Making Maps Available for Play: Analyzing the Design of Game Cartography Interfaces

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Maps in video games have grown into complex interactive systems alongside video games themselves. What map systems have done and currently do have not been cataloged or evaluated. We trace the history of game map interfaces from their paper-based inspiration to their current smart phone-like appearance. *Read-only map interfaces* enable players to consume maps, which is sufficient for wayfinding. *Game cartography interfaces* enable players to persistently modify maps, expanding the range of activity to support planning and coordination. We employ thematic analysis on game cartography interfaces, contributing a near-exhaustive catalog of games featuring such interfaces, a set of properties to describe and design such interfaces, a collection of play activities that relate to cartography, and a framework to identify what properties promote the activities. We expect that designers will find the contributions enable them to promote desired play experiences through game map interface design.

CCS Concepts: • **Human-centered computing → HCI theory, concepts and models**; **Interaction design theory, concepts and paradigms**; • **Information systems →** *Collaborative and social computing systems and tools*; *Geographic information systems*; *Massively multiplayer online games*; Location based services;

Additional Key Words and Phrases: Game design, cartography, maps

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PREFACE: SCENARIO-BASED INSPIRATION

Like many researchers in human-computer interaction, the authors of this article work and live among disparate realms of scholarship and fandom. The complex web of interest, scholarship

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Fig. 1. Screenshots from *The Legend of Zelda: Breath of the Wild* [LZ:BW] showing its game cartography interface for placing pins through the Sheikah Slate's scope mode in a 3D gameworld. Pins appear in the full-screen game cartography interface (F) and in the mini-map (visible in the bottom-right corner of A, C–E). (A) Avatar standing next to the tutorial guide atop a tower in third-person view; (B) Transition when avatar holds up the Sheikah Slate to activate scope mode; (C) Initial view through scope mode, pointed where the avatar is pointing, now in first-person view; (D) Pointing the scope at a far-off tower; (E) Placing a pin by "firing" at a the tower, resulting in the violet pin being added to the mini map; (F) Complete map showing the avatar's location and the violet pin that was placed. (Screenshots taken ⓒⓘ P. O. Toups.)

needs, and hobby inform each other. In light of that interconnected web, we provide a non-traditional opening to this article: a fictional scenario that synthesizes the independent experiences of the first two authors, Toups Dugas and LaLone. We seek to provide an understanding of where and why this research began so that the reader may understand what it is and where it is going. The scenario is intended as illustration only, developed from the shared recollection of authors and written in first-person singular:

> As I tried to relax between conference submission deadlines, the opening tutorial of *The Legend of Zelda: Breath of the Wild* had guided me back to the top of a large tower I had visited earlier. The view on top of the tower was astounding. From this vista, I could see far off places of interest, spaces to which I'd eventually travel. While I stood there, the tutorial guide, a non-player character, explained how to use one of the key tools for playing the game (Figure 1(A)). This man instructed me to press a particular button on my game controller. Upon being pressed, my avatar responded by raising his Sheikah Slate[1] in front of his face like he was going to take a picture with a tablet computer (Figure 1(B) and (C)).
>
> Using the Sheikah Slate in this *scope mode* shifted the game from third-person (Figure 1(A)) to first-person (Figure 1(B) and (C)). I could scan the distant horizon and zoom in (Figure 1(D)). With another button press, I could "fire" at what I was looking at, adding a glowing mark to the scope view (Figure 1(E)). In response, the mini-map in the bottom right corner panned to follow the line I had "fired" to pinpoint the location, then panned back to center on my avatar. I found that, on looking at my map interface, those markers appeared as pins on the map

[1] Essentially a magic tablet computer in a fantasy setting that functions as a diegetic interface to the game's subsystems.

> (Figure 1(F)). Being high up on the tower, I could see quite a ways off and this made me want to go and explore those spaces, wander the vast gameworld.
>
> This simple in-game system impressed me, as my research work focused on maps and mapping technologies for crisis response and management. Further, because of my extensive background in gaming, I knew such a system had never been made before. I thought, "why has no one considered this feature until now?" Further, I began to wonder what the inspiration was for Nintendo—the game's creator—to create this system. Had Nintendo been inspired by products from elsewhere? What other game maps had systems like these? Finally, could any of the things that game makers have been doing provide design insights for better ways to integrate maps and mapping with real life?

As the authors had these experiences, it also became clear in the gaming media that *Breath of the Wild* is influential and would impact the design of games for years to come [45, 47, 87, 101]. Its collection of mechanics and clever integration of its gameworld and map systems are likely to be taken up by other designers. With these concepts in mind, we began a deep dive into video games and mapping technologies, identifying, and working from other games with cartography oriented interfaces.

1 INTRODUCTION

Many video games rely on real-life concepts to provide players with senses of familiarity, immersion, detail, and depth inside their alien environments. One often overlooked connection between real life and video games are maps of video games' virtual worlds. Maps, both in video games and in real life, enable wayfinding and communication. Many of the features of maps are ignored during their everyday use as users often *only* focus on wayfinding for individuals or groups—direct movement from point A to point B.

Video games tend to highlight concepts that extend beyond everyday life. This often results in maps and mapping technologies that are more robust and interactive than those for real-world use: locations (e.g., those visible, but not reachable; locked doors) and objects (e.g., plants; stones; puzzles) all have the potential to be essential to the everyday life of a *video game* resident. Different games, different gameworlds, different genres, different premises all shift the needs of the game map, yet the features of the systems that make up the game map are mostly unexplored and undefined.

Game map interfaces are nearly ubiquitous, especially open-world games, and foster exploration and aid navigation of virtual worlds, much like their physical counterparts [23, 69]. *Read-only map interfaces* allow players to situate themselves in gameworlds and engage in wayfinding. The present research analyzes affordances for map development, modification, and/or annotation in existing video games, which are a part of the subset of game map interfaces that we call *game cartography interfaces*. When users can actively engage in cartography to develop, modify, and/or annotate maps, the range of capabilities expands to include exploring, remembering, and planning. Paper maps readily accept annotation [23, 52, 65, 80, 81]. While there have been great strides in democratizing production in digital maps through technology [23, 37, 82, 89], such affordances are nascent in everyday digital maps [23], including those in games.

Early digital games, grounded in tabletop gaming and limited by technology, relied on players using pen and paper for mapping and notes [86]. The addition of computational memory and speed allowed for more complex games, creating the need for and ability to have new subsystems (e.g., game map interfaces, inventory interfaces, dialogue subsystems). Automated mapping systems brought all activity required to play a game into the computer itself. While these quality-of-life improvements [86] eliminated much of the need to manipulate the map, players were left with a read-only tool for play. Thus, players were now beholden to a designer's insight into the data players would need to have to play the games they designed.

In the present research, we analyze the atomic affordances of game cartography interfaces to understand how games enable and constrain player interaction with maps. *Atomic affordances* refer to the individual user interface components manipulated by players. We develop the atomic affordances into a framework of interface properties that account for design choices in a game cartography interface. These address the design of SYMBOL SUPPORT, WAYPOINT SUPPORT, DRAWING SUPPORT, TEXT SUPPORT, ALIGNMENT ASSISTANCE, and MAP CONSTRUCTION.

A designer's choices of interface properties promote what we call *high-level play activities* or things a designer can nudge the player to do by limiting their access to information via the game cartography interface in some way. Identified high-level play activities include marking repeated events, identifying areas for exploration, tracking remote information, and collaborative planning. These activities are often performed using an aggregated representation of the space of play that is most easily referred to as a map. We connect interface properties to game input hardware, noting how system design influenced the design of game cartography interfaces. Through understanding what systems have existed and how those systems fostered certain kinds of behaviors over time, our framework will provide a useful baseline for designers seeking to develop or use game cartography interfaces to foster new kinds of player behavior.

1.1 Contribution

The design parameters of a successful game cartography interface are not well understood. Intuitively, we can state that a successful game cartography interface design demands careful attention to what information should appear on a map, its interactivity, and how to access it. Yet, in actuality, the success of a map system is far more complex and contextually situated with the world it represents and, more recently, with the way maps are used in the real world. As games have become more complex and situated in the present, game designers have begun to rely on the ways that products like Google Maps direct their users from one place to another. But this reliance on existing user behavior in game cartography interfaces is spotty and not well understood. We contribute to the design of map systems by providing a rich history and catalog of affordances, features, and activities surrounding the game cartography interface over time. We also contribute a framework that assembles these features into a useful set of interface properties and types of behaviors those properties can be used to promote.

In addition to our contributions to understanding game cartography interfaces, we also contribute to the method of evaluating interface designs. To our knowledge, our carefully curated purposeful sample of games includes *all* game cartography interfaces that are currently in or have been in use out-of-the-box. Our research represents a discussion about how maps are used in games. This discussion is nascent, in general, yet valuable to fields outside of video game design such as crisis response, civic technology, and geography. Our framework will also be valuable to game designers who might build such interfaces and researchers who study them.

1.2 About the Authors and Research Perspective

A key argument to be made in this work involves the perspective of the authors and our ability to find games that fit into a particular corpus developed using the tenets of purposeful sampling [83]. Because so much of the present research relies on first-person experiential data, we feel it is important to provide background on our experience to lend credibility to the work. The authors are *well-played* game historians as well as HCI and crisis response researchers. "Well-played" is to games as "well-read" is to books [9, 31]. This is to say that we have consumed a vast variety of games over our lifetimes, which include much of the early history of video games as a whole. We digest these games from the perspective of HCI researchers and crisis response researchers, looking at how they afford interaction, what feedback they develop, and how what we learn from them might be applied to user interfaces in general. This process is similar to how Norman [76] and Tufte [111] approach analyzing the design of existing artifacts. As part of our professional lives as scholars, we are immersed in game culture and are constantly absorbing material from professional and independent game designers, journalists, and historians: news, retrospectives, interviews, reviews, podcasts, and postmortems of games. We provide this insight, here, to assure the reader that, when we develop our purposeful sample of games in this work, we are well-positioned to provide as comprehensive a perspective as possible.

1.3 Article Organization

Much of the focus of this article is un-discussed elsewhere. As a result, there is considerable history and context that needs to be provided. We begin by discussing affordances, play, and game design. We then explore game geographies and maps by developing a history of maps in games. Our history begins with pen-and-paper role-playing games and concludes with 3D gameworlds that replicate modern mapping technologies. A methodology section explains our thematic analysis process in detail, providing a week-by-week account of the research activities and providing insight into how our corpus of games was developed; this is followed by details of the data corpus, its characteristics, and sampling methodology. From there, we develop results in the form of a framework that identifies properties of game cartography interfaces and the set of identified high-level play activities. In discussion and conclusion, we develop design implications based on the framework and the play activities, discuss how play relates to device affordances, consider the wider field of game modifications, and then address implications beyond the design of games. Appendix A provides a table of all the games in our corpus (i.e., those with game cartography interfaces), along with their resulting interface properties. Appendix B provides a list of book and internet sources that were used to develop the corpus of games used in this project.

1.4 Ludography and Citing Games as Sources

Finally, the present research uses games, game mechanics, and game interfaces as primary data sources, building up a corpus of published games. Like the References section, this article includes a *Ludography* that describes the games in our data corpus. Games that are discussed, but are not in the corpus, appear in References. In the case of needing to cite a game *series*, we cite all relevant games from the Ludography. In the special case of needing to discuss a series that is not a part of our data (i.e., not in the Ludography), we cite a single exemplar; this happens when defining exclusion criteria.

We use a special notation for games in our Ludography; when they are cited, we use an abbreviation of the title (e.g., *The Legend of Zelda: Breath of the Wild* [LZ:BW]) instead of a numeric citation.

