preference.

Once the challenge started, a dynamic 8-minute timer was shown on screen at all times, showing each minute separately. There was a sound indicating the end of each minute, and participants were verbally reminded to start a new design. There was a reminder of the instructions on screen as well. After all 8 minutes of the challenge ended, participants were asked to scan a QR code which took them to a survey, where they were asked to write a brief explanation of all their designs. They were also asked to upload their sketches to a shared Dropbox folder by scanning another QR code. Figure 1 shows an example design sheet from one participant.

Finally, there was a brief discussion, where participants were asked to share some of their favourite designs, and to choose designs from other participants they liked the most.

In the end, we collected a total of 242 individual design ideas from participants, as not all participants had a full set of 8 designs.

3.4 Analysis

3.4.1 Inductive Category Formation and Coding. We followed an inductive category formation approach—a form of qualitative content analysis—as defined by [36]. The goal of this method is to directly extract and develop categories from textual materials, taking into account the context in which the material resides within. Similarly to other qualitative analysis methods, such as grounded theory, it utilises a systemic procedure where data is coded line-by-line, forming initial categories which are then revisited and revised iteratively until the final categories are agreed upon.

When compared to other, similar methods, inductive category formation has two additional requirements: selection criteria and degree of abstraction for relevant text segments need to be

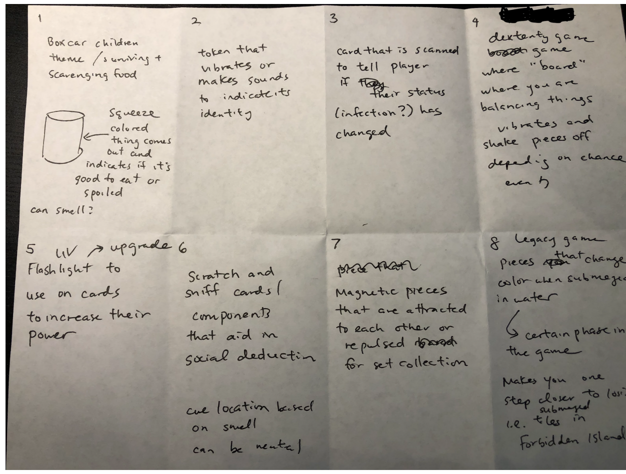

Fig. 1. A design sheet from one of the participants, created during the timed portion of the workshop. (Note that all such sheets were accompanied by longer, typed explanatory text submitted after the timed portion.)

predetermined explicitly; and, an intercoder agreement needs to be carried out on either the full, or a percentage of, the dataset to achieve greater objectivity.

For the context of the analysis, the following criteria were predefined:

- Extract and categorise all game components mentioned by participants, i.e., *what* players are interacting with
- Extract and categorise all interactions mentioned by participants, i.e., *how* players interact with the components
- Extract and categorise the effects caused by the technology, i.e., *what* effects were triggered by the interaction

Open coding was conducted systematically on each individual design idea. The first stage of coding extracted a boardgame component, as named by the participant; an interaction or action happening to that component; a technology mentioned, or implied by the description used by the participant; the effects the interaction would cause through the technology; and any thematic implications. Even though each individual design contained a full idea, and therefore these artefacts could be seen as self-contained designs by themselves, analysis was conducted with categorisation in mind: in that sense, designs were seen as a collection of individual elements—rather than as a whole—and the way these individual elements were later grouped formed the basis of the resulting taxonomy.

Categories were formed through the entire coding process, following the direction from *micro*—the smallest units named by participants themselves—towards *macro*, where units formed increasingly broad groups based on shared characteristics, such as their function or broader purpose.

Once all categories were finalised by the first author, a partial intercoder agreement was carried out on a randomised, 25% portion of the full dataset, due to the extensiveness of the material. The second coder was the second author, who received the material together with all content-analytical rules, including category definitions to ensure an understanding of the context of the material. Results from both coders were compared and discussed, and disagreement was counted on all codes where the second coding was accepted as better. Cohen's Kappa was calculated with a final agreement score of 0.8.

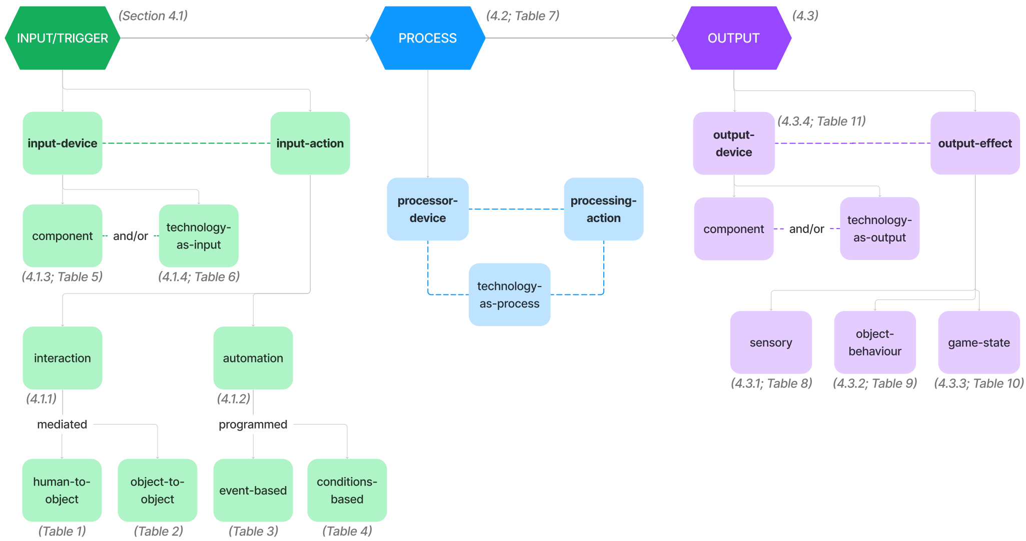

Fig. 2. The Taxonomy of Analogue-Digital Hybrid Board Games. Grey italicised text refers to the corresponding paper section and/or table number.

