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RESEARCH ARTICLE

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From treetops to tabletops: a preliminary investigation of how plants are represented in popular modern board games

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Societal Impact Statement

Plants have been elements in games throughout history. In an era where "digital push-back" is becoming more common, the impressions that representations of plants in board games have on an audience is not to be overlooked. By acknowledging the importance, beauty and history of the botanic world and its considerable impact on the daily lives of human beings connected to it, modern board games may offer an entertainment route towards awareness as well as an educational resource to challenge plant blindness.

Summary

Plant blindness is the inability to appreciate plants in one's own environment, in the biosphere as a whole and their relationship to human affairs. Here, we discuss a community of interests in which we suggest that an appreciation of plants is vital for success: namely the world of modern board gaming. We present a classification system for the presentation of plants in the 500 most popular modern board games, where games are categorised based on their complexity, and representation and portrayal of plants. This initial mapping exercise defines a potential scope for the future analysis of how modern board games may offer a novel and interactive entertainment mechanism to challenge plant blindness and a framework for future analysis work in this area.

KEYWORDS

active learning, board games, botany, edutainment, photosynthesis, plant blindness, plants, taxonomy

1 | HISTORY OF MODERN BOARD GAMING

Board games in some form have been played in nearly all societies and cultures throughout human history, reflecting the values and culture of the time (Booth, 2015). Recreational activities have often reflected the sociological, historical and cultural framework that birthed them (Begy, 2015; Ranchhod & Vieira, 2014). Many primordial board games simulated war (Allen, 2002) and the concept of luck in the form of a deity-driven blessing, not just probabilistic outcome (da Col, 2012). Wooden sticks, split reeds, nuts, seeds and other plant materials often formed the components of these early games (Voorhies, 2013), being the most readily available and accessible resources. *Mancala* is arguably the first board game where plants themselves were more than just physical gaming components. Thought to originate somewhere between 1,000 and 3,000 years ago, this game is still played today

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FIGURE 1 Plants in board games. (a) *Mancala* using plants as a primary artistic element, shown with glass beads, but traditionally played with seeds; (b) the beautiful tree art on the cards and box of *Arboretum*; (c) *Takenoko* with its striking bamboo columns forming part of the primary gaming artwork and; (d) *The Settlers of Catan* the arguable forefather of modern board gaming

(Schädler, 1998) (Figure 1a). The *Mancala* playing pieces are traditionally seeds, beans, stones or other small undifferentiated counters, and the act of moving them around the board is termed "sowing". This is possibly the first game to feature agricultural themes at its heart and it has been hypothesised that it may even have been inspired directly from the creation of agriculture itself (Bromiley, 1979).

It is generally agreed that the transformation from classical and mass-produced games into the current form of modern board games can be traced back to Germany in the 1980s (Woods, 2012). The focus of board game design shifted to keeping players entertained by eliminating the often brutal, luck-driven, exclusionary style of gameplay in older games (such as *Monopoly* [Hasbro, 1903][1]), replacing it with more inclusive, interactive and engaging experiences (Booth, 2015; Woods, 2012). The game often credited as the starting point of this modern board game revolution is *The Settlers of Catan* [Kosmos, 1995] (Figure 1d), which embraces thoughtful pattern-making and long-term strategic

[1]Please note that in this paper all board game titles are italicised and followed (in square parentheses) by the first publisher and the year of first release. This information was found on www.boardgamegeek.com. The authors acknowledge that not all games related to plants can be reviewed for this paper.

planning (Woods, 2012). The collaborative nature of its play, limited player exclusion and alluring visual design proved immediately popular on release and have remained so ever since. To date, more than 22 million copies of *Catan* in 30 different languages have been sold (McNary, 2015). It is, perhaps, no coincidence that the increasing popularity of modern board gaming closely tracks the increasing global ubiquity and social pervasiveness of the internet. This might, perhaps, be attributed to a "digital pushback": a trend reported by public media sources not just in the UK, but across Europe and America (Boycott-Owen, 2018; Graham, 2016; Wüllner, 2017). Arguably, modern board games now have a level of cultural relevance that could be mentioned in the same breath as comics, videogames, books and film (Heron, Belford, Reid, & Crabb, 2018). They are considered a "legitimate form of media", with board games reflecting societal and cultural norms, values and beliefs, forming essentially a snapshot of society at that time (Flanagan, 2009).