2 BACKGROUND

Each concept discussed in this section grounds our work in the article and each builds on the earlier concepts. We start by establishing Norman's theory of affordances and signifiers, then move on to explanations of play and game design. The concept of game mechanics identifies player affordances or, in this case, the designed decisions that players can make within the context of a game. Gameworlds refer to the virtual spaces that games construct and within which players engage game mechanics. Gameworld interfaces are the ways in which players make those decisions.

Finally, we synthesize the background to discuss our concept of game map interfaces: alternative views onto the gameworld, which may be read-only or game cartography interfaces.

2.1 Affordance Theory

An *affordance* is a concrete relational mapping between an element of the environment and an actor's ability to interact with that element [44, 46, 56, 58, 76, 123]. The concept of affordance was originally established for animals living in the physical world (i.e., [46]) and was adapted to the design of human-computer interfaces to identify effective ways for designers to render capabilities to users. Perceptible affordances and signifiers of imperceptible affordances indicate to a user how to interact with physical and virtual interfaces [44, 76].[2] A *perceptible affordance* is readily identifiable to the actor, a signifier is designed *into* a component mapped to an action. *Signifiers* indicate an opportunity to take action when it is otherwise not perceptible, enabling the user to see where and how to use an affordance.

Many game interfaces, such as game map interfaces, offer functionality like those of productivity interfaces, and so make careful use of signifiers to indicate how to use them. In the present research, we are concerned with what we call *atomic affordances* in game cartography interfaces: individually identifiable components of the interface that allow the player to accomplish some change to the map [123]. We take into account the signifiers that support discovery and interaction in identifying these; however, our focus is on what changes to the map that a player can make.

2.2 Play and Game Design

Research that centers around video games can be found in every discipline that includes the study of people. This disparate, loosely connected domain of interdisciplinary research examines the design and/or playing of video games in a nearly infinite variety of contexts. The concept that separates each approach is how they define the act of engaging a video game, often referred to as play or playing. The definition of *play* explicates the foundation upon which each piece of research is built. For the present research, we speak from the perspective of human-computer interaction (HCI).

2.2.1 Defining Play. We define *play* as an act that does not explicitly identify its affordances before the act begins [18]. Within that act, expression is limited by the focus of the player and limitations of the space in which the act is performed. Play is not a diversion, but a name for the act of *getting something to work* and observing the results [18]. This definition of play allows researchers to identify a number of aspects around which to design research.

First, by calling to the act of figuring out how to get something to work, researchers can observe users react to certain kinds of limitations. Second, play is a performance that occurs in its own space, thus making research about play explicitly contextualized to itself but repeatable given similar sets of limitations. Finally, each type of limitation and each type of system allows for different results. This difference allows researchers to break different limitations down to their own sets of research. The term used to describe how limitations manifest in a digital space and foster choice during play is game mechanic [1, 19, 55, 96].

2.2.2 Game Mechanics. One of the most important limitations to consider when referring to play are those mechanisms that make a system work. We call these *game mechanics* or the *designed moments of choice* in games [1, 55, 96]. Game mechanics form a fundamental, but often invisible, building block of interactivity. They are characterized as a play [19] loop: player observes a game state, makes a choice based on the observation, and then observes what happens. Some

[2] The separation of signifiers from the affordance they represent is a revision to Norman's earlier theory of affordances [77], which puts it more in line with later thinking on the subject [44].

game mechanics serve as the feature of that particular space of play. Those focal game mechanics are often referred to as *core mechanics*. The present research uses game mechanics and their atomic affordances as a unit for analysis; further, we consider the core mechanics of the games in the corpus and how these connect to game cartography interfaces. The combination of game mechanics within a space of play often present themselves as a unified whole that we refer to as a gameworld.

2.2.3 Gameworlds and Gameworld Interfaces. We use *gameworld* to refer to the unified space of interaction for players. *Gameworld* is defined as a computer-mediated, virtual world artificially limited in such a way as to foster unique opportunities for exploration and meaning-making [54]. The systems (i.e., game mechanics) that allow the player to interact with the world are typically invisible, as an assistant to player exploration [54]. The invisible systems serve as a metaphorical body for players, but some aspects of gameworlds are not completely knowable by a user or player. Those systems that are not invisible are typically aspects of the gameworld that exceed available cognitive load [51] for players. Designers bridge these barriers of cognitive load and presence with *gameworld interfaces* [5, 8, 11]. Some examples of gameworld interfaces include hyper-local minimaps, character statistics in visual formats, and object inventory systems. Each of these gameworld interfaces communicate with the player about their current relationship with the gameworld.

Gameworld interfaces additionally provide many of the limitations that create each gameworld's unique sense of play. For example, in a game about survival, water and food may be limited to provide a sense of scarcity to foster innovative problem-solving techniques. A character might be given limited health to heighten the challenge of staying alive. A timer might be inserted to give a gameworld an ominous sense of pending finality. Players might wash ashore on a strange land that players can see the shape of on a map. This allows players to see the space they must explore. Each of these interface elements aid in providing limitations meant to engage players in play: reflecting that act of *getting it all to work* [18]. Each of these systems are integrated with the study of games but game map interfaces are unique in and of themselves.

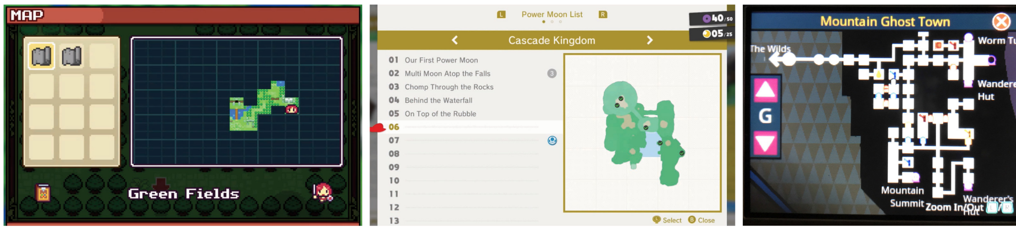
2.3 Synthesis: Game Map Interfaces

Based on our syntheses of prior work on play and game design, maps interfaces, and affordance theory, we develop the concept of *game map interfaces* [23, 46, 69]. Game map interfaces are a form of gameworld interface that provides an alternative perspective, typically showing the local segment of or even the entire gameworld at once. Because game maps show the whole gameworld at once, they often reflect a high-level, abstract representation of a gameworld in much the same way as world maps represent the physical world. While separated, the affordances offered by game map interfaces are sometimes loosely connected to gameworld through a number of game mechanics. An example of this level of interactivity would be showing more detail of the gameworld as the player explores the space around them. By allowing an abstract view of an entire world, the gameworld gains a deeper sense of place. Interestingly, the separation of the game map interface and how these systems interact and aid each other are both relatively nascent in their development.

3 VIDEO GAME GEOGRAPHIES AND MAPS

The need for maps in video games has been present since their creation. Through our definition of play, we can posit that games are essentially sets of unique limitations. The first limitation then is the act of learning the interface [76], what players are allowed to do in the gameworld [64], and where they currently are inside of it.

The size and complexity of gameworlds has changed over time, growing in complexity and need with the advent of 3D game worlds [71, 72, 107]. Some game worlds have become so large that no



(A) (B) (C)

Fig. 2. Example read-only map interfaces. Each of these interfaces provides a highly detailed alternative view of the gameworld. As is typical of read-only map interfaces, these provide some range of affordances for panning, zooming, and/or fast-traveling, but do not provide any means to manipulate the map. (A) In *Fairune Collection* [39] the map is gradually revealed through play and shows the player's location; the game map interface can also show maps from other parts of the game. (B) The map for *Super Mario Odyssey* [75] provides the map for the entire space and shows the player's location; fast travel waypoints are discovered through play and can be accessed via the game map interface. (C) In *Severed* [34], the game map interface shows how the rooms in the world are interconnected and important contents; it includes the ability to see which rooms are layered on top of each other by shifting through the layers (using the controls on the left). (Screenshots (A), (B) taken 🅭🅯 Nicolas LaLone; (C) taken 🅭🅯 P. O. Toups.)

single player can navigate them without the help of a map. That need for help has been a driving factor in the creation and development of a mediating, abstracted layer representing the whole of the world—the game map interface. To begin to understand game map interfaces, the first step is to separate them into two distinct types.

3.1 Read-Only Map Interfaces versus Game Cartography Interfaces

We differentiate between *read-only map interfaces* and *game cartography interfaces*. The former does not allow modification, though the user may move and zoom the map, find their location, and trigger activities (e.g., fast travel to an existing waypoint) from it. Game cartography interfaces generally have the same viewing and game-activity-triggering affordances as read-only map interfaces, but also allow for modifying or creating the map by making decisions within the game map interface. Some aspects of map interfaces offer modification affordances in what is otherwise a read-only interface; we discuss our definitions here and later address our work on identifying the scope of our data corpus.

Read-only maps are able to provide for players' informational needs. In these interfaces, many of which are a simple skeuomorph[3] of a paper map or digital map with location tracking (e.g., a standalone GPS or smartphone) might provide the player with information about the general shape of the gameworld they inhabit (Figure 2). Occasionally, these interfaces provide digital affordances for filtering and/or searching existing waypoints. These systems often will also provide a way for players to identify where they are and perhaps a general sense of where they need to go next. These types of maps allow players to make sense of the world in their own way [40].

Game cartography interfaces enable a player to engage with the map as part of play and manipulate it. These interfaces allow players to do things like augment a head-up display (HUD) for navigation, use map markers and drawings for large-scale planning, or allow users to collaborate to solve problems in-game [8]. These interfaces resemble those of online tools that facilitate physical-world map annotation [23], yet, in some games, supply much greater freedom and support for creation.

[3]"An object or feature copying the design of a similar artefact in another material." [79].

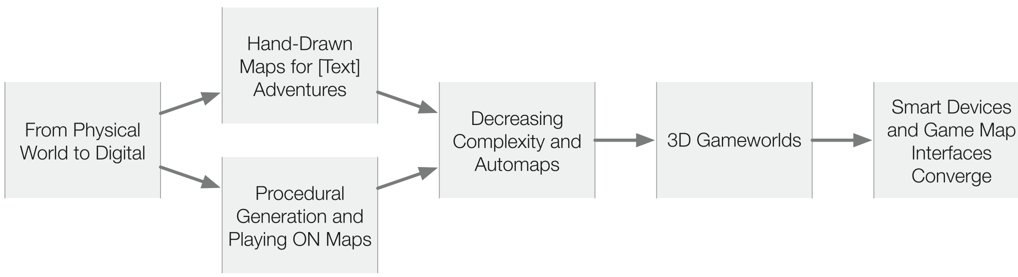


Fig. 3. Ages in game map history, separated by notable developments in use of maps.

3.2 A Brief History of Game Maps

This section describes the history of the use of maps, by players, in games, situating the present research. A number of research papers address maps in games (e.g., [25, 40, 62, 94]); however, these prior works have not looked at the affordances of game cartography interfaces or the play they enable. Instead, these works examine how a map communicates between textual communication and graphic communication, thus forming a tour of any space [40], not the interface itself. Or, these works examine how the construction of a map creates meaning for a space [94]. These works also examine how maps in games generally maintain a sense of space in a world where our relationship to space and place is diminishing [62, 100]. Each of these projects are not about the interface, but the map as an object; its relationship to the gameworld; and its function as a creator of space, time, and story. In order to best understand the current state of game cartography interfaces, it is necessary to situate the history of maps in video games.

Despite a well-maintained history of video games and video game technologies, it is difficult to determine dates and technologies in their *exact* order, so we develop overlapping ages of the design of games. These account for trends in game design, driven by a number of factors, but it is worth noting that, naturally, people still play games from earlier ages and that modern games may be designed as “retro” or “throwbacks to an earlier era.” So, games from every era continue to exist, be played in, and be designed in the present time.