3.4.2 Taxonomy Creation. We also chose to distil a taxonomy from these categories, in order to communicate relationships and hierarchies between the categories. To construct a taxonomy that illustrates how these categories relate and function together, we also borrowed terminology from the field of *Internet of Things (IoT)*, which is concerned with transforming "real-world objects into intelligent virtual objects" [34, pp. 164]. IoT is as much conceptual as it is practical, where every object has the potential to connect and communicate with any other object through a shared network [34].

Situating the taxonomy in the context of IoT, therefore, allows us to examine boardgame objects through their potential for "connectedness." To illustrate the relationships and hierarchies between categories in the taxonomy, we can imagine following the journey of a signal—the element which fuses analogue with digital—through standard data-processing principles. It starts with an *Input*: the first point of contact which creates the signal itself; followed by a *Process*: a digital "brain" that decides what the signal is for; and finally, it all comes together in an *Output*: an event that occurs and that is the final destination of the signal. Technology is part of every category, but has a different form or function in each. It is the enabler of the signal's journey. Technology can stand and function on its own, or in combination with, the analogue parts of a boardgame.

4 Results

As recommended by [36], we tabulated code frequencies for each of the final categories; these are shown in Tables 1–11. Figure 2 illustrates the full taxonomy. Each node of this taxonomy corresponds to a category employed in our analysis, with multiple subcategories of analysis within each of these used to code the data. (For instance, Table 1 provides examples and code frequency counts for the subcategories "move," "touch," "roll," "manipulate," and "voice" within the "Human-to-Object Interaction" category, which corresponds to the bottom-leftmost leaf of the taxonomy in Figure 2.)

4.1 Input (trigger)

Inputs are "triggers", so to speak, which send a signal towards processing. Inputs exist in two forms: as *input-devices*—objects and technologies in the physical space—and as *input-actions*, the forces which set things in motion. Input-actions and input-devices are interconnected in a way that one needs the other for the trigger to happen; this mutual dependency is represented with the dashed line between them in Figure 2. Input-actions can be further divided into *interaction* and *automation*, and input-devices divided into *components* and *technology-as-input.*

4.1.1 Interaction (input-action). Interaction happens as a result of deliberate human mediation. A player carries out an action which sets off a trigger. Interaction can be further categorised into *human-to-object* interaction (Table 1), where the trigger is the result of the player interacting with the object specifically, and *object-to-object interaction* (Table 2), where the trigger is a result of two or more objects interacting with each other. In the latter, there is still human mediation, however, the trigger only happens when the specific objects come into interaction. In that sense—whilst there is some overlap—the difference between the two is what the point of contact is at the moment the trigger is activated. The following two examples from participant ideas further illustrate this difference:

> *"Each player has a card with various information, including their hitpoints/health. When they are damaged, the player taps on the card, and the life points reduce automatically, along with a 'negative' sound to denote losing health." (P17, idea 3/8)*

In the example above, *touch*—or tapping on a card—is the human-to-object interaction, which sends a signal of the "player losing health" into a processor, which in turn outputs two effects: a thematic sound, and a change in the player's stats. In contrast:

> *"Cards with screens, I'm thinking Kindle-like. These could be blank but reveal information depending on where they are placed on the game board. Could be used in a detective type game, where the card only reveals the information you need if placed in the right place." (P16, idea 5/8)*

In this second example, the trigger is when the card is placed onto a specific space. It requires the card and the game board—two objects—to come into contact with each other, forming the object-to-object interaction. When they do, the signal is sent forward to a processor, and in turn, information is revealed as an output.

When looking at examples of object-to-object interaction, "placement" and "contact" are both similar in the sense that two objects come into contact with each other to form the trigger. However, there is a distinction to be made in the requirement of a specific area in which the object is placed, for it to become a "placement." Tables 1 and 2 show more examples of both human-to-object and object-to-object interactions, as well as the fine-grained codes used in our analysis and the frequency of each code.

4.1.2 Automation (input-action). Automation, in contrast, does not have conscious mediation from the player. It is a pre-programmed action which happens seemingly on its own, through the unfolding of gameplay. Automation can be *event-based*, where changes in the game-state or narrative cause the trigger; or, *conditions-based*, where preset conditions need to be met for the trigger to happen.

> *"Pieces that respond to the passage of time The longer you don't interact with them, the more they change/decay. 4x / civ-type strategy games - roads, buildings that break down when you don't interact with them." (P20, idea 6/8)*

This first example is conditions-based automation, where a certain amount of time needs to pass, which triggers the effects of "decay." Time is measured by a processor, and as conditions are met, an output is triggered accordingly.