As well as offering a social experience, the incorporation of games into the lives of children and adults alike offers an opportunity for learning (Taspinar, Schmidt, & Schuhbauer, 2016). Games that fall into the "edutainment" category support the shift in teaching from a listen-and-learn style to active learners methodology (Garris, Ahlers, & Driskell, 2003), with evidence of implementation of both digital and physical components or role playing games for learning in higher education (Lean, Moizer, Towler, & Abbey, 2006). Games also offer a way to construct and preserve cultural memory, creating a simulation of a historical event or time in the form of a board game (Begy, 2015). Given that board games are now being included in the wider cultural discussion and tend to reflect society's values, it is important to consider how they incorporate and represent plants, as they offer an opportunity for wider public education, engagement, and knowledge about this subject matter.

2 | HOW BOARD GAMES CHALLENGE AND REINFORCE PLANT BLINDNESS

Plant blindness is the inability to appreciate plants in one's own environment, in the biosphere as a whole and their relationship to human affairs (Wandersee & Schussler, 2001). Here, the authors propose that plant blindness in modern board games is addressed primarily through the incorporation of accurately represented plants as a key artistic element and the treatment of plants within the game as a sophisticated, complex element of play. This can be accomplished via a number of methods; plants as a theme, as a constraint, as characters, as aspects of a supply chain or through the replication of botanical processes.

2.1 | Plants as a theme

Many modern board games are often characterised by a "theme": the artwork, the aesthetics and feel or atmosphere a game portrays (Woods, 2012). These themes can be wildly disparate from the exploration of outer space to conquering the Wild West, and everything in between. A theme is different to the "mechanics" of a game: the way it is actually played, for example using cards, rolling dice or placing tiles, often in varying combinations to create a myriad of different experiences (Woods, 2012).

Arboretum [Z-Man Games, 2015] is an example of the beauty of plants appropriated as a primary gaming theme. Players are competing to create the most beautiful garden by collecting and organising sets of cards (Figure 1b). This game presents plants in the form of colourful tree patterns as its visual design, but this is a purely artistic embellishment; these tree patterns could be replaced with animals or abstract patterns and the game remain the same. *Takenoko* [Bombyx, 2011] uses a clever plant-related gameplay mechanic, where players stack plastic parts to grow coloured bamboo to match patterns on objective cards (Figure 1c). Both of these titles echo the classical human fascination with the ordering and control of nature prevalent since classical times (Albers, 1991). We argue that those games that have appropriated the beauty of plants for a secondary theme may not directly challenge plant blindness; on the other hand, plants that are represented realistically, scientifically or provide a key and integral aspect of the game do.

2.2 | Plants as a constraint

The constraining nature of the variable availability of plants as resources is also important to subvert plant blindness. *Agricola* [Lookout Games, 2007] probably best exemplifies the constant pressure to gain plant-based resources to feed workers. Over a typical 4-hr game, players grind out an existence on a subsistence farm, always facing the overriding responsibility of generating sufficient wheat and vegetables to feed their own household, balanced with the desire to build pens and fill them with higher value animals such as sheep and cattle. Upgrading buildings allows players to gain more workers, but they in turn become extra mouths to feed. Similarly, in Aztec-themed worker placement game *Tzolk'in: The Mayan Calendar* [Czech Games, 2012] players periodically need to feed their workers with corn and instead of considerately farming to gain this necessary currency, a player may choose to burn the forests to obtain it. In keeping with the Aztec theme, this results in "angering the gods", and a player suffers gameplay penalties for doing so. This balance of pressured competitive resource acquisition begins to introduce a more interesting interaction between the concept of play and plant exploitation, which we argue subverts plant blindness, as to ignore the value and importance of plants would mean to lose the game.