We begin with a discussion about how physical games made use of maps and how these transitioned directly into early video games. Then, we reach parallel ages where the text adventure drove a need for hand-drawn maps while procedural generation enabled creating gameworlds out of maps that obviated a need for drawing. Next, we discuss how the increasing complexity of gameworlds drove a need to provide more accessible interfaces for players, including the automap. Automapping technology and future development leads to a discussion of the addition of how 3D-worlds kept 2D-maps. Finally, we discuss the convergence of game cartography interfaces and mapping software like Google Maps and MapQuest. Figure 3 shows the ages, including the two in parallel and where they converge.

3.2.1 From Physical World to Digital. As early machines that resembled modern personal computers became more commonplace, early programmers attempted to mimic one of the most popular games in the world at that time: *Dungeons & Dragons* (*D&D*) [27, 74, 86, 107]. *D&D* is a pen-and-paper role-playing game focused on exploring imaginary dungeons in search of treasure and adventure [24, 67, 117].

In these games, players moved through imaginary worlds, described by other players, drawing maps of progress by hand, often on grid paper (see Figure 4). Since such games were played in the imagination, drawing the map served to ground play, enabling players to explore a space and engage in combat. Annotations and modifications of these maps were made during play by

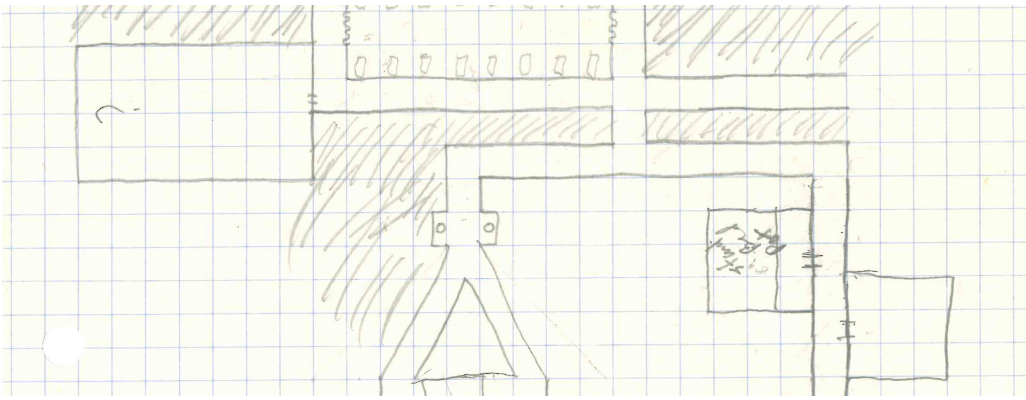


Fig. 4. A graph paper map from a first-edition game of *D&D*, circa 1983. (🅭🅯 P. O. Toups.)

players (note in Figure 4 the question mark on the left, the various door markings on walls, and the scribbled note on the right) to indicate what was discovered and what remained unexplored [22].

Programmers could not encapsulate the immersive experience of *D&D* visually as the story is driven by another human player. Instead, they replicated the "dungeon crawl" component of the game, which focuses less on strong narrative components and more on numerical mechanics. In a dungeon crawl, one or more characters explore a grid-constrained space (as in the sample *D&D* map on Figure 4) and use rules for exploration and combat.

Dungeon-crawl-style play is built on a space. This implication drove two parallel ages (Figure 3) in game design, each with its own implications for how the gameworld was (or was not) mapped by players.

3.2.2 Hand-Drawn Maps for [Text] Adventures. One means of creating the spaces for dungeon crawls was through adventure games, the earliest of which were text-based [10, 14, 70, 74]. The exploration of dungeons is borrowed from the wargame-inspired *D&D*; however, another activity also serves as the basis for exploration. The seminal spelunking-inspired text-adventure game, *Colossal Cave Adventure* used the Mammoth Cave system in and around Kentucky as its inspiration and actual map [70, 74]. The result is a mixture of goals within a space, exploration as experience, and spelunking (i.e., trying to map and survive the cave itself).

Like pen-and-paper games, text adventures consist of gameworlds described by text (e.g., "`You are in a maze of twisty little passages, all alike.`"), which worked well with terminal interfaces (i.e., text-based feedback and keyboard input) at the time [27, 74]. To interact, players type in actions they wish to perform (e.g., movement via "`South`" or "`Left,`" or other actions, such as attacking monsters or picking up items) [27, 74].

In games, maps are dynamic and constantly shifting scale and abstraction, such as the transition from an overworld map to one for a particular town or dungeon. These multiple types of maps were not represented from the birth of video games but came later. The game series that united these elements is difficult to pin down, exactly, but the first game in the *Ultima* series is often credited as being one of the first games to have an overworld map [99, 114]. In *Ultima*, players are given an overworld map and a series of maps for towns, dungeons, and castles to explore. Play inside of dungeons was often done through a first-person perspective and the players were meant to draw maps of the area as they walked around inside of them.

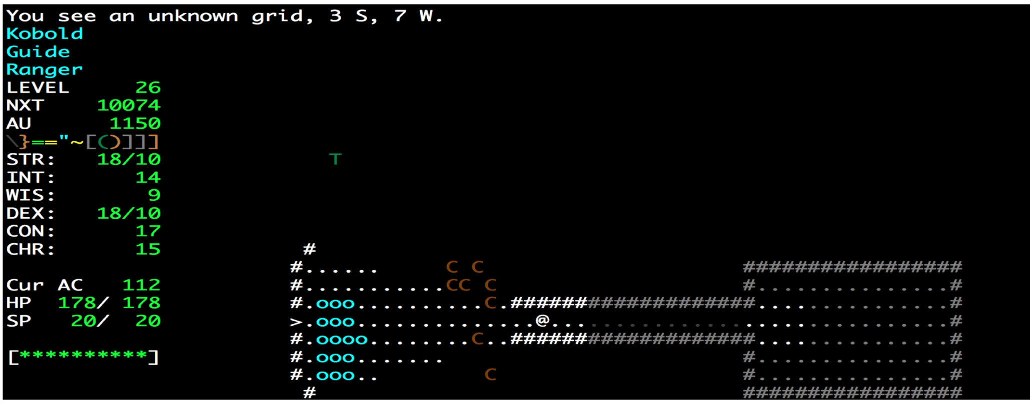


Fig. 5. An example of a *Rogue*-like in action. The strip on the left side shows game status information. The bulk of the right side is the procedurally generated gameworld. The "at" sign represents the player and the gameworld space is represented as pound signs (walls) and periods (floors). Other gameworld objects are also visible. (Screenshot taken P. O. Toups.)

Developing a functional mental model of these spaces and ensuring the player did not get lost often forced players to draw maps by hand [86, 88]. Because these games were generally (with some notable exceptions) organized into grid-constrained blocks or "rooms" that were connected at the cardinal directions, their design was amenable to drawing squares on graph paper.

3.2.3 Procedural Generation and Playing ON Maps. Contemporaneous with the first text adventure games were *Rogue*-likes[4] [27]; Figure 5 shows the *Rogue*-like, *Angband* in action, with a partially revealed map. *Rogue*-likes are important in the history of game maps because they represent the first games in which the player revealed and played *on* the map itself, moving an avatar around in a space. These games were displayed as if from a top-down view of a dungeon crawl, and player's embodiment can move around on the map *cum* gameworld and engage with all game mechanics in this way.

A combination of the interest in mimicking *D&D* combined with technical limitations led to the use of procedural generation for these games [19, 27]. *Procedural generation* uses a set of rules and heuristics along with controlled randomness to create new content [103]. To ensure a compelling and ever-changing experience (e.g., as one might get from another human player), game designs focused on using procedurally generated dungeon layouts. A key benefit of using procedural generation is that such designs reduced memory costs: gameworlds did not need to be stored beyond the current playthrough [27].

While players used the map as interface, there was little value for them to store it or annotate it, since it would cease existing when completed and since all relevant information was already displayed in the interface. Despite being created as an innovative way to display geography that often required cartography, the form has remained active since its creation; it has not been completely replaced.

3.2.4 Decreasing Complexity and Automaps. Both graphic and text-adventure games existed concurrently for a while. These two points of history, hand-drawn maps for adventure games and playing on the map, form a classic science and technology studies *moment of choice* [15]. At this

[4]While *Rogue* was an early exemplar, many *Rogue*-likes were *not* made in response to *Rogue*, nor was it the first in the genre [27].

fork in the road, consumers could choose to go down the route of text adventures and continue making hand-drawn maps or they could choose to see their maps represented graphically, even if they were simplistic and little more than play surfaces. Text-adventure games were the first to get networked and this caused the choice to be delayed for a time. Multi-user dungeons (MUDs): multiplayer gameworlds that are fully text-based [13]. As players wandered around these gameworlds, they would have to draw a map of the dungeon on paper so that they could make sense of where they were going and where they had been (or, in later times, use add-ons that provide game cartography interfaces [Mike "Zugg" Potter,[5] personal communication]). But ultimately, consumers seemed to choose playing on the map directly. The surge in home-console video gaming paired with the creation of new franchises like *Final Fantasy* [106], *DragonQuest* [105], *Wizardry* [Wiz8], and *Ultima* [78] quickly overwhelmed the Infocom-led text-adventure video game lines.

As gameworlds became more complex, there was a need to decrease complexity for players and the UI improvement of the *automap* materialized [86]. Automaps freed players from needing to map space by hand, providing the player with a map of the virtual space, generally filled as the player explored. As home video game consoles became more powerful, another development began to appear: 3D virtual spaces.

3.2.5 3D Gameworlds. The addition of the *Z*-axis in video games began the age of three-dimensional play. Early attempts to map 3D gameworlds took the same path that 2D gameworlds did: use pen and paper to map out areas. Massively multiplayer online role-playing games have been a driving force in the creation of game cartography systems. These games often present their players with multiple continents to explore. Each of these continents are split into multiple geographic regions called *zones* [12], which may be further subdivided into *sub-zones*. Zones serve to reduce the computational power necessary to maintain the persistent 3D world for so many players in the same gameworld. As these games have become so large as to allow players to get lost, the need for a game cartography interface has increased significantly.

Early 3D games used two-dimensional representations of their gameworlds. On a two-dimensional surface, elevation changes are difficult to display. Instead, walls and objects that looked like they would be on a higher elevation often served as complete barriers, rather than differences in elevation, that needed to be circumnavigated. To give these objects the facade of depth, players would change floors by moving up and down virtual stairs in order to give the appearance of elevation shifts.

With 3D gameworlds, elevation shifts became real time and represented directly in the gameworld being explored. The use of 2D maps of 3D gameworlds have remained constant since the appearance of 3D games (with a few notable exceptions, e.g., *Elite: Dangerous* [43], *Descent* [84], *Metroid Prime* [92]). This freed the map up to become a separate object from the surface being played on (with notable exceptions). Despite being free, maps that represent 3D gameworlds have mostly remained two-dimensional.

The game that served as inspiration for this work, *The Legend of Zelda: Breath of the Wild* [LZ:BW], has been an exception, but within that exception seems to be a growing trend in game mapping. That new trend is simply the re-creation of existing mapping software in video games. This skeuomorphism allows users to harness existing knowledge in order to navigate the increasingly vast worlds of video games.

3.2.6 Smart Devices and Game Cartography Interfaces Converge. In tandem with the development of 3D gameworlds has been the proliferation of smartphones and the growing ubiquity of

[5]Mike "Zugg" Potter is a software developer who founded Zugg Software (http://zuggsoft.com), a developer of mapping software for MUDs and other games.

the internet. The smartphone has now become so ubiquitous in the game-playing developed world that it is often difficult for players to think of a human without a smartphone or tablet in their hand [32]. In fact, the constant companionship of these devices is so pervasive that it does not seem out-of-place to see a smartphone, tablet, or similar device in nearly every type of setting. As a result, designers seem to be using skeumorphisms of existing mapping interfaces to migrate [53] users to the game map interfaces of their gameworlds. The most direct example of this growing trend is *Legend of Zelda: Breath of the Wild* [LZ:BW]. This game was described in the preface, but we return to it in the context of map history.