> *"Meeples that can fall over when something bad happens to them in the game. You pull the wrong card and suddenly a third of all meeples on the board topple. That could be quite dramatic."* *(P9, idea 5/8)*

This second example is event-based: a chance-event of pulling "the wrong card" is the trigger. The processor is recognising the card drawn, and in turn creates an output: the effect of meeples falling over. Although here players pull the cards themselves, the information is hidden from them, and they are not directly causing the events happening.

> *"Thinking of Catan: when the dice are rolled and you have buildings on the correct resource, your buildings light up to remind you to pick up your resource. I am terrible of keeping track of when I should pick up resources." (P15, idea 1/8)*

This third example is conditions-based as well, requiring the player to possess certain resources and pieces. When the condition of owning them is met, a trigger automatically happens, in turn outputting lights. The role of technology in automation is enabling these triggers to happen on their own, through pre-programming. Tables 3 and 4 provide examples and code information for event-based and conditions-based automation.

Table 1. Subcategories of Human-to-Object Interaction, with examples and code frequencies for each.

Human-to-Object Interaction		
Interaction	**Examples**	**Code Frequency**
Move	The trigger is the movement itself, not the destination of the object.	25
Touch	Touching, pressing, tapping, squeezing or otherwise coming into contact with an object.	12
Roll[1]	Rolling dice (specifically).	12
Manipulate	Flipping, flicking, opening, closing, spinning or otherwise handling an object.	7
Voice	Speaking, singing, or otherwise making sound that becomes a trigger.	5

Table 2. Subcategories, examples, and code frequencies for Object-to-Object Interaction

Object-to-Object Interaction		
Interaction	**Examples**	**Code Frequency**
Placement	Area or proximity is the trigger.	47
Contact	Pieces stacked, attach, interlock, hit other component, etc.	15
Scan	Using an object to scan another object, e.g., a phone to scan a card.	11

[1]While "rolling" can be understood a specific form of manipulation, we coded it separately here because dice are a heavily represented component in boardgames, and participants specifically mentioned dice rolls very frequently.

Table 3. Subcategories, examples, and code frequencies for Event-Based Automation

Event-Based Automation		
Event	**Examples**	**Code Frequency**
Game Event	Game-state changes, in-game actions, in-game outcomes.	10
Narrative Change	Changes based on story events/progression.	5
Randomness/Chance	Chance-based events.	4
Game Progression	Events happening as the game progresses.	3

Table 4. Subcategories, examples, and code frequencies for Conditions-Based Automation

Conditions-Based Automation		
Condition	**Examples**	**Code Frequency**
Requirement Fulfilled	Certain score, certain resources, etc.	9
Set Time	Timer ends, passage of time.	8
Card/Dice Result	Results of rolls and draws specifically.	6
Completion	Completing routes, sets, buildings, etc.	5

4.1.3 Components (input-device). Boardgame components are analogue objects which become input devices by fusing with, or interacting with technology. They can house technology within them, which creates the illusion of only interacting with the component, not the technology. Or, they may remain fully analogue, and still contribute to the trigger through contacting other objects that have—or are—technology. When thinking about components, any given part (or parts) of a boardgame can become input-devices. These components can be custom—representing the thematic setting of the game—or standard, such as common dice and cards or generic cubes and tokens. Looking at examples from participant ideas can illustrate this further:

> *"Voice activated character standees that can refuse to move. If you give them the wrong order, a magnet in the board locks them in place." (P1, idea 3/8)*

This idea implies that ordinary player pieces are fused with a technology element which can interact with another object: the game board, which also has a technology element. When voice commands are recognised by a processor, the effect of "locked in place" is triggered.

> *"Cards which can feel the pulse rate of the player holding them, and which change their appearance. The cards represent police that become more suspicious if your pulse is elevated." (P1, idea 7/8)*

In this second example, game cards contain two forms of technology: one which can sense the pulse of the player, and another which creates a change in the card's appearance as a result.

> *"Dice which, when rolled in particular combinations, causes some specific reaction on the board (could be that the board spaces move around, doors open, walls rise, water pours in, etc). The reaction could be close to the player pieces or not." (P8, idea 1/8)*

This final example implies either the dice having a form of technology which can send signals, or the play area (such as game board) being able to recognise the results of rolls. Once a processor receives these results, an effect happens.

All of the above examples show how players imagine interacting with seemingly regular boardgame pieces. What enables these interactions to trigger effects beyond what would normally happen in analogue games, however, is the technology: whether it currently exists, or whether it is imagined, analogue objects can become *connected, intelligent components* through technology whilst retaining their analogue look and feel. Table 5 lists the subcategories, examples, and code frequencies for Components.

Table 5. Subcategories, examples, and code frequencies for Boardgame Components

Boardgame Components		
Components	**Examples**	**Code Frequencies**
Game pieces	Such as meeples, tokens, resources or thematic pieces.	96
Play area	Components on which play happens, such as game boards, modular boards, tiles etc.	75
Cards	Any type of cards from standard to custom.	46
Dice	Any type of dice, from six sided through rpg to thematic	26
Player pieces	Game pieces that represent the player, such as miniatures, standees, pawns etc.	22

4.1.4 Technology (input-device). Technology can be embedded into components and remain hidden, or, retain their form and be seen as they are. When technology is an input-device, it is usually a form of sensor which can send a signal forward to the processor. Sensors, as the name suggests, *sense and detect* through interaction and automation, as detailed in previous sections. They can detect touch, for example, or the place of an object. They can be as simple as using a phone—a device which has multiple sensors—which could read QR codes through a camera, or scan boardgame pieces or parts of a gameboard. They can be, however, a lot more intricate when imagining how they could be built into boardgame pieces themselves.