2.3 | Plants as characters

The representation of plants as a mystical source of natural energy or represented as characters is a traditional backbone of many modern board games with a fantasy setting. Anthropomorphising plants can arguably subvert plant blindness by directly giving plants agency and power. In *Spirit Island* [Greater Than Games, 2017], players cooperatively control evocatively named spirits defending their island from colonisers. The invaders are seen as blighting the land, ironically

FIGURE 2 Board and thematic plant-related cards of (a, b) *Spirit Island;* and (c) *Terraforming Mars*

playing the role the players, themselves, have probably played in many games: stealing resources, pillaging the land, building cities and exploiting resources. Only this time, it is the players themselves that rouse the forces of nature to protect and save the island. One spirit: "A Spread of Rampant Green" is a plant-like creature that narratively is "more concerned with the process of life than with things like 'consequences'" and can be paired with fearsome powers such as "Death Falls Gently From Open Blossoms" and "Twisted Flowers Murmur Ultimatums" (Figure 2a,b). In contrast, *Magic: the Gathering* [Wizards of the Coast, 1993], arguably still the most popular collectible card game worldwide, has an entire mythology and lore tied to the concept of "Forest" as a mana source to summon fearsome creatures and cast powerful spells. Thematically, the use of plants as a generic basis to fuel magic is similar to the presentation of plants as a generic source of food, and therefore could be argued to be more supportive of plant blindness.

2.4 | Botany in games

If plant blindness is encouraged by the generic or misrepresentation of plants, then the accurate representation of plant processes and biology is an important route to challenging it. Biology is a discipline of chains, patterns and processes, and so it is no surprise that it has been the source of inspiration for many board games. For example, themes of evolution and ecological competition sit at the heart of critically acclaimed board games like *BIOS Genesis* [Sierra Madre Games, 2016], *Dominant Species* [GMT Games, 2010] and *Evolution* [North Star Games, 2014]. A commentary on the education and entertainment value of three evolution themed games reached Nature in 2015 (West, 2015). Even highly granular scientific processes have been examined in *Cytosis: A Cell Biology Board Game* [Edinorog, 2017] (a worker placement game based on the inner functioning of the cell) and *Pathogenesis* [WIBAI Games, 2017] (a game about a bacterial assault on the human immune system). There has also been a published review on the use of board games for education in the medical profession (Bochennek, Wittekindt, Zimmermann, & Klingebiel, 2007).

Botany was recently placed front and centre in the popular board game *Photosynthesis* [Blue Orange, 2017] (Figure 3). Played in phases that represent seasons, it requires players to place saplings on a hexagonal board, gaining light points, the main currency in the game and based on how much sun reaches a player's trees. This is determined by tracking the path of light emitted from a sun token, which moves around the board each phase. Players upgrade seedlings to larger, more substantial trees, which cast shadows onto whichever unfortunate saplings grow behind them.

2.5 | Plants in production chains and processes

A common play mechanic that unifies even games with radically different themes is the concept of resource management: where a

FIGURE 3 The gaming components of *Photosynthesis* showing the player boards and the main board incorporating a large cardboard sun. Tree colour is not critical to the game, denoting player ownership rather than tree function. "Light points" are accrued each round and spent on upgrading trees or spreading new seeds

player needs a currency or raw materials to build, trade, feed and ultimately win (Woods, 2012). In the games that use this mechanic, plants are almost always one of the simple resources available, often in the form of wood, corn or wheat, and, as in real life, tend to form the base of a production chain. In these chains, a raw material is often upgraded, affording the player better or higher valued materials, game progress or the all-important victory points towards winning the game. In *The Settlers of Catan*, players exchange grain and wood (along with wool, clay and ore) amongst themselves as the game develops, ascribing a relative value to each resource depending on whether a player has a monopoly on a certain resource and the desire of other players to get their hands on it. This prototypical economic interaction is a familiar trope across many board games, where players have a limited set of choices each turn with which to maximise the throughput of resources to attain victory, through either social interaction or intelligent play (Woods, 2012). When plants as resources are generic, for example, presented as a simple nondescript token, or can be transformed or traded in for more valuable products, we argue that players exploit plants purely as a means to an end to win the game, thus encouraging plant blindness.

Many games also make little distinction between plants and "food" resources (if they are distinguished at all) and if they appear, plants are often considered as a starting point to upgrade into something more exotic. For example, *Oh My Goods!* [Mayfair Games, 2016] defines plants as sources of low sophistication products, such as wheat and wood, which are purely a stepping-stone to more desirable buildings and outcomes, such as baking bread or making charcoal. In the same vein as exploitation of plants as a generic undifferentiated resource, plants presented as purely raw materials also encourage plant blindness. This can be contrasted with the handling of plants in *Terraforming Mars* [Fryx Games, 2016] where players assume the roles of various corporations preparing Mars for human colonisation. Here, plants are a resource once again, but their status is vastly different. Thematic cards enforce interlinking between climate and plant management and when players add a green plant tile to the board it increases the planet-wide oxygen levels (an important timer in defining when the game will end) (Figure 2c). Plants in *Terraforming Mars* are powerful: they no longer languish at the base of a production chain but sit alongside resources like steel and titanium on a valid route to victory. It is possible for players to play the role of a corporation entirely focused on plants and to build their personal empire with a plant-centric strategy.