In *Breath of the Wild* [LZ:BW], the avatar is given a magic fantasy "slate" (effectively a modern tablet computer). On the tablet's map, the player sees a vast outline of a world map that is not filled in. The player can see swathes of land expand into the horizon. Throughout the game's initial tutorial area, the player learns that there are many climbable towers throughout the gameworld. Accessing the top of each of these towers will download a file that contains the map topology of a region (but not points of interest). In addition, from anywhere in the gameworld, the player can use the tablet as a scope with which to mark far-off locations (Figure 1 shows this in action). By mimicking things like favorites on Google Maps and inserting these affordances into a system that includes the existing mapping norms of 3D video games, *Breath of the Wild* serves as an example of what is possible.

Other recent games also incorporate smartphone or tablet skeuomorphs. In *Grand Theft Auto V* [93], as well as the *Watch Dogs* series [112], players could use their smartphones to map paths automatically by plugging in a destination. Like current mapping software, these paths would reroute depending on user behavior. With the game map interfaces that these games offer, the map serves as an abstract object on which players point to destinations. With *Breath of the Wild*, the map served as more of a game mechanic than passive tool: the map, itself, is becoming a play space within a gameworld. With this standpoint in mind, we constructed the present research.

4 METHODOLOGY: ITERATIVE THEMATIC ANALYSIS OF GAMES

We employed thematic analysis across a series of iterative coding cycles with an interest in understanding the atomic affordances players are offered to construct and annotate maps in games. *Thematic analysis* is a set of techniques that construct a qualitative description of a set of research data [21]. Its value is in its ability to explore new research domains, enabling researchers to summarize and provide insights into the characteristics of a data corpus [21]. In this section, we describe our iterative thematic analysis process; in the next section, we provide a summative perspective on the characteristics of the resulting corpus.

Our process took the form of analyzing video game mechanics and their respective interface components. This is in similar style to previous video games studies (e.g., [2, 110, 121]). While thematic analysis is normally used on text (e.g., interview data, documents), our perspective is that of game designers and HCI researchers, which equipped the research team with an understanding of games, game mechanics, gameworlds, and user interfaces. This perspective grounds our understanding of game user interfaces and enabled us to identify qualities of the data items in the corpus.

We frame our research phases according to those provided by Braun and Clarke [21]. It is worth noting that the process of thematic analysis is iterative and not necessarily sequential. The phases represent a rough sequence within which the process jumps repeatedly. Phases are numbered for indexing purposes, not order. Figure 6 provides a graphic view of how the phases were addressed, and Table 1 provides detail on the week-by-week process. The following is an overview of the research phases:

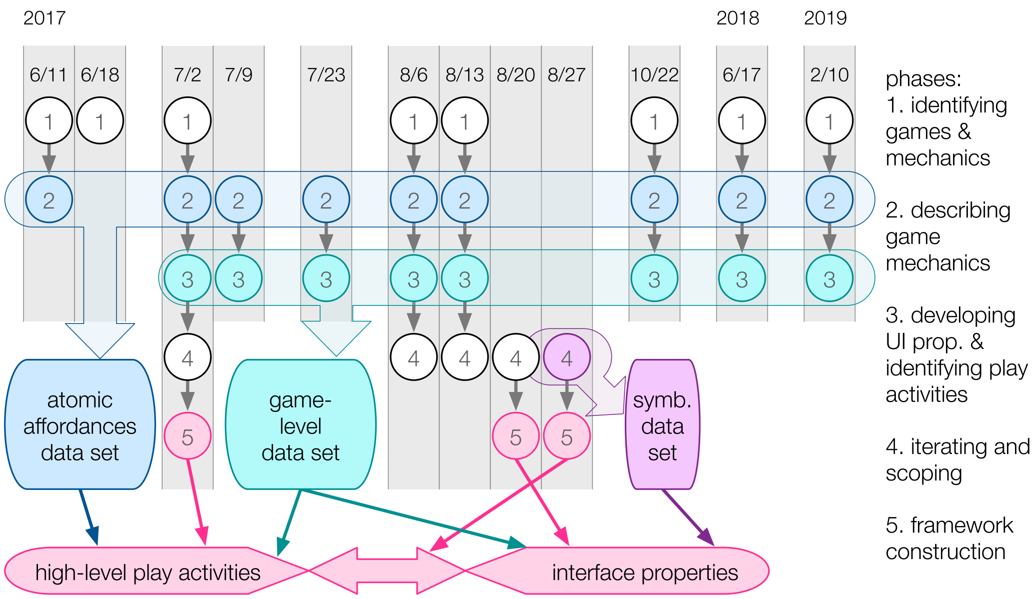


Fig. 6. Diagram of thematic analysis process broken down by weekly activities. Phases match those described in this Methodology section. Phase 2 activities primarily filled out the items in the game mechanic dataset; Phase 3 is where we developed the game-level data set; and Phase 4, near the end, developed the symbol data set. Phase 5 made use of the data sets to develop the interface properties, high-level play activities, and the relations between them. Table 1 provides additional insight into the process at each week.

(1) Familiarizing yourself with your data: we broadly identified games with map interfaces and considered how these did or did not enable acts of cartography by playing the games, observing them being played, and/or collecting reading material about them.
(2) Generating initial codes: we carefully described the affordances identified in Phase 1, beginning to identify similarities across games. We extracted UI affordances that involved choices in map making (multiple were identified for each game), developing the atomic affordances data set.
(3) Searching for themes: we collaboratively developed a set of UI properties that holistically considered the affordances and the game mechanics they enabled, creating the game-level dataset. At the same time, we considered what high-level play activities these interface properties support.
(4) Reviewing themes: we undertook a series of iterations of the above steps to expand the data corpus and identify its edges. In this phase, we determined criteria for inclusion and exclusion over a series of iterations. This phase developed the symbols dataset.
(5) Defining and naming themes: we constructed a framework for interface properties and linked these to high-level play activities.
(6) Producing the report: we developed the framework and this document.

The remainder of this section provides more detail about each phase of the process, with the exception of Phase 6: Producing the report.

4.1 Phase 1: Identifying Games and Mechanics

Our first step in understanding game cartography interfaces was to identify what kind of cartographic actions could be performed and what portions of play or game mechanics these enabled.

Table 1. Weekly Description of the Thematic Analysis Process

Week	Change	Total games	A.A. disc.	Process notes
2017-06-11	+25	25	15	Initial loading
2017-06-18	+11	36	15	Initial loading
2017-07-02	+7	43	30	Created game-level data set; seeds of framework; seeds of high-level play activities
2017-07-09		43	40	Assessing games for atomic affordances
2017-07-23		43	60	Assessing games for atomic affordances
2017-08-06	+1/−5	39	60	Assessing games for atomic affordances; clearing games outside of scope
2017-08-13	+14	51	76	Unify affordance codes; perform independent coding
2017-08-20	−4	47	72	Revise game-level data set; unify game-level codes; eliminate pure automap as outside of scope; continue populating game-level data set; discuss and revise coding
2017-08-27	−3	44	68	Discuss and revise game-level codes; create symbol data set; discuss revise all codes
2017-10-22	+1	45	68	[EO5] released and added to data sets
2018-06-17	+4	49	71	Add additional recent and borderline games
2019-02-12	+3	52	73	Add additional recent and borderline games

Change column indicates number of games added to or removed from the datasets. Total Games indicates the number of games in the datasets. A.A. disc. shows the number of atomic affordances discovered in the dataset at that time (one or more per game). Process notes provide insight into important events in the research process during that week. Figure 6 provides a diagram of the phases each week and their impact on datasets.

The investigation took the form of playing the games in question; watching play videos online; and/or reading manuals, reviews, wiki pages, forum entries, and other ancillary materials. We identified specific affordances for cartography in each game (or rejected the game as not having such affordances) through this process.

Identifying games with cartography mechanics proved non-trivial; to find them, we engaged in purposeful sampling [83] using prior experience, game history books, and web-based resources to identify relevant games. Each researcher independently made a number of internet searches to find websites where we could identify such games. Through the searches, we found starting points in Giant Bomb's game mechanic wiki as well as a number of web forums. It is worth noting that no existing database covers game map interfaces [Simon Carless,[6] personal communication] and so there is no way to know if our corpus is exhaustive, but we strove to develop as comprehensive a corpus as is possible. The list of sources we used to discover games is provided as Appendix B.

4.2 Phase 2: Describing Atomic Affordances

We evaluated the design and affordances of the game cartography interface of each game in our corpus. The actions that were possible and how they were triggered allowed us to identify multiple affordances per game. This section developed items in the atomic affordances dataset, described in more detail in the next section.

[6]Simon Carless is the co-runner of Moby Games (http://mobygames.com), a comprehensive database of games and their characteristics.

4.3 Phase 3: Developing User Interface Properties and Identifying Play Activities

We began to identify properties that the game cartography interfaces shared as our investigation continued. This resulted in adding a game-level dataset within the overall corpus. Our initial dataset was at the atomic affordances level, but we later developed a higher level one that considered all affordances and mechanics in each game. This game-level dataset was used to finish identifying interface characteristics by considering game mechanics and affordances in combination. The game-level data afforded us the ability to identify and organize how games used grids, waypoints, drawing, and symbols empirically. It was at this point that each researcher coded the dataset on their own in an effort to see where the researchers agreed and disagreed. Our game-level data was refined after each iteration and as a result, a set of possible states for each property began to appear.

As our collection of user interface properties developed, we began to consider what play activities each enabled. First, we considered the core mechanics of the game in question. Second, we began to look for the ways that the identified game cartography interface supported them. For example, writing on the map (or more specifically: taking notes) often supported the act of solving puzzles elsewhere in the gameworld. We sought to determine what game cartography interfaces are good for and why players might engage with them through this process. This allowed us to extend our game-level data to play activities.

4.4 Phase 4: Iteration and Scoping

A number of collaborative iterations on the prior steps were performed to code the datasets, each resulting in a more clear picture of how games enabled mapping. Individual researchers also made additional iterations throughout. We considered new games; removed irrelevant games; and merged, deleted, added, and edited codes during each iteration.

A third dataset emerged during this phase of analysis: the symbol dataset. As we came to understand the ways in which players could mark their maps, we recorded information about the ways that the game restricted marking (e.g., could players use a single "pushpin"—style mark, or could they place icons that mapped directly to gameworld objects?). The symbol dataset is contained within the game-level dataset.

4.5 Phase 5: Framework Construction

We developed a framework to understand game cartography interfaces after coding atomic affordances, their various states, and the play activities they fostered. This involved converting codes into interface properties, and considering what states the properties might take on, forming a framework. Commonalities in the planning behaviors we call high-level play activities were identified across the dataset and formulated into a list, which was then connected with the properties. This framework is discussed in Results and Table 2 provides an overview; Appendix A shows how the framework applies to the games from the Ludography.