> *"MEEPLES WITH VR CAMERAS in [them] to enable seeing [the] board from their point-of-view." (P30, idea 7/8)*

In this example, the sensor—a camera—is built into meeples, sending a signal to VR headsets players would be wearing. Whilst there is no clearly defined trigger moment, there is continuous processing of the video feed, and continuous effect of players seeing gameplay as the meeples would "see".

> *"Pressure sensitive board, mimicking detecting - the more a player pushes down on a particular spot, the further you get ripples appearing on the board, showing locations of things buried under it." (P1, idea 5/8)*

In this second example, the game board has built-in pressure sensing—a form of touch sensor that is able to detect force—and ripple effects happen the more force is applied.

> *"A game that includes a motion sensor and reacts to motion. People need to gesture in front of each other." (P29, idea 1/8)*

This third example has an interesting human-to-object interaction, where player-movement is the trigger, as opposed to moving a boardgame component. The sensor—a motion sensor—is either built into an object, or is part of the game in some other way. This sensor then sends the signal to a processor. The resulting effect here is unnamed.

Sensing technology can create intelligent boardgame components which can send information to a processor through either interacting with players directly, or with other components. Whilst there are existing objects—such as smartphones—which are already used in existing boardgames, participants recognised many possibilities for utilising sensing technology that is built directly into components themselves (Table 6). Notably, often participants described sensing that can remain hidden, potentially harnessing the benefits of technology whilst keeping the analogue interaction in focus.

Table 6. Subcategories, examples, and code frequencies for Input Technology

Examples of Input Technology		
Sensors	**Examples**	**Code Frequencies**
Location Detection	Proximity, orientation, etc. Sensors which recognise the place of objects.	31
Detection	Umbrella term for unspecified detection.	23
Identification	Sensors which can recognise things, e.g., RFID, NFC, barcodes, camera etc.	18
Touch	Contact with objects, e.g., pressure, button, etc.	9
Motion	Detects object or player movement.	6
Wearable Device	Smart watch, fitness band, etc. Can sense players, such as heart rate.	5
Temperature	Senses the temperature of objects.	3

4.2 Process

Process is the intermediary step where the signal is received from the input, and processing is applied to determine what output(s) to trigger. It is a type of technology which has two parts: *processor-device*, a form of hardware which is capable of running scripts, and *processing-action*, the script itself which runs on the hardware. Like the input-device/input-action pair in Figure 2, both a processor-device and a processing-action are necessary for processing to happen, and here "technology-as-process" is linked to these nodes to underscore that technology may play various roles in both these parts. The role of the "process" components are to take in the signal as information from the trigger, analyse that information, make decisions about it, and send it forward to an output. This is, arguably, where most participant examples become somewhat vague. Nonetheless, highlighting the importance of this step should aid analogue-digital hybrid boardgame designers and researchers in understanding the potential avenues future designs can take.

> *"Dice for games where when they land they record the number onto your attached app which goes right to the dm so you can't cheat (with any bonuses you've attached to character sheet etc), and the side it's landed on will glow until another roll is made. So if you drop a dice under a chair etc you'd know what it was too. Sound effect on d20 for a 1/20 roll." (P3, idea 4/8)*

In this first example, there is an obvious processing method: an app on a phone, which can understand the results of dice rolls. It then sends the signal forward, and outputs sound effects on certain rolls. There is, however, another form of processing here: dice "knowing" when they have been rolled. This implies either information between the dice and the same app, or, some form of processing built into dice themselves. There is a second output here as well, sides lighting up until they are re-rolled.

> *"A game where you need to teach a little robot to move to a goal. The robot uses a reinforcement learning algorithm and the user can help it learn better by providing obstacles or certain prompts. It's a coop quick physical tamagotchi-style game." (P29, idea 6/8)*

Once again, the processing is named in this example: a reinforcement learning algorithm, which is a form of machine learning. Input is created through "obstacles or prompts", which determine how the algorithm—and the robot—learn.

> *"Moving one game piece automatically moves another - like the pieces are connected through the board. The idea is that the players are connected telepathically." (P8, idea 4/8)*

This third example, however, does not specify how processing happens. It implies a connection between two game pieces and the game board. Movement is the human-to-object interaction which is the trigger here. However, it is unknown where the signal is sent by this trigger. There could be, for example, a micro-computer built into the game board. Or, there could be an external device which receives the signal. This device then sends the signal to the second boardgame piece, and the output is the automatic movement of this piece.

Whilst how processing is carried out might be difficult to imagine without significant knowledge of the current workings and possibilities of technology, these examples nonetheless illustrate how players envision the future capabilities of analogue-digital hybrids. Table 7 lists additional examples and the code frequencies related to processing.