The aim of this study was to scope the representation of plants through the categories outlined in the introduction and establish the appearance of these categories in a subset of modern board games. Because of the various categories, types and complexity of board games available, a binary classification framework based on the previously discussed themes in this section was created and a restricted list of commercially and critically successful games were analysed across these criteria.

3 | METHODS

To investigate how board games might influence players' plant blindness, the authors of this paper created 20 binary categories to assess each game in the selection for its coverage and presentation of plants. Sixteen of these categories are outlined in Table 1. These categories, along with an additional four binary fields indicating the board game complexity (shown in Table 2), were used to drive our analysis by ordering the plant content of the games into a structured visual format. For the purposes of our analysis no quantitative grading of whether these categories support or subvert plant blindness was made.

The website BoardGameGeek (BGG, https://boardgamegeek.com/) is approaching its 20th anniversary and is seen as a universal

TABLE 1 The 16 binary classifiers on how a board game presents plants and the seven aspects those classifiers belong to

Aspect	Classifier	Description
Artistic Representation	Primary	Plants form the primary artistic theme components of the game. Plants are clearly defined morphologically and are recognisably the most eye-catching aspect to the game when laid out and ready to play.
	Secondary	Plants are an artistic element to the game and are represented visually in some aspect of the game. They must be represented accurately and not inferred (e.g. a green backdrop on a map is not classified as grass).
	Realistic	Plants presented in the game are accurately represented with a physical plant, a token or plant drawing that accurately represents the growing/living plant (not the resource itself).
	Physical	Components in these games are either represented by plants themselves (e.g. seeds/unprocessed wooden pieces) or have been at some point in history.
Resource Differentiation	Generic	Plants are represented by one (or two in the case of a food and building resource) generic physical tokens or other nonspecific representations in game.
	Complex	Plants are represented in a differentiated way, with either multiple plant types (all with different properties) or are treated differently by the game or player.
Plant Type	Food	Plants are represented as a generic food resource (e.g. grain). This may have a visual representation with a plant image but will be referred to generically as food or grain or another generic term during a play.
	Raw	Plants are present as a raw building material (e.g. wood or hemp). This will normally be a form of a material that will be exploited in the game to fabricate structures.
Knowledge	Educational	The game has some educational merit but may not be fully scientific. For example, the game may represent a plant-centric process (such as winemaking), but only with some limited educational reinforcement of the process.
	Scientific	The game represents a plant-scientific process and reinforces the process through the use of scientific terminology or the direct representation of scientific concepts or terminology in the game.
Resource Processing	Tradeable	Plants in the game have a nominal monetary value, either via trading with other players for resources, or with a game bank for money.
	Transformable	Plants are transformed either up a processing chain (e.g. grain -> bread or wood -> paper) or can be exchanged to fabricate buildings or other more advanced products not directly related to the plant material used.
Game Flow	Points	Collected plants are directly worth victory points (and are counted as part of end game scoring) or are directly tied to a win condition in the game.
	Constraint	Plants must be paid periodically as a cost: usually as a food cost to be paid every game round. This is a common constraint in games, and acts as a "brake" to the amount of actions a player can take without incurring some form of punitive pushback.
Representation	Character	Plants exist as physical living characters in the game, or characters are present heavily covered in clearly plant-derived armour or clothing.
	Mystical	Plants exist as a mystical natural resource usually as some form of natural "mana" for casting spells or other mythical or mystical element.

centralised repository for board gaming knowledge. The authors used this website as a basis for selecting games. No distinct "plants" category for games is available to filter this list. It is, therefore, impractical to cover all available titles in this review. Instead games included in our analysis were chosen from the top 500 rated titles on BoardGameGeek (BGG)[2] as of the 9 March 2019. Insights into the plant representation and allocation of binary categories within these games were based on personal familiarity with each game analysed (through playtime or knowledge of similar games). The top 500 games on BGG are ranked using a crowd-sourced mean user rating with corrections made to remove bias for more recent games or games with a low number of user votes (https://boardgamegeek.com/wiki/page/BoardGameGeek_FAQ#toc4).