5 DATA CHARACTERISTICS

In this section, we provide a summative view of the data we collected. This summation is a reflection on the final outcomes of the iterative process previously described. We begin by describing the scope of the corpus and what criteria were used to add and remove games from it. We then provide details on the three developed datasets. Each dataset is an alternative perspective on the overall corpus of the 52 games in the Ludography. The first dataset, atomic affordances, addressed UI components for game cartography interface mechanics in each game; there were one or more entries for each game in the corpus. Second, the game-level dataset was assembled from the data

Table 2. Framework for Game Cartography Interface Properties, List Form

Property	States	Description
SYMBOL SUPPORT	[*place symbol* | *place ping* | *N/A*]	What types of pre-defined marks the player may put on the map and how they function semantically.
WAYPOINT SUPPORT	[*single* | *multiple* | *draw* | *N/A*]	How locations may be specified in the game cartography interface in order to provide navigation assistance in the gameworld interface.
DRAWING SUPPORT	[*freehand* | *paint grid* | *lines* | *N/A*]	How the game cartography interface allows the player to put arbitrary marks on the map.
TEXT SUPPORT	[*attach memo* | *text on map* | *N/A*]	What ways, if any, players can add arbitrary text to the map.
ALIGNMENT ASSISTANCE	[*grid provided* | *snap-to-grid* | *snap-to-room* | *straight lines* | *N/A* | *none*]	What support is available for ensuring map elements are aligned.
MAP CONSTRUCTION	[*revealed* | *automap* | *triggered* | *manual*]	How ground truth map information is added to the game cartography interface.

in the atomic affordances dataset; it contained one entry for each game in the corpus. Third, a symbols dataset was developed to address the types of symbols in games that involved placing symbols and contained one entry for each such game.

5.1 Scope of the Corpus

The scope of the corpus was developed during repeated iterations of the fourth stage of the thematic analysis process (see Figure 6 and Table 1). This emergent process helped us to identify characteristics that were important to developing the sample of games needed to fully examine the concept of game cartography interfaces in video games. We identified the following three characteristics of the scope of our corpus of games:

— inclusion criteria: game choices that relate to maps and directly involve changing a map in some way;
— excluded mechanics: game choices that relate to maps, but that do not directly involve changing a map; and
— borderline cases: classes of games that provide a rudimentary way to modify the map, but over which the player has little control.

It is somewhat controversial to not include certain games that *do include* game cartography interfaces like our borderline cases. However, we did not include *all* possible games with these characteristics, just one game that represented that characteristic. For example, the *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON] has an in-depth game cartography interface, but this interface is unchanged across the games. To avoid inflating numbers, we included the core games, but not the remakes and spin-off games. We also only counted their atomic affordances once, since these are identical in each game.

5.1.1 Inclusion Criteria. The present research is concerned with game mechanics that involve acts of cartography. To be included, a game first needed to have a gameworld in which the player acts, which generally excludes puzzle games. Games also needed to have an interface through which the player modifies a map of the gameworld in some way (e.g., drawing, annotating). Modifications need to be persistent, so that they can be referenced during play. One last criterion was that for the present study we were interested only in game cartography interfaces that were included by the designers of the games themselves. This means that games that had no ability for the players to modify the map but did allow for add-ons, mods, and supplemental tools were not included.

5.1.2 Excluded Mechanics: Annotations on the Gameworld. Aside from games that had no ability for the players to modify the map but did allow for add-ons, mods, and supplemental tools, there were other criteria that excluded game. We excluded annotations placed directly in the gameworld, rather than in a separate game cartography interface. Examples of this include the messages functionality in *Demon's Souls* [41] and the *Dark Souls* series [42] that enables players to place predefined messages on the ground and have them appear in other players' gameworlds. Another example of this type of mechanic are signposts in *Minecraft* [68]. Although these annotations are interesting and point toward activities of wayfinding [102] and collaboration [110], they modify gameworlds, rather than maps.

5.1.3 Borderline Case: Map-Reveal Mechanics. A borderline case are those game mechanics that reveal portions of a map in response to a specific choice or by simply walking into an unexplored area of the map. A number of games are effectively played *on* a map, which is progressively revealed through exploration. Such games include *Rogue*-likes [27], the *Diablo* series [17], and many simulation games (e.g., *SimCity* [118], *Rollercoaster Tycoon* [98]). In many of these, the player reveals the map by playing the game and engaging directly with the gameworld, but the player is not directly acting on the map as an object.

In games featuring map-reveal mechanics, the player may interact with the gameworld to show all or part of a map, possibly including important points of interest. Examples include *Breath of the Wild* [LZ:BW], the *Assassin's Creed* series [AC1, AC2], and *Horizon: Zero Dawn* [H:ZD], which all include high points that, when reached, reveal the map in a nearby region.[7] Others, like *Firewatch* [FW], have optional, partially hidden locations that will add valuable, pre-defined, annotations to the in-game map.

We determined that map-reveal mechanics are an edge case in the present framework during thematic analysis. We saw that they enable players to make active decisions about what information will be shown on their maps; at the same time, these games are often nearly unplayable if players opt out of this activity, so it is rarely truly optional (i.e., you cannot choose to play in an area and *not* get its map data). Our dataset and prior game experience indicated that there is not a great variety in how these mechanics work. We did not include any games whose *only* map modification was revealing the map as the player moved through the gameworld; however, we did retain games in our corpus that included this mechanic as long as the game involved other player choices. We stopped adding games with other map-reveal mechanics to the corpus once we had achieved saturation.

The following games from the corpus included map-reveal mechanics: *Assassin's Creed* [AC1], *Assassin's Creed II* [AC2], *Firewatch* [FW], *Horizon: Zero Dawn* [H:ZD], *The Legend of Zelda: Breath*

[7] Due to their prevalence in games by the developer Ubisoft, this game mechanic is pejoratively referred to as an "Ubisoft tower" [115].

of the Wild [LZ:BW], *The Legend of Zelda: Phantom Hourglass* [LZ:PH], *The Legend of Zelda: Spirit Tracks* [LZ:ST], *Planetside* [PS1], and *Planetside 2* [PS2].

5.1.4 Borderline Case: Waypoint Mechanics. Waypoint mechanics are a set of affordances through which a player can add one or more points to a map that they, and potentially their collaborators, can see. These mechanics support navigation, coordination, and teamwork and are well-represented in games featuring large gameworlds. The way that these mechanics tend to work are that a map interface is opened and a player has the ability to mark a spot on the map. These spots on the map are either a specific point of interest already discovered or arbitrary grid coordinates contextually understood within the gameworld itself. These points where players mark will then be shown on the player's HUD to support wayfinding. These mechanics are relatively common and also lack variety in how they are implemented. After encountering a number of these games, we stopped including them when we had enough representation to achieve saturation.

The following games from the corpus featured waypoint mechanics: *Assassin's Creed* [AC1], *Assassin's Creed II* [AC2], *Elder Scrolls V: Skyrim* [ES:S], *Fallout 3* [FO3], *Fallout 4* [FO4], *Horizon: Zero Dawn* [H:ZD], *Planetside* [PS1], and *Planetside 2* [PS2].

5.2 Characteristics of the Three Data sets

In thematic analysis, different views upon the overall corpus or different levels of analysis form *data sets* [21]. Each dataset consists of *data items* [21]. The entire process of analysis resulted in three datasets as follows: atomic affordances, game-level, and symbols.

5.2.1 Atomic Affordances Dataset. We define *atomic affordances* as individual actions a player can take to perform an activity; in our case, atomic affordances needed to relate to changing the map in some way. The atomic affordances dataset was our initial level of analysis and looked at the individual actions that a player might perform through a cartography interface. It was developed through Phase 2 (Figure 6, Table 1) of the thematic analysis process.

As we identified interface affordances relating to cartography, we carefully recorded each of them in a spreadsheet. For each affordance, we recorded the following:

- the game containing the affordance;
- the game's platform[s];
- a game-specific affordance name, if provided (e.g., "paint the floor" [EO1, EO2, EO3, EO4, EO5, EON] or "scan pulse" [M:SR]);
- a short description of the affordance and related game mechanics;
- an extended description, including interaction details; and
- one or more links to the source of the information.

To this, we linked the way in which we discovered the game (e.g., using one of the sources in Appendix B) and any corroborating evidence (e.g., videos of gameplay, game manuals). The result was the atomic affordances dataset whose data items were descriptions of affordances, with multiple affordances per game. The dataset contained 72 data items. Again, because the *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON] uses many of the same affordances in each game, we counted them as a single game.

5.2.2 Game-Level Dataset. We began developing a game-level dataset as we performed Phase 3 of the analysis process. The game-level dataset provides a collection of all of the atomic affordances for each game in our corpus. These data allow us to examine how the interface is used during game play while also affording us the ability to compare interfaces between different games. We identified properties of game cartography interfaces that span games through the process of developing and iterating this dataset. The game-level dataset contains the same number of cases as games our corpus: 52.

5.2.3 Symbols Dataset. The symbols dataset identifies what symbols may be used by a player to annotate a map in games that provide such functionality. The symbols dataset emerged late in the process, being developed during one iteration in Phase 4. This dataset emerged as we began to notice iconography that differed between games that were in the same genre. Additionally, we noticed that certain kinds of activities that were afforded for in the game-cartography interface also tended to be represented by in-game symbols. This dataset contains 24 entries.

6 FRAMEWORK: INTERFACE PROPERTIES

Our framework begins by identifying the ways that players can interact with game cartography interfaces. These ways of interacting are their *interface properties*. They provide a framework for identifying patterns of UI design in existing games. Interface properties enable discussion about such interfaces by providing a vocabulary and common frame of reference. In addition to the terminology, we will later connect interface properties with ways that these properties promote certain kinds of play or our term for them, high-level play activities. *High-level play activities* can help designers identify how interface properties have been used in games and how they might be used to guide future designs. These interface properties are more than signifiers, they are the capabilities of the systems that force designers to signify affordance in some way.

Next, we deepen our framework past simply describing interface properties. Each interface property also exists in a number of states and for each property the interface may support only a single state. There are always exceptions, but this is generally true. A game cartography interface can be described by identifying the state of each property. This approach is not new; in fact, our approach to describing game cartography interfaces derives from Lundgren et al.'s [66] analysis of design properties in co-located mobile systems. Each interface property is named with SMALL CAPITALS with a range of possible states in square brackets and always *italicized*. Appendix A shows the game-level dataset after coding, with states for each property of each game filled in. Figure 8 features a number of the properties in action.

Note that the *N/A* and *none* states are different, and one property can have either state. When a game has an *N/A* state, it means that property is not applicable to the mechanics of that game. For example, if there is no way to mark locations on a map, there is no way to have SYMBOL SUPPORT or ALIGNMENT ASSISTANCE. If there is no need to navigate a gameworld, there is no way to assess WAYPOINT SUPPORT. The *none* property indicates that a game meets the pre-requisites to feature a particular type of support, but does not feature it (e.g., there is a way to mark locations, but there is no ALIGNMENT ASSISTANCE). While we develop each of the states in the remainder of this section, we presume that the *N/A* and *none* states are self-explanatory.

6.1 SYMBOL SUPPORT [*place symbol* | *place ping* | *N/A*]

The SYMBOL SUPPORT interface property describes how players may mark locations on their maps. These symbols can serve two purposes. First, players may be able to *place symbol*. Symbols, in this case, covers the range from simple pins to iconic symbols representative of something in the gameworld. Second, in multiplayer games, players may be able to *place ping*, which is a special symbol that is traditionally accompanied by a sound that alerts teammates to a place on the map [63, 110, 122].

6.1.1 Place Symbol. The ability to *place symbol* affords players the ability to attach detail to a location on a map. We cataloged the *types* of symbols that could be placed in a symbols dataset when assessing SYMBOL SUPPORT. A summary of this dataset is shown in Appendix A. In many

Fig. 7. Collection of tool palettes for SYMBOL SUPPORT. (A) *Samus Returns* [M:SR] offers multiple colored pins. (B) *The Legend of Zelda: Breath of the Wild* [LZ:BW] provides place-able icon stamps for the map (top row) and colored pins for use with the scope (bottom row) (see Figure 1 for details, for further details). (C) and (D) *Etrian Odyssey V* [EO5] and *Etrian Odyssey* [EO1] provide multiple labeled icons, which can have *memos attached* for TEXT SUPPORT and provide DRAWING SUPPORT. (E) *Legend of Grimrock II* [LoG2] offers a larger range of icons than its predecessor along with TEXT SUPPORT. (F) *EverQuest* [EQ] is a fully manual map with multiple tools for DRAWING-, TEXT-, and SYMBOL-SUPPORT. (Screenshots taken 🅭🅯 P. O. Toups and Nicolas Lalone.)