Table 7. Subcategories, examples, and code frequencies for Process Technology

Examples of Process Technology		
Technology	**Examples**	**Code Frequencies**
Processing	Connection & Intelligence, e.g. AI or ML algorithm, remote access server, etc	52
Processor	Mobile device, computer (microcontroller, chip), breadboard, etc.	20

4.3 Output

We can think of outputs as the outcome of the initial trigger input. It is the end destination of the signal that was created by the trigger, and it has two parts: an *output-device*—a technology device or a boardgame component—and an *output-effect*, which is the effect presented through technology, or which "happens" to the component. The dashed line between these in Figure 2 reflects the fact that both are needed for an output to occur. This outputted effect is why the whole interaction happens in the first place, and it is an event which utilises the strengths of technology compared to analogue alone.

An output-effect can be *sensory*: engaging the senses of players; it can be *object-behaviour*, where boardgame pieces "do something" on their own; and it can be a *game-state change*, where the outcomes of the game are altered. Furthermore, effects can contribute to a game's thematicness through providing atmospheric elements or through representing in-game events in the 3D space. They can also aid gameplay, or present novel game mechanics.

4.3.1 Sensory (output-effect). Sensory effects (Table 8) can help convey a setting of a boardgame through strengthening its thematic elements by adding "more" of what is already there. For example, a boardgame set in a zombie apocalypse would already have art and components representative of the theme. Utilising audio, however, can provide an additional layer to elevate the game's perceived thematicness:

> *"Sound effects on boards to add music of theme elements like zombie noises if you're near a hoard." (P3, idea 7/8)*

Other design scenarios envisioned other types of sensory effects to convey a setting, for example:

> *"Pawns that change temperature as you move them around the board into different climates." (P1, idea 1/8)*

In the example above, themes of climates are reinforced through feeling the temperatures associated with those climates, through touch. In the example below, scent is utilised similarly, by reinforcing a setting through scents associated with a location:

> *"Scent producing meeples which provide a scent appropriate to the board location. Jungle/mine/sea scents etc." (P15, idea 4/8)*

Participants envisioned sensory effects not just for strengthening a theme, but also as novel game mechanics.

> *"In a secret identity game (Werewolf, Mafia etc.), players are each given a player token at the start of the game, before they know which players have which roles. And then, as they all hold their tokens and look around at one another, one or more players' tokens silently vibrate in their hands, letting them know that they're the ones who need to betray the group. This is fun, because it'll involve a moment where everyone is trying to maintain a straight face, while reading the expressions of their friends for clues." (p9, idea 1/8)*

In the above example, a popular party game type—a hidden identity game—could use haptics in place of cards for players to find out their identities. This would be a spin on typical existing mechanics, and could further enhance the core of these games, which is to deceive opponents. Similarly, in a spin on deduction games, visual effects could be utilised in a "hot-and-cold" manner to guide players when searching for a location:

> *"Game board with holes in a detect the hidden intruder game. Pieces moved by the players are detected by the board which also tracks the movement of the hidden thingy (e.g. Whitechapel). The board can then illuminate with a range of colour lights (green/amber/red) depending on how close they get." (P21, idea 8/8)*

Table 8. Subcategories, examples, and code frequencies for Sensory Effects

Sensory Effects		
Effect	**Examples**	**Code Frequency**
Audio	Thematic music, sound effects, reactive audio, directional sound, etc.	74
Visuals	Projection, light, colour, steam, fog, moving image	29
Touch	Haptics, temperature	8
Olfactory	Scent	4

4.3.2 Object-behaviour (output-effect). Whilst boardgame components are often input-devices, they can also become part of an output effect through behaviour. Behaviour is triggered the same way as sensory effects, and can manifest in a variety of ways. These behaviours can simulate thematic evens in the 3D, physical space—the space in which play happens—through "acting out" actions on the board. The way technology contributes to this effect is that behaviours are autonomous in the sense that even if they happen as a result of a player-induced trigger, the behaviour is carried out on its own, seemingly by itself.

> *"Game pawns that change shape and weight over the course of the game with time, mimicking ageing. As they get bigger and heavier it is harder for them to move, and they move more slowly." (P1, idea 6/8)*

Transformation is a form of behaviour in which the properties of game components change in some way. In the above example, the thematic event of "ageing" is physically represented through the transformation of the pawn. The trigger here is passage of time through automation, and processing is tracking the time and outputting the component change. Even though it might be difficult to imagine this example as a real boardgame, it illustrates how this player envisions technology's future capabilities to create novel experiences.

> *"A dexterity/stacking game based on articulated figurines. Depending on their configuration, such as which creatures they are next to or have affinities with, different figurines can activate their limbs and animate, changing the game state." (P2, idea 2/8)*

In this second example, object-to-object interaction through proximity detecting is the trigger, and the outputted object behaviour is pieces animating. There are various ways in which objects can animate in a boardgame, such as through automatic movement of pieces, objects being released, or pieces falling over. These behaviours could represent dramatic, thematic events, such as in this next example:

> *"Car/ship pieces pulled or pushed apart via magnets to simulate explosions." (P6, idea 7/8)*

Object behaviours overlap with visual sensory experiences as they are inherently perceived visually by players. However, the distinction here is the involvement of physical objects to a greater extent. Sensory visual effects can happen independent from boardgame pieces, such as projections or effects delivered through screens. Object behaviour always involves a boardgame component, and the piece will either "act on its own", or go through a transformation. Still, there are instances where we can classify an effect as both object behaviour and sensory visual effect: for example, if a meeple changes colour, it would be considered both. Table 9 provides the subcategories, examples, and code frequencies for object-behaviour effects.