The BGG top 500 is widely regarded in the hobbyist board gaming community as the fairest way to aggregate a list of board games by the best to worst, without unjustified hype for newer titles or vote manipulation causing unpredictable changes to the ranking lists. BGG also crowdsource a complexity rating (or "weight") for all games. BGG define weight as a players' consideration of how

[2]To ascribe 16 binary categories of plant coverage to 500, often dense and detailed boardgames is a difficult task. The authors of this paper have played many of the titles, but friends, relatives, social media acquaintances and online FAQs, and manuals were often consulted for clarification on rules or mechanics in titles they were less familiar with. The subjective nature of assigning categories and variability in how games work mechanically means that we present this analysis as our best efforts and recognise that a group of board gamers might argue over some of our decisions (as we, the authors often argued among ourselves).

TABLE 2 The four categories of games assigned by the BGG weight rating

BGG weight average	Game category	Description
1 to <2	Casual	A game suitable for people with no direct interest in board gaming as a hobby. A game with little or no teaching requirements, accessible to all levels of player.
2 to <3	Lightweight	An entry level game for an enthusiast or hobby gamer, but a game that might be seen as complex by a casual game player (or someone with little direct interest in board games). May introduce some of the more complex elements of board gaming and require some teaching investment to learn to play.
3 to <4	Medium weight	A sophisticated and detailed game with potentially deep and detailed rules and playing strategies. A game that would require an investment of time to learn and would likely not be suitable for casual players or people new to the hobby.
4–5	Heavyweight	A complex, deep and detailed game, suitable only for board gamers with significant experience in the hobby. The game may be long, require a significant time investment to learn and play efficiently.

difficult it is to learn and play the game (boardgamegeek.com, 2019). BGG users can rate a game between 1 (light) and 5 (heavy), and this result is averaged to give potential purchasers of the game an idea of whether it will suit their (and their group's) play style. Table 2 defines how these weights are split for our analysis in later sections of this paper.

3.1 | Visualising the data

A cladogram was constructed using a matrix of the binary categories in order to display the associations of games with the 16 binary categories examined. The binary data were provided as in phylip format to RAxML (Stamatakis, 2014), and a maximum likelihood cladogram was built using the GammaX distribution for binary frequencies. The cladogram was visualised using the Interactive Tree of Life (iTOL, (Letunic & Bork, 2007)). Binary categories are represented around the outside of the cladogram for each board game, with the presence of a classifier marked with a coloured symbol. Of the 500 games selected for analysis, 256 (51.2%) contained no plant representation (no scoring criteria recorded across any of the binary categories). The remainder featured one or more positive scores across the 16 binary categories.

TABLE 3 Distribution of game by complexity category in BGG Top 500

Game category	Count
Casual	88
Lightweight	219
Medium weight	165
Heavyweight	28

4 | RESULTS

Table 3 demonstrates that the majority of games in the BGG top 500 fell into the Lightweight category with the fewest in the Heavyweight category. Table 4 demonstrates that the Secondary binary classifier (plants featured via secondary artistic representation) was present at relatively high percentages across all game weights. The Food binary classifier was the highest percentage classifier overall in the Heavyweight game category. Medium weight and Heavyweight games appeared to feature higher percentages of games containing binary plant classifiers when compared to the Casual and Enthusiast games.

Figure 4 demonstrates that of the 48.8% of the BGG Top 500 that feature plants, those that feature them across multiple binary categories are less prevalent and confirms the most common use of plants is in terms of a noncritical design motif or Secondary artistic element to the game design. Figure 4 also demonstrates that plants in board games appear to present themselves in three clusters: those with no plant content, those with only minor secondary plant derived artwork, and those that contain a richer blend of the binary categories, as listed in Table 1.

Figure 5 demonstrates that the balance of games featuring different plant binary categories has not markedly changed as the total volume of board games released has increased or over time. The incidence of plants in the BGG top 500 is generally proportional to the total number of games released that year with a slight bias towards more recent titles. It is notable that plants as a Primary visual component do not appear in any top 500 games from 2005, 2006 or 2008. Certain years (2012, 2013) appear to be good years for plant concepts in acclaimed board games, as opposed to 2008 and 2015.