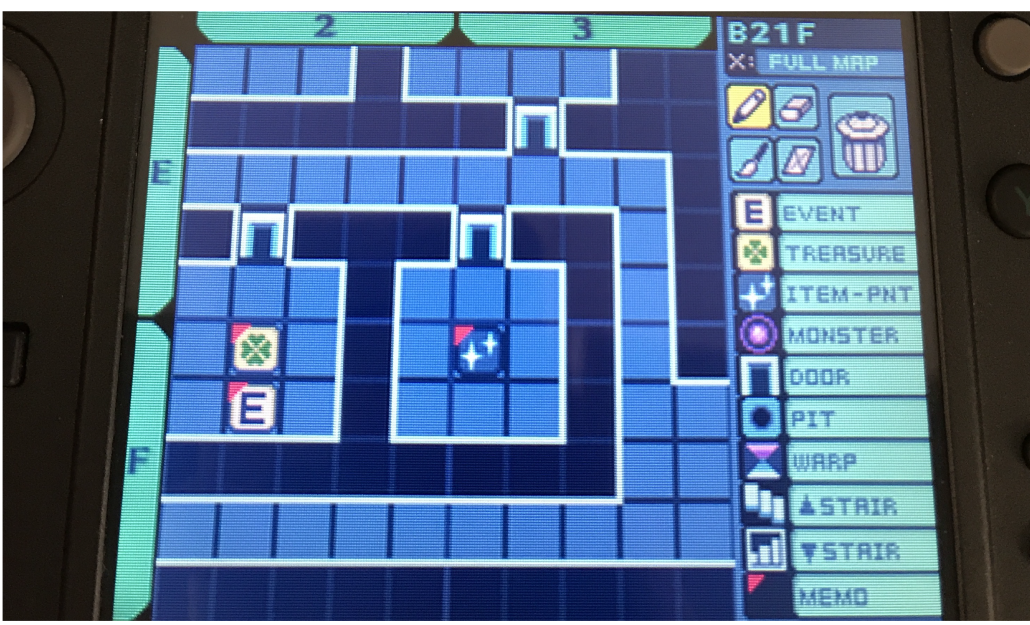


Fig. 8. Multiple annotations on the bottom touch-screen game cartography interface in *Etrian Odyssey* [EO1]. The right side of the screen shows painting tools for *paint grid* DRAWING SUPPORT and *place symbol* SYMBOL SUPPORT. All annotations require *snap-to-grid* ALIGNMENT ASSISTANCE. The three symbols on the map each also have *attach memo* TEXT SUPPORT with details attached. This map is facilitating marking repeating events by showing the player where to find resources that respawn (the centered "item-pnt"). Identifying areas for exploration is also common play, but is not seen here. (Screenshot taken 🅭🅯 P. O. Toups.)

cases, games allowed single pins to be placed on the map. For example, in *Metroid: Samus Returns* [M:SR] (Figure 7(A)) players can press a button when looking at the bottom screen of the *Nintendo 3DS* and bring up a number of multi-colored pins. Players can drag those pins to portions of the map that they need to mark for whatever the reason may be. In other games, a wide variety of symbols could be placed, providing iconic representations of elements of the gameworld that were worthy of annotation (Figure 7). Typically, when multiple symbols or pins with different colors are available, a palette UI provides a grid of potential symbols for the player to drag-and-drop, either with a mouse cursor or with a touch interface, onto the map (e.g., [EO1, EO2, EO3, EO4, EO5, EON, M:SR]); some games allow the player to select the marker and change its representation (e.g., [LZ:BW]).

We observe that, in some games, it is up to the player to connect symbols to meaning in the gameworld, while some game objects are directly represented as icons. For example, in Appendix B, the entry for "How is everyone using stamps?" involves player discussions of what the various icons in *Breath of the Wild* [LZ:BW] might mean to them; Figure 7(B) shows the palette in question.

In *Etrian Odyssey V* [EO5], the provided symbols *mostly* readily match in-game objects (Figure 7(C) and (D)), though these can be ambiguous. Continuing with *Etrian Odyssey V*, there are different in-game actions that rely on different pieces of game state, consequently, it is logical for players to want these unambiguously displayed on the map. Certain grid locations allow harvesting food using a skill (i.e., *take*), harvesting food without a skill (i.e., repeatable in-game events), and harvesting material using a skill (i.e., *chop*). While there are three related activities to mark, only two of the symbols make sense: a pair of scissors and a hand (Figure 7(C), bottom-left of image); it is unclear for which activity each is meant (and what to do with the third case).

In some cases the symbols are meant to provide insight into the type of annotation the player has put down, as in the *Legend of Grimrock II* [LoG2] (Figure 7(E)), where players can place an exclamation point, to represent a piece of information, or question mark, to indicate a place in need of investigation, along with an annotation.

6.1.2 Place Ping. The second state of the Symbol Support interface property is the ability to place a ping on the map. Pings are a way of calling other players' attention visually and audibly to a location on a map that persist for a period of time during a game [63, 110, 122]. *Place ping* is a state that is available only for multiplayer games, where one player needs to coordinate with others. This type of map interaction has been shown to be effective for team performance [63]; it serves as a lightweight means of interacting with the map that is not disruptive to game play. In some cases (e.g., [AL, Dota2, LoL]), pings can be augmented with semantic information [110, 122], such as a request for help or identifying a location as containing an enemy, which allows players to transmit more complex messages with simple pings.

6.2 Waypoint Support [*single* | *multiple* | *draw* | *N/A*]

A waypoint is essentially a map symbol that represents a place to do something, a place to gather, or a point in a journey. These are important items for maps especially as wayfinding and navigation are a portion of game design that has been replicated in a number of different ways. For waypoint support we consider the design of map annotations to support wayfinding in the gameworld. For something to count as a waypoint, its navigational data, as set by the player, must be available during play with the gameworld, outside of the map interface. Waypoint support may come through having a detailed mini-map or HUD elements that display points-of-interest information. In many games on the Nintendo DS series of systems, this includes having access to map annotations on a second screen during play.

6.2.1 Single. Games with *single* waypoint support only allow one waypoint to be set at a time. Generally, this waypoint is displayed with information to enable the player to reach it. This could take the form of a marker on a HUD compass (e.g., [ES:S, FO3, FO4]), or it could include more detailed wayguiding that provides the shortest route around obstacles (e.g., [H:ZD]).

6.2.2 Multiple. To provide *multiple* WAYPOINT SUPPORT, a game needs to let the player place more than one marker and provide access to it from the gameworld. Designs with *multiple* waypoints were uncommon, likely due to the complexity of providing multiple pieces of wayfinding information in the game's UI, as well as enabling the player to disambiguate the waypoints. A common design is to provide a second screen with map information on which any number of waypoints can be displayed. *Breath of the Wild*'s [LZ:BW] pins allow multiple different symbols in different colors, which are easy to tell apart. While not exactly a *multiple* design, several Bethesda games (e.g., [ES:S, FO3, FO4]) allow the player to set a *single* waypoint, but also indicate other nearby points of interest using symbols for different types of places.

6.2.3 Draw. We develop DRAWING SUPPORT as its own property, but, as a property for WAYPOINT SUPPORT, we are referring to how such drawings may be used as navigational data and are accessible during play with the gameworld. *Draw*-style WAYPOINT SUPPORT was only observed in Nintendo DS games, where a secondary touch screen is accessible at all times, generally with a map displayed on it. In these games, drawn map annotations are always available to the player can be used for wayfinding. In *The Legend of Zelda: Phantom Hourglass* [LZ:PH] and *The Legend of Zelda: Spirit Tracks* [LZ:ST], drawing on the map served to specify a route for the player's vehicle to follow.

6.3 Drawing Support [*freehand* | *paint grid* | *lines* | *N/A*]

This property addresses the ways in which players may make marks on the map. Many games with DRAWING SUPPORT allow players to choose multiple colors, and possibly brushes (e.g., wide or thin lines), when drawing. *Freehand* is common in games with touch-screen-based maps, enabling the player to put arbitrary "ink" on the map. Some games constrain the player to *paint grid* (which generally goes with *snap-to-grid* ALIGNMENT ASSISTANCE). Additionally, many games allow the player to create straight *lines*, facilitating triangulating locations and noting down components of the built environment (e.g., walls, doors).

6.3.1 Freehand. Freehand DRAWING SUPPORT allows a player the unconstrained ability to put information on a map [8]. Device resolution and artistic ability are the limitations for such systems. Various colors and strokes may be available, along with some ability to erase existing marks.

6.3.2 Paint Grid. With *paint grid* DRAWING SUPPORT the player can fill in an existing grid with colors. This was only observed in the *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON], where each grid space has a particular characteristic (e.g., land, water, dangerous material) and the player will color it accordingly.

6.3.3 Lines. Lines DRAWING SUPPORT refers to the ability of the player to put straight lines on the map. Generally, this is to allow a player to mark out the location of walls and other elements of a built environment that would be straight.

6.4 Text Support [*attach memo* | *text on map* | *N/A*]

The TEXT SUPPORT property is concerned with how players can attach large amounts of arbitrary information to the gameworld. For example, in the game *Final Fantasy XI* [FFXI], players could open up the game cartography interface and add a symbol to the map. Once that symbol was attached, players could then add an amount of text to it. This allowed players to note the death time of monsters, which was often once-per-day at that specific time plus or minus 3 hours. We consider both typed text and voice memos, but not drawing for this interface property. *Freehand* DRAWING SUPPORT *could* be used to put text annotations onto a map by simply writing. However, in practice this is often hard due to a combination of awkwardness of hand-writing with computer-input devices, the tracking resolution of such devices, and screen resolution being too low to render hand-written text legibly.

6.4.1 Attach Memo. As noted in the introduction of this interface property, *Final Fantasy XI* [FFXI], a game that allowed players from the Sony Playstation 2, Sony Playstation 3, Microsoft Xbox 360, and personal computer to play together on the same server, afforded players the ability to attach memos to pins placed on a map. In addition to *FFXI*, other early PC games, which make use of a keyboard and mouse, allow players to *attach memo*, so that a particular location has notes attached, accessible as details on demand. Usually SYMBOL SUPPORT is part of this, so that a memo has an icon associated with it.

6.4.2 Text on Map. A few games enable the player to simply put *text on map*, which means that the map interface shows the text directly, alongside gameworld geometry, instead of hiding it as details on demand. Games like *Everquest* [EQ] and *Elder Scrolls: Arena* [ES:A] would display these data alongside maps that looked hand drawn. These early games experimented quite a bit with their game cartography interface but many of their features have not been replicated.

6.5 ALIGNMENT ASSISTANCE [*grid provided* | *snap-to-room* | *snap-to-grid* | *straight lines* | *N/A* | *none*]

This property describes how much the cartography interface constrains player placement decisions, usually with some form of grid. The types of elements placed are covered by SYMBOL-, TEXT-, and DRAWING-SUPPORT. In some cases, there is no ALIGNMENT ASSISTANCE needed, because the interface does not support annotating or drawing (i.e., *N/A*), which is different from completely free-form placement where no constraints are provided (i.e., *none*).