Table 9. Subcategories, examples, and code frequencies for Object Behaviour Effects

Object Behaviour Effects		
Effect	**Examples**	**Code Frequency**
Change Properties	Transform or change appearance, change size, change temperature, image/text appears on object, change colour	38
Animate	Automatic movement (whole piece or parts), objects released, objects open (doors, etc), pieces auto-distribute, objects fall, object shakes, etc.	33
Lock-in-place	Objects automatically locked/prevented from movement	5

4.3.3 Game-state-change (output-effect). Output effects can influence the course of the game through handling game-state changing information. These game-state changes can advance gameplay, narrative, player scores and other statuses within the game. Game-state changes happen in all boardgames, with or without technology. Technology can be utilised, however, to automatically record, store, calculate and track in-game events and statuses. After the game-state is altered, this new status then needs to be signalled to players. As such, game-state change effects are followed by sensory or component behaviours:

> *"Each player has little "unit" pieces of their colour. To capture an opponents piece, one of your units jumps on top of the opponent's piece. At this point, the opponent's piece changes colour to your colour to show it is now owned by you now." (P17, idea 2/8)*

In this above example, the trigger is object-to-object interaction when two pieces come into contact (the "jump" is possibly manual), and the game-state change effect is that an opponent's piece has a new status: "captured". There is a visual sensory effect here signalling the status change when the opponent's piece changes colour.

> *"Spaceship miniatures battle games could be made more interesting if instead of resolving combat through open dice rolls you instead point your camera at the target ship, and by recognising the ships profile the probability of hit/miss is calculated and the outcome determined automatically, including the possibility of critical hits and the consequences they have on gameplay." (P24, idea 5/8)*

Here, the trigger is scanning spaceship miniatures with a smartphone camera to find out their battle stats. These stats then go through processing in the process step, and the resulting status change—whether it is a critical hit or not—is determined and displayed to players. Without displaying the status change on an output-device, the results of the battle would be lost on players.

> *"In a narrative-based detective game, a meeple piece is placed onto a location card, and a spoken story of that location is played. Or the meeple is placed onto a person, and a spoken version of a conversation with them is played." (P17, idea 8/8)*

In this final example, storytelling is aided by technology. The trigger is object placement, and upon placement, the game-state effect is advancing the narrative. This narrative status-change is delivered through a sensory effect: dialogue through audio. Even though game-state change effects require the presence of another output-effect, or output-device, to become "visible" to players, these effects still utilise technology through relying on triggers and processing. The resulting status changes are more technology-adjacent in the sense that they happen because of, and by the use of, technology—as opposed to be technology themselves—but they form an important part in the overall analogue-hybrid player experience. Game-state-change effect subcategories, examples, and code frequencies can be seen in Table 10.

Table 10. Subcategories, examples, and code frequencies for Game State Change Effects

Game State Change Effects		
Effect	**Examples**	**Code Frequency**
Status Change	Automatic calculations, send-, receive-, record-, track-, exchange information, hidden information, narrative change, clues revealed, give instructions etc.	77

4.3.4 Output-Device. An output-device is technology, or an object, which can enable the effects previously outlined. For example, sensory-effects such as audio would need speakers—an output-device—to be audible. Similarly, visuals would need some form of projector, a screen, augmented reality (AR), etc. Boardgame components can also become output-devices when object behaviour effects happen to them. Examples of output-devices can be seen in Table 11.

Table 11. Subcategories, examples, and code frequencies for Output Technology

Examples of Output Devices		
Device	**Examples**	**Code Frequencies**
Screen	LCD, mobile device, computer, built-in (such as built into cards).	12
Speakers	Connected speakers.	5
Wearable	Glasses, headphones, etc.	5
AR	Augmented Reality projection.	4

5 The Analogue-Digital Hybrid Board Game Ideation Deck

Complementary to the taxonomy, we have designed a card deck aimed at non-academic audiences—particularly boardgame designers—as an alternative way to present the information detailed in the previous section. We have made a digital version of this deck available as a free and open-source resource.[2] These cards take inspiration from previous examples such as: *Generominos* by Compton et al. [13], which is an ideation deck to aid in the design and analysis of new controller systems; Rogerson et al. [42]'s SMeFT deck for aiding the design of hybrid boardgames for "distanced" play; and, a review paper by Roy and Warren [46] into card-based design tools. Roy and Warren analysed 155 card decks which can be used for design ideation, concluding that due to their unique characteristics and engaging nature, cards have certain advantages over other, similar tools when it comes to aiding design. According to the authors, user feedback also indicates that designers enjoy using them, and find them useful. However, they can be prone to being confusing, or presenting too much or too little information. Furthermore, when compared to other methods to generate ideas, groups using cards did not produce better quality ideas than groups who did not. However, both Rogerson et al. [42]'s and Compton et al. [13]'s validation of the decks had positive findings in their helpfulness for design and enjoyment for use, and a number of other validation and review studies for card-based design tools [1, 19, 21, 33, 53] evidence the benefits these decks can provide in the ideation process.

The purpose of our Hybrid Board Game Ideation Deck is not to be better than other design and brainstorming methods. Instead, it was created to be used together with the taxonomy, or as a reminder of the ideas within the taxonomy, in a more visual and distilled way. In addition to providing a more accessible representation, the cards afford interactive use meant to be conducive to design ideation: they can be shuffled, randomly drawn, matched together, swapped, etc.