TABLE 4 For each weight category, the percentage of those games in that category that contained a plant binary classifier is given. Higher percentages are coloured green, and lower percentages are coloured red. Note that games may have more than one binary classifier or none at all

Game category	Primary	Secondary	Realistic	Physical	Generic	Complex	Food	Raw	Educational	Scientific	Tradeable	Transformable	Points	Constraint	Character	Mystical
Casual	8.0	22.7	2.3	1.1	1.1	1.1	4.5	0.0	0.0	0.0	3.4	1.1	8.0	0.0	2.3	1.1
Enthusiast	5.9	37.0	5.0	0.0	9.6	7.3	8.2	7.8	2.3	1.4	4.1	9.1	13.2	3.2	0.0	8.2
Medium weight	9.1	32.7	11.5	0.6	18.8	13.3	22.4	15.8	3.0	0.6	14.5	15.2	15.8	13.3	1.8	5.5
Heavyweight	17.9	35.7	10.7	0.0	21.4	10.7	35.7	25.0	14.3	3.6	14.3	25.0	21.4	21.4	0.0	7.1

5 | CONCLUSIONS AND FUTURE RESEARCH

Our analysis demonstrates that plants are included in a large proportion of critically acclaimed modern board games, although the nature and depth of their inclusion varies. *Photosynthesis*, for example, uses a botanic theme and scientific process at its core, a feature that the authors argue contest plant blindness. However, plants do only exist as a simple resource in the game (trees and seeds) and are abstractly used as a theme over a relatively simplistic strategy game (a Lightweight game). Our analysis also suggests that while plants can be front and centre of game design a game may need to contain a richer blend of binary classifiers to fully challenge plant blindness. With this in mind, although *Photosynthesis* may be initially viewed as a plant blindness challenging board game, it could potentially act as a Trojan horse for abstract design tropes that potentially encourage it, taking advantage of an alluring plant theme without offering substance or richness to the concepts it exploits.

As a contrast, *Terraforming Mars* is a game that features many plant binary categories. It uses the visual greening of the Martian surface, scientifically accurate terminology and accurate artwork with plants elevated to the same status as metal and money to provide a more integrated presentation of theme and mechanics. As the plant blindness challenging film *The Martian* (20th Century Fox, 2015) positively helped the general public's perception of botany as a scientific discipline, *Terraforming Mars* also helps put plants on the map as a critical part of our space-conquering future. Plant-blind astronaut Rick Martinez dismissively states in *The Martian* that "...it's only botany. It's not real science", but both film and game teach that to make a planet a survivable location for human beings, plants are, of course, the most important thing, not the least. This integration of mechanics, theme and scale of vision across multiple binary categories, we argue, elevates *Terraforming Mars* above games such as *Photosynthesis* and *Arboretum*.

While our analysis revealed that plants are represented in all game weights, it is also clear that more complex games tend to contain a richer blend of the plant binary categories. This naturally may be a part of what makes them more difficult to play, also acting as a barrier to some players to experience and enjoy such games. The difficulty in simplifying what makes a "good" plant game demonstrates the validity in performing a more granular analysis of plant representation in modern board games.

It is notable that German designer Uwe Rosenburg is responsible for many of the games rich in multiple binary plant categories (e.g. *A Feast for Odin*, *Fields of Arle*, *At the Gates of Loyang*, *Ora et Labora*, *Agricola* and *Caverna*). This is testament to his skill as a designer, but also to his careful consideration on how plants and their multiple uses can be adapted into deep, satisfying board games. However, this sophisticated presentation of plants as a theme in games may (as with other forms of entertainment media) have a cyclical nature. The popularity of various themes and mechanics in games tends to cluster: as