6.5.1 Grid Provided. The interface may have a *grid provided*, in which case a grid is visible, but does not actually affect placement at all. Such designs support the player in lining elements up visually and in more easily visually processing the layout of other elements, but do not provide anything more. For example, *ARMA III* [ARMA3] provided players with a grid in order to allow them to coordinate things like rocket fire, where to gather before moving into an enemy camp, where certain types of soldiers should set up (e.g., snipers), and where they felt enemy placement would be.

6.5.2 Snap-to-Room. Snap-to-room is for games that feature distinct, non-square spaces, to which items are anchored. In *UnEpic* [UE], a player can add notes to rooms in a dungeon, which consists of a series of rectangular rooms of varied sizes. In *Zafehouse: Diaries* [Z:D], the player has a city map with a series of separate buildings, which can be annotated to indicate their contents. In these designs, spaces may have arbitrary shapes (not just those that are grid-shaped) and may be laid out with space in between the rooms.

6.5.3 Snap-to-Grid. The grid might be enforced or otherwise enabled through *snap-to-grid*, which requires that the player adhere to a grid when putting things on a map. In many cases, this means drawing on-grid line edges, filling in squares, and/or placing symbols inside of squares. All of the data of this type used squares, but there is no reason that hexagons, or other tessellating, geometric structures, could not be used. If the spaces are laid out as linked rooms on grid, then the game is still *snap-to-grid*, even if the gameworld space does not fill out every space (e.g., *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON], *Legend of Grimrock* series [LoG1, LoG2]).

6.5.4 Straight Lines. Some games provide *straight lines*, based on line-of-sight for an avatar in a 3D gameworld. These aid in ensuring that cartography elements are lined up with elements of the gameworld. In all observed cases (e.g., [LZ:BW, Miasm], *straight lines* involved pointing an avatar's vision at a particular location in order to get information added to the map.

6.6 Map Construction [*revealed* | *automap* | *triggered* | *manual*]

This property describes how the player goes about building up substrates of map data from which to make play decisions (or to annotate). Most games provide a base layer of map data that is progressively, automatically recorded, often with topography, walls, and so on. The player can then build upon the base layer, developing persistent annotations.

6.6.1 Revealed. The *revealed* state refers to games in which complete map data is always available. When the map is *revealed*, the player does not need to explore to acquire it, it is simply readily available. Such a state is most common in multiplayer games (e.g., [AL, Dota2, FBR, LoL]), as the gameworld is intended to be well-known to players [108], and in which coordination, rather than exploration, is a more critical concern.

6.6.2 Automap. Many games now feature an *automap*. The automap feature populates an existing blank surface with detailed data as the player visits locations and persists once the player leaves. *Automap*s are a near-ubiquitous feature of games with open worlds, representing a quality-of-life improvement for games that used to require pen-and-paper mapping [86]. Such map types encourage players to explore to fill out the maps. The data provided by an *automap* design enables the player to see where they have been and where they still might go. The *Elder Scrolls* [ES:A, ES:S] series often auto-mapped the world the player was exploring. In addition, players exploring these worlds would slowly gain an ability to click on the map and warp to that area later.

6.6.3 Triggered. *Triggered* is in between *revealed* and *automap*: when the player reaches a particular location or activates a location-specific game mechanic, part or all of the gameworld map is added to the game map interface. A *triggered* map also often provides *multiple* waypoint support in that it populates the map with points of interest within the area revealed by the trigger. This type of design is so common that we limited the number of games in which *triggered* map construction is their *only* game cartography interface component. For example, *Legend of Zelda: Breath of the Wild* [LZ:BW] started the player with a blank map. As players explored the world, they would climb to the top of towers and download data from them, thus automatically populating their map.

6.6.4 Manual. Finally, the rare *manual* map construction refers to games in which the player is responsible for mapping the gameworld using a cartography interface (or otherwise forgoes having access to a map). *EverQuest* [EQ] is notable because players had to manually map the gameworld. As a contribution to the game community, players would post map data online, along with information on how to load it into one's game.[8] The *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON] is famous for requiring players to draw in walls as they explore (although it has an optional *automap* setting to paint the floors of visited rooms, but not other details, reducing tedium).

7 FRAMEWORK: HIGH-LEVEL PLAY ACTIVITIES

A core contribution of this work is the identification of high-level play activities certain kinds of affordances for game cartography interfaces promote. The play activities we identify are directly supported by the game cartography interface and generally represent activities that are outside the core mechanics of the games in question. We do not make claim that these activities represent an exhaustive list of the kinds of things that players find maps useful for. Instead, we offer that

[8]e.g., Brewall's EverQuest Maps: http://www.eqmaps.info; EQ Atlas: http://www.allakabor.com/eqatlas/atlas.html.

Table 3. High-Level Play Activities and the Games in Which They Were Identified; "Count" is the Number of Games in the List

Play activity	Games	Count
Marking repeating events	[AL, ARMA3, DE:HR, EO1, EO2, EO3, EO4, EO5, EON, EQ, FFXI, GW2, LZ:BW, MH:W, PS1, PS2, SotS, SS1, SS2]	19
Identifying areas for exploration	[AC1, AC2, ARMA3, BoI:RB, C:LoS, Civ4, DE:HR, Doom2, Dota2, EO1, EO2, EO3, EO4, EO5, EON, EQ, ES:A, ES:S, FBR, FFXI, FW, FO3, FO4, GW2, H:ZD, LoG1, LoG2, LZ:BW, LZ:PH, LZ:ST, Miasm, M:SR, MH:W, PS:T, Rust, SC2k, SH:SM, SotS, SS1, SS2, T2, Tibia, UE, UU, Wiz8, Z:D]	46
Tracking remote information	[ARMA3, DE:HR, Doom2, EQ, FFXI, EO4, EO5, EON, ES:A, GW2, LoG1, LoG2, LZ:BW, LZ:PH, LZ:ST, PS:T, SH:SM, SotS, T2, Tibia, UU, Wiz8, Z:D]	23
Collaborative planning	[AL, ARMA3, AS, Dota2, DP, EQ, FBR, Rust, GW2, LoL, PS1, PS2]	12

the historic development of these tools allows researchers to observe a certain kind of interaction. The constraints of hardware and memory that pushed designers to create these systems have fostered certain kinds of play activities among those who have engaged them. These high-level play activities that have yet to be fully cataloged or understood.

High-level play activities are sets of game choices that appear in multiple games having game cartography interfaces. They are actions that the designs of particular game cartography interfaces, in conjunction with a game's core mechanics, enable. Generally, these activities took the form of *how* different types of interfaces afford a player knowledge, planning, and/or coordination. Identifying high-level play activities was the result of intimate knowledge of the games in the dataset, based on the overall mechanics that the games provided. Not all high-level play activities are available for all games (e.g., single player games would not support collaborative planning; games without resources that respawn would not involve marking repeating events).

We stop short of calling these "behaviors," because future research will address how players interact with them. We revisit the activities in the next section, connecting them to the properties, to identify how designers may promote these activities through design. The high-level game activities are as follows:

— *Marking repeating events*: the player identifies locations of gameworld elements (e.g., resources, enemies) that respawn, so that they can be found, and then farmed, fought, collected, and so on, repeatedly later. Such play requires that the game have elements that respawn after they are used and that the player is motivated to revisit them.
— *Identifying areas for exploration*: the player marks entrances to locations to revisit later in the game, possibly after they become accessible, after gaining new abilities, or after other activities.
— *Tracking remote information*: the player annotates site-specific information to support activity in another part of the game (e.g., for solving puzzles based on the configuration of a space or information elsewhere in the gameworld).
— *Collaborative planning*: a team of players use map annotations to make choices about future play [8].

Each high-level activity is connected to the games it is found in, as shown in Table 3.

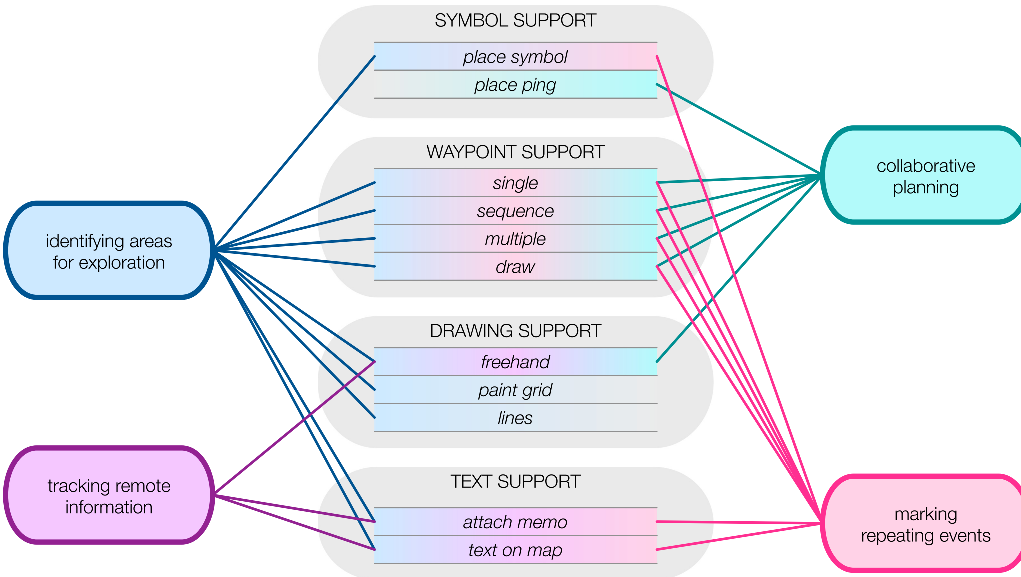


Fig. 9. Visualization of how property states map to high-level play activities. Colors are for highlighting.

8 DISCUSSION: BRINGING IT ALL TOGETHER

In this section, we put everything together and discuss the implications of our framework. There are a number of design implications manifested by our framework and this allows us to make suggestions about what a game cartography interface is. It also allows us to discuss what makes those systems successful. One point that we have mentioned, but not discussed, is the co-creation of annotation tools between developers and players. These are most often called add-ons, mods, or websites that catalog maps of a particular gameworld that might not even possess a map system, such as the Zombie/Survival horror augmentation of *Arma II*, *DayZ* [20]. These tools are created because of how game cartography interfaces enable or restrict their users. Sometimes, these affordances are not enough and results in players creating their own. Our final point of discussion is about how our game cartography interfaces framework supports designs beyond games.

8.1 Design Implications: Properties for Play Activities

A number of high-level play activities are enabled by having cartography interfaces in games and the properties that enable and support them. We can best define these play activities as the things a designer can nudge the player to do by limiting their access to information via the game cartography interface in some way. Each of these high-level play activities connects to the interface properties previously discussed as well as their specific states; Figure 9 shows these graphically.

8.1.1 Marking Repeating Events. Many games task the player with returning to locations for different reasons, including the collection of resources or to fight different enemies. The gameworld is designed to accommodate these types of activities and the game cartography interface is the means through which the communication of these concepts is performed. In addition, there are multitudes of content that may be optional. Special monsters, special resources, bonus content, and other types of activities can be hidden or displayed through the game cartography interface. This results in players making decisions about places that will be valuable to return to later in the game. It is here where the need for players to annotate their maps becomes important. For example, in *Legend of Zelda: Breath of the Wild* [LZ:BW], certain monsters and resources only appear in certain kinds of weather or at certain times of the day. By marking an area for later, players can continually check back to see if that event is currently happening or not.

Symbol support and text support are key for marking repeated events. In cases where there are multiple events the player will want to track, access to many symbols and/or colors facilitate a player in distinguishing events easily. *Attach memo* or *text on map* can supplement or enhance the ability to *place symbol*, enabling the player to add detail. This is especially useful for unusual or unique elements of the gameworld that a player might want to distinguish from others.