The deck consists of 35 cards ordered into 4 groups, following mostly the same structure as the taxonomy, with a few notable differences. First, cards are organised into Interaction, Components, Technology and Effects, as opposed to Input, Process and Output. This is to make it simpler compared to the taxonomy. As a result, Automation is contained within the Interaction card group. Furthermore, technology here has its own group—as opposed to the taxonomy where it is divided by its function—however, sensors are collected as a separate, "golden" card, similar to a Joker card in a standard playing card deck. At the bottom of every Technology card, and the Sensor card, a circle at the bottom left, centre or right corner of the card indicates whether the technology can be used as an input, process or an output. Technologies that fall into more than one of these categories have all indicative circles, with corresponding colour coding. An example of a card from each group can be seen in Figures 4 and 3 respectively. The full deck can be found within the supplementary materials submitted with this paper.

[2] URL removed for anonymous review. The deck has been uploaded as supplementary material to this paper submission.

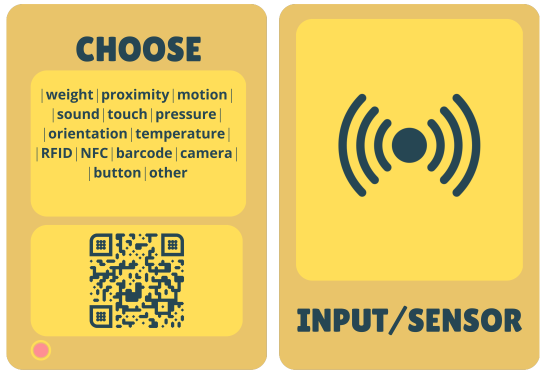

Fig. 3. The Sensors Ideation Card, with a pink circle in the bottom-left corner indicating its "input" status. A QR code at bottom links to a URL with novice-friendly sensor descriptions.

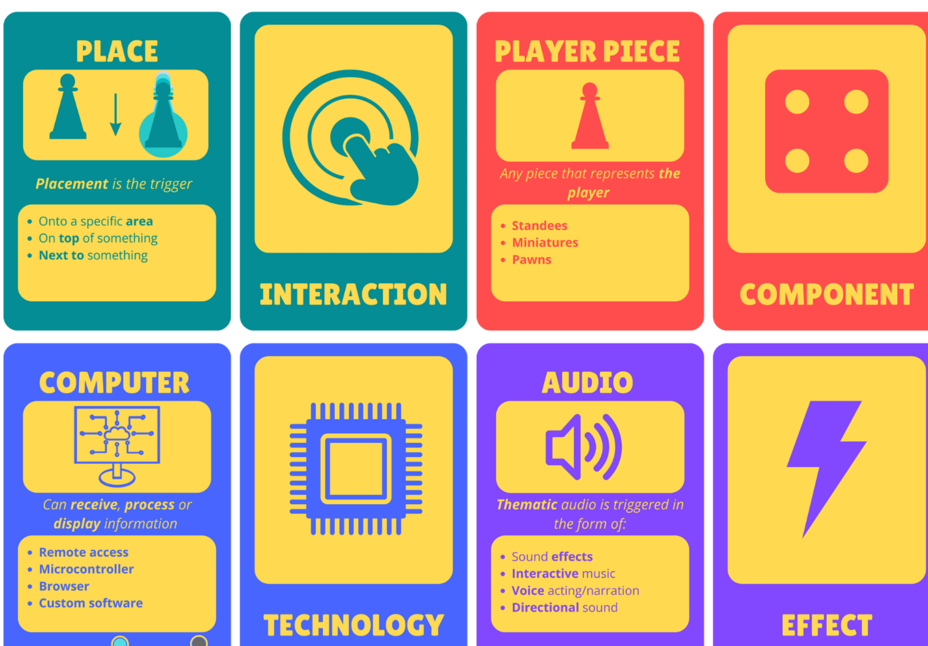

Fig. 4. Example Ideation Cards for Interaction, Components, Technology and Effects. Circles in the middle, and bottom-right corner on the Technology card indicate that it is both a Process and an Output.

6 Discussion

The results of this study confirmed that players envision novel interactions with hybrid analogue-digital boardgames that go beyond the use of digital screens. The taxonomy presented in this paper is useful in illustrating the current and future potential of technology in many aspects of a hybrid boardgame, from interaction to the resulting effects. Whilst some of the examples in players' design ideas seem impossible without further technological advancements, the taxonomy provides theoretical exploration of the design space, from a perspective which favours player experience. As shown in previous work [4, 30], players' feelings towards technology are mixed, with one of the leading reasons for dislike being the presence of screens. Whilst there is evidence of the importance of analogue pieces in the enjoyment of boardgaming as a hobby [40], technology has clear roles and benefits within analogue games as well [43, 44]. Future analogue-hybrid boardgame designs could potentially utilise existing boardgame pieces as input devices—with interactions players already do and enjoy—and harness the benefits technology can provide, whilst making technology less "visible" to players.

One of these benefits include the potential of contributing to thematicness [17]. Players' designs in our study suggest that reinforcing theme with sensory elements (e.g., the example referenced in section 4.3.1 of adding zombie noises) could potentially aid how realised the setting is perceived by players. According to Farkas et al. [17], the more realised a thematic setting is, the more it is possible for players to perceive a game as thematic.