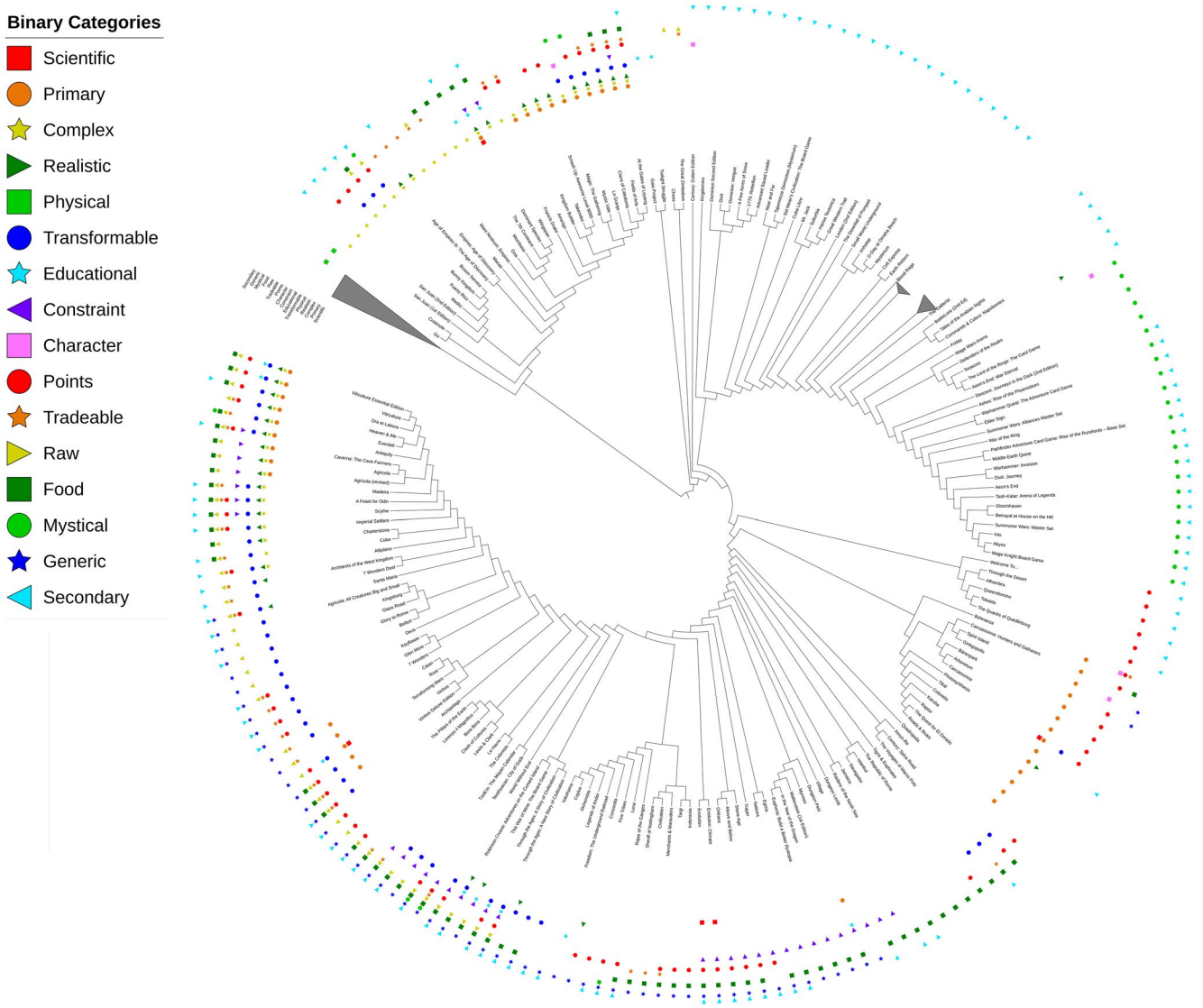

FIGURE 4 A cladogram showing groupings between games based on the presence or absence of plant binary classifiers. A symbol on the outside denotes presence of that classifier for that game. The large cluster of games with no plant representation present has been collapsed, as well as two categories of games that had only Secondary representation, indicated by the grey triangles