For example, we used the game *Final Fantasy XI* [FFXI] to discuss the ability to attach memos. In that game, players were afforded the ability to note things on their map interface. This allowed players to note when certain monsters that appeared every 21–24 hours previously died, where resource gathering points were, and other such information. Developing these systems in-game enables players to stay in the game, and not need to constantly refer to wikis, fan-driven documents, and other, external places.

While drawing support could be used for this type of play, it was not observed in our dataset, further, drawing support is likely to be imprecise when trying to put a mark at a specific location. Enabling any kind of waypoint support, which supports player wayfinding in the gameworld, on *placed symbols* can aid players in reaching marked locations more easily.

8.1.2 Identifying Areas for Exploration. Supporting exploration was a core component of almost every game in the corpus. In games where there are many branching paths, it is important to facilitate identifying areas for exploration. Affording marking maps up in this way allows players to make their own notes *as well as* allow designers to insert special content throughout the game for players to discover.

Metroid: Samus Returns [M:SR] is a game that requires substantial backtracking as the player gains new abilities. Parts of the gameworld are "gated" by these abilities, and must be revisited later in the game. The game's *automap* map construction can make it hard to see, at a glance, which places on the complex map have not been explored, but game's *place symbol* symbol support through a series of colored pins allows the player to easily call attention to unexplored areas.

In the *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON], the player may signal unexplored areas in a few ways. Typically, spaces the player has not visited remain uncolored on the *manual* map construction map, gaps in the drawn walls show where paths branch. Further, a player can use the provided symbol support put down icons for locked doors and monsters to signal places that are important to find again later in the game.

These interfaces use symbol support, especially with semantically meaningful icons, to allow players to flag areas for future exploration, backtracking with new abilities, or simply revisiting a space. This is especially critical in enabling players to maintain continuity of their activities after leaving the game [2, 59]. Without the ability to annotate maps, it can be challenging for players to remember what they had planned for next, what remains unexplored, and where essential locations are in the gameworld.

Certain types of map construction can be *at odds with* the needs of identifying areas for exploration, a negative point; other forms of support are needed to counteract this. While *automap* map construction helps substantially, it may be insufficient. In many cases, it may be hard to spot un-opened doors, paths that are simply not yet filled in the *automap*, or places visited with remaining activities. In other cases, *revealed* and *triggered* map construction can make it challenging for players to identify what is explored and what is not, because so many locations are automatically added to the map (as is the case with many Bethesda games: [ES:S, FO3, FO4]). By affording the player the ability to make their own annotations, many of the complaints about automapping technologies and map systems can be avoided. However, this also presumes that the iconography set and afforded systems are themselves sufficient in context to the game world itself.

In order to enable players to make choices about what to keep track of, we recommend using strategies similar to marking repeating events. The use of types of DRAWING SUPPORT, SYMBOL SUPPORT, and TEXT SUPPORT all can serve to let the player mark locations for exploration. Exploration is also facilitated by having WAYPOINT SUPPORT, so that players can find their way to unexplored locations (or back out of them to known territory).

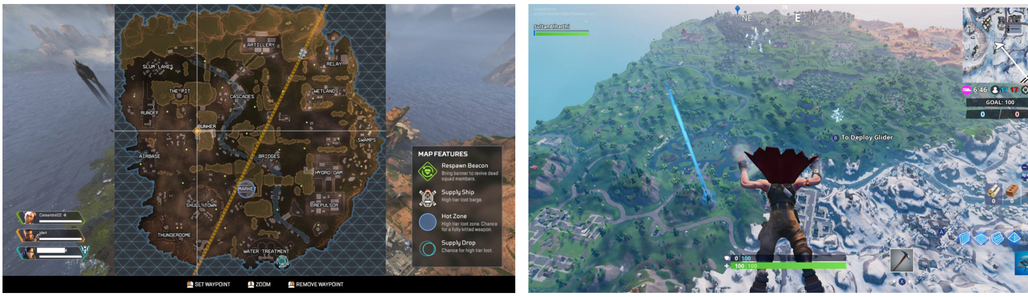
8.1.3 Tracking Remote Information. Sometimes information embedded in the gameworld is needed in other parts of the game. Most examples are puzzles that rely on the player to remember or otherwise store information about a remote location. One of the implications of our design history is that designers have slowly stopped asking players to put their controller down to draw a map, write a note, or use their memories outside of how to play the game. This is best exemplified by *Legend of Grimrock* series [LoG1, LoG2] where there may be a word or panel with something written on it that will allow players to solve something in another part of the level. Similarly, *Phantom Hourglass* [LZ:PH] and *Spirit Tracks* [LZ:ST] require that the player record visual information about a space for puzzle solving, using *freehand* DRAWING SUPPORT.

To track remote information, DRAWING SUPPORT and TEXT SUPPORT are most valuable though it depends on the game world. These two interface properties allow the player to track large amounts of location-based, arbitrary information. In some cases, *freeform* DRAWING SUPPORT is needed to mark down imagery observed in a location or to record some set of actions to be performed. In others (like the example mentioned in the previous paragraph), the ability to write down a riddle, phrase, or other bit of text through *attach memo* or *text on map* is needed.

8.1.4 Collaborative Planning. In multiplayer games, players may need to collaboratively plan action and coordinate activity [7, 8, 109]. Game cartography interfaces are ideal for supporting these kinds of *cooperative communication mechanics* [110], ways of communicating through the gameworld, using game mechanics, rather than verbally. Cooperative communication mechanics enable players to work together within the gameworld and leverage information within it, shortcutting verbal communication [108, 113], which improves efficiency and reduces errors.

WAYPOINT SUPPORT is not uncommon in team-based multiplayer games, enabling players to mark locations on a map, giving other players direction. Games that use *place ping* SYMBOL SUPPORT are growing in frequency and are especially prevalent in high-energy games like multiplayer online battle arenas (MOBAs) (e.g., *Dota 2* [Dota2], *League of Legends* [LoL]). In this games, players can click on a point on a mini-map to indicate a spot where players need to concentrate, where enemy combatants are, or where a skirmish is taking place. Other games like third-person, over-the-shoulder-style battle royales like *Apex Legends* [AL] have begun to expand the functionality of this system by expanding the types of pings into a tonal library of sorts (Figure 10). In other games, designers will use multiple symbols to push additional information out to the team [63, 121, 122], thus combining iconography and waypoint mechanics.

A few interfaces use cartography mechanics as cooperative communication mechanics, so that players can construct plans in the gameworld. These make use of DRAWING SUPPORT, usually *freeform*, so that players can expressively mark out paths. The ability to draw is important, because a shortest path, as is often provided through WAYPOINT SUPPORT, is not always desirable for strategic reasons (e.g., surprising opponents). The military-simulation inspiration of *Arma III* [ARMA3] is heavily invested in these types of interface properties as coordinating military units requires a significant degree of planning. These systems, especially waypoint systems, have begun to replace the chat-systems of games due to numerous issues with player-toxicity, shared languages for international games, and efficiency due to the tension of the game. Use of these



(A) (B)

Fig. 10. (A) The Ping system in *Apex Legends* [AL] allows each team member to coordinate and collaboratively plan actions. Placing a pin into the map or gameworld will display a colored marker that is visible to all teammates. (B) In *Fortnite* [FBR], markers allow each team member, in the squad and duo modes, to collaboratively plan actions, allowing each member to set a single colored waypoint. (Screenshots taken ⓒⓘ Sultan A. Alharthi.)

systems will no doubt expand as designers endeavor to provide a means through which to allow players to coordinate in-game but not necessarily communicate about things outside of the game.

8.2 Designs Depend on Input Modalities

The available input affordances [76] in games vary, especially depending on available input modalities like touch screens, controller, or keyboard and mouse [48]. Some, but not all games we observed leveraged the available affordances of the input modality. Those games that did leverage the available affordances often offered different cartography interfaces dependent on the different controllers different platforms used. Two of the most common interface properties in our dataset: enabling TEXT SUPPORT (mostly through *attach memo*) and *freehand* DRAWING SUPPORT, rely heavily on input modality. TEXT SUPPORT is historically very old, whereas DRAWING SUPPORT has materialized only recently due to the hardware necessary for it to be accessible. In both cases, these two interface properties are the most blatant evidence about hardware driving design of game cartography interfaces.

TEXT SUPPORT typically involves pressing a button to bring up the map, moving a cursor to an area or location, and then pressing another button to bring up a window to make a text memo via either the PC-keyboard or if on a console, on-screen keyboard. The on-screen keyboard is often seen as a negative as entering text with other control schemes is challenging for players [116]. This has resulted in new, more varied ways of marking up maps. The early games in which this functionality was observed were played with a mouse and keyboard on PCs such as *Planescape: Torment* [PS:T], *Ultima Underworld: The Stygian Abyss* [UU], the *System Shock* series [SS1, SS2]. It is worth noting that the version of *Unepic* [UE] we assessed was on PC and has the ability to *attach memo*. However, when the game was ported to the Nintendo Switch, the designers removed this capability, likely due to the lack of a keyboard. In this rare circumstance, movement from one platform to another was not an impetus to change that functionality but remove it due to the loss of the game's input device.

Likewise, interfaces with DRAWING SUPPORT follow the proliferation of touch screens. These interfaces often feature drawing in the simplest possible way: a draw mode allows the user to put arbitrary marks on the map screen and an erase mode removes them. Most of these interfaces are implemented using the second touch screen of the Nintendo DS-series of consoles such as *The Binding of Issac: Rebirth* [BoI:RB], *Castlevania: Lords of Shadow—Mirror of Fate* [C:LoS]). Some games without touch screens have attempted to use DRAWING SUPPORT with the proliferation of motion controllers. *Silent Hill: Shattered Memories* [SH:SM] afforded players with a ray-casting stylus that players could use by simply waving their controller around. This mode of input is often tied explicitly to the hardware they are initially created for. As a result, the versions of these games played on other consoles do not have the drawing functionality.

Cartography mechanics are largely absent from 3D console games. These large virtual worlds often use dual analog sticks which are driven by thumbs and buttons [48]. The console controller has undergone rapid re-design throughout the development of the video game industry. As noted in previous paragraphs, the addition of an on-screen keyboard will disrupt gameplay. The legacy of notations and memos are notable and many games do attempt to use the memo functions where appropriate. However, designers have begun to use console controllers as a means through which to create new ways to view maps and record memories or make notes. This is what made the recent *Breath of the Wild* [LZ:BW] such an interesting source of inspiration. This game enables map annotation through a scope, or camera-style, first-person interface (Figure 1). This enables the dual analog sticks to serve the function they do best: facilitate movement and looking in a 3D gameworld.

8.3 Game Modifications and Extensions

Many games do not feature annotation systems out-of-the-box, instead, players develop *add-ons* and *modifications* (i.e., "mods") for these games to enable them to annotate game maps. Add-ons are simple programs embedded in the game that enables players to perform specific tasks not possible in the standard version of the game [30]. In some cases, developers anticipate players using mods, and so some use a built-in application programming interface to access gameworld data for mapping (e.g., player coordinates). In other cases, mods manually extract the needed data by capturing on-screen information or reading data files related to the gameworld [Mike "Zugg" Potter, personal communication]. Examples of add-ons and mods include the following:

— several extensions in *World of Warcraft* [16]: ArtPad,[9] HandyNotes[10] to create of point-of-interest databases, and DrawingBoard[11];
— mapping clients for text-based adventures (e.g., zMUD[12]) and interactive fiction[13]; and
— a number of separate programs to support planning strategies and tactics in multiplayer games (e.g., *LoL* Planner,[14] Tacnet[15]).

The creation and widespread use of these third-party game cartography interfaces is a testament to their value for players. The current research does not include these add-ons or extensions because we wanted to investigate what has been done by designers first. The investigation