Similarly, Farkas et al. [18] found that a more realised thematic setting can also contribute to certain types of immersion. According to the authors, players can feel submerged into a game and its setting when the setting is sufficiently detailed. Whilst this thematic setting already has to be strong though art, components and narrative in the analogue parts of the game, technology could provide additional sensory input which—to some players—has been missing from purely analogue experiences, preventing players from experiencing them as immersive. Sensory elements, such as audio or moving visuals, are traditionally absent from boardgames even though they are said to contribute to immersion in video games [5]. Therefore, using technology to strengthen the audio-visual capabilities of boardgames could potentially bring these experiences closer to the types of immersion experienced in video games.

As with many aspects of player experience, both thematicness and facets of immersion happen when the experience matches a player's expectations of the experience. Still, technology has the potential to facilitate these experiences. Sensory Effects have a clear advantage here, however, it would also be interesting to see how Component Behaviour could be utilised in future boardgame designs to enhance the immersive/thematic capabilities of boardgames.

Whilst the taxonomy presented here has some clear distinctions between categories, these categories are not exclusive. Nothing would stop a designer from combining all three Output Effects—sensory, object-behaviour and game-state-change—for example, in the same analogue-digital hybrid boardgame. The purpose of this taxonomy—alongside the ideation card deck—is to be used, either as inspiration, or as information in future boardgames design and boardgames research, through understanding how players envision technology implemented into analogue experiences.

Our taxonomy complements the Hybrid Digital Boardgame Model (HDBM) proposed by Rogerson et al. [44]: most obviously, that model captures the key functions (e.g., housekeeping, calculating) that technology plays in *existing* (as of 2021) boardgames with apps, whereas our taxonomy reflects *potential* uses of technology in boardgames, as envisioned by participants who were encouraged to think beyond the exclusive use of screens. Further, the scope of our taxonomy spans Inputs, Processes, and Outputs, whereas the HDBM focuses mainly on the purpose or effect of a technological process. Our study also focused participants' ideation activities around technology that could increase thematicness, which arguably encouraged ideas related more to the "Storytelling" HDBM category than the others. Nevertheless, some of our participants did identify scenarios in which technology was used to follow and to change the status of game-state, or to automate certain player tasks—such as calculations or score keeping—and these align with the HDBM categories of calculating and housekeeping.

7 Limitations and Future Work

A limitation of this research is that the usefulness of the resulting taxonomy, alongside the complementary ideation deck, are not tested with boardgame designers (who are the main target users of the ideation deck). Whilst the main focus of this study is understanding boardgame players and their ideas, designers could potentially benefit from many of the findings presented here, and this is one motivation for creating the ideation deck. However, we do not yet have evidence of whether or how designers might make use of these tools.

We therefore plan for near-term future work to involve designers in evaluating and refining the design of the cards; ideally, the final version of this deck should reflect feedback of this target user group. Subsequently, design workshops with designers using the cards could be used to both validate the utility of the cards and provide insight into how designers might identify new possibilities for hybrid games. Such work could potentially inform a rule set for using the cards, providing additional (optional) structure to designers' interactions.

Our experiences with game designers and students in related areas suggest that another barrier to the design of hybrid games—not addressed in this study—-is designers' lack of knowledge and/or confidence in how sensors, actuators, and related technologies work in practice. The card deck could be augmented, for instance, with an online resource (e.g., a database of sensors organised by category) which designers could use to begin to move from ideas to working prototypes, and to facilitate communication with technical collaborators.

Another limitation is that the majority of participants were hobbyist boardgame players who have played a hybrid boardgame before. This knowledge of current practices for technology implementation could potentially create a bias for these participants. Further, the results of this study cannot be generalised towards the wider population, as more casual players and non-boardgamers could potentially have different priorities and ideas towards future hybrid boardgames. The players in our study also came from a relatively narrow set of geographic regions, so are not necessarily representative of players from regions with different gaming cultures or relationships to technology.

Our study focused game players' ideation activities around technology that could enhance thematicness. As such, our findings are not representative of what players might imagine for technology that aims to serve other purposes. For instance, technology could clearly take many shapes to improve accessibility to players, and one participant scenario in our study did explore components that could assist colour-blind and blind players. However, a different ideation task focus and different participant group (e.g., players with disabilities or those experiencing access barriers) would be needed to establish a player-led understanding of the design space for technologies that improve accessibility. As we did not recruit for participants with expertise with any particular technologies (e.g., sensors or microcontrollers), participants' ideas were not constrained by what is feasible or affordable to implement with current technology (though this was intentional on our part, as our aim was to inspire new approaches to boardgame design rather than provide a prescriptive framework or practical tools for building new games).

Finally, participants' feelings towards hybrid games were not assessed. We assume that participants had no strong feelings against technology inclusion in this study. However, we do not know whether any of the future ideas presented would potentially "fix" already existing problems towards technology inclusion presented in other research [4, 30].

8 Conclusion

This research has investigated how boardgame players imagine alternative ways of interacting with technology in analogue-digital hybrid boardgames. The resulting taxonomy categorises the possible ways in which technology can be utilised to trigger, process and output various effects, taking into account potential advancements in technology's capabilities in the future. The main contribution of the taxonomy is to expand the design space for novel hybrid boardgame experiences—at present and in the future—and for designers and researchers to use as inspiration, and as a reference, in their future works when considering hybrid boardgames from a player interaction-centric perspective.

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