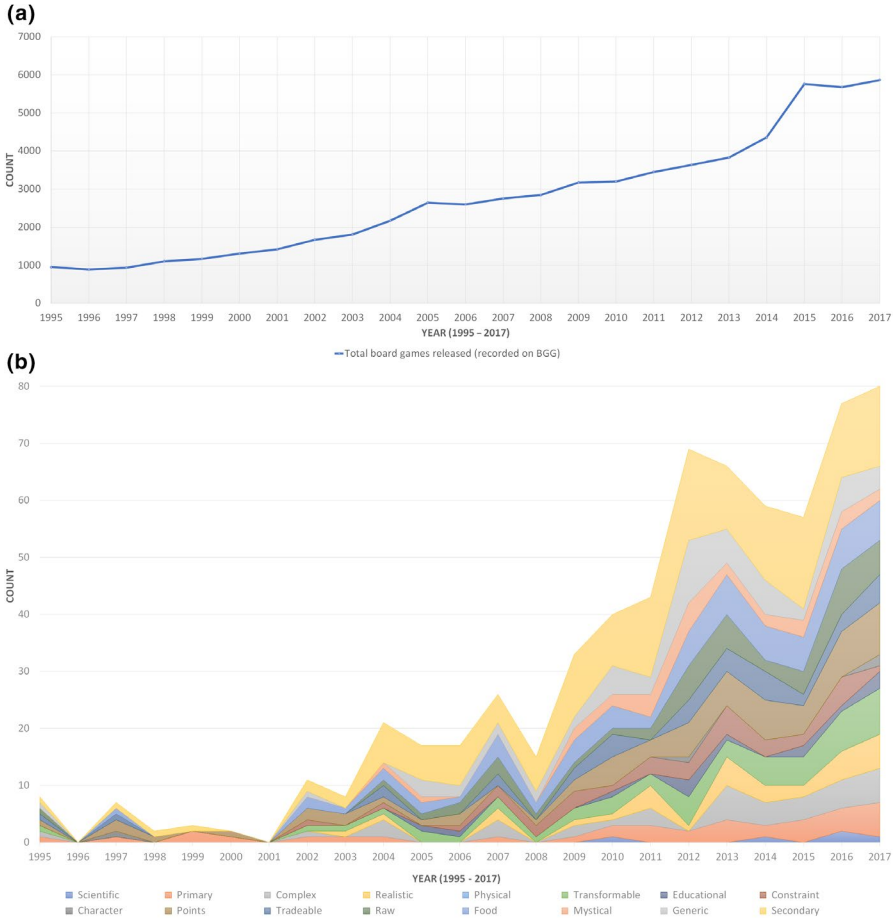

FIGURE 5 (a) Total number of board games released between 1995 and 2017 recorded on BGG. (b) Sum of binary classifier scoring across time for all weights of game (1995–2017) from the BGG Top 500

one type of game becomes popular, other designers rush to copy that style and as time passes there is a re-correction and that type of game becomes less popular. While there is, perhaps, no overall trend for an increase in any particular binary classifier as a proportion of all the games released year-on-year (Figure 5), it is inevitable that the overall increase in the amount of new board games should naturally lead to a wider variety of games being available containing a rich variety of the binary plant categories. As Uwe Rosenburg demonstrates, tapping into this rich potential of plants can, theoretically, lead to critical and commercial success as well as titles that can possibly subtly educate and inform about plant processes.

Because board games suit active learning styles, those rich in our plant binary categories (like *Viticulture* and *Terraforming Mars*) could be useful tools for educational engagement to challenge plant blindness among the next generation of board game players. They may also act as stepping-stones to encourage those players already developing an interest in the pastime, opening up a route to new botanical worlds and experiences. The variety of plant rich games (and the way plants are represented) in the BGG Top 500 also shows that *Photosynthesis* need not act as a full stop to game design in this area and that plants still offer a rich canvas for the creation of future games. How the richness of plant depiction in games directly reinforces or challenges plant blindness will require more qualitative work. Future analysis will need to be performed to determine the links between the binary categories presented in this paper and how they are perceived and internalised by players when experiencing them as part of gameplay.

Unpicking the connection between the presentation and perception of plants in interactive media may, ultimately, be a difficult relationship to quantify. But with the advent of games like *Terraforming Mars* we see a lot to be encouraged about in terms of how board games will represent plants in the future. If game designers can be inspired by its scientific rigour and detailed gameplay, future games could also potentially be a vital part in enhancing the wider public's appreciation of the role that plants play in their emotional well-being and physiological survival.

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AUTHORS' CONTRIBUTION

Benjamin J. Thomas was involved in data collection, analysis, writing and editing. Jessica C. A. Friedersdorff was involved in analysis,

writing and editing. Hannah R. Hay was involved in editing and photography. Brodie A. Freeth-Thomas was involved in game selection and research. Christopher J. Creevey was involved in editing and proofing.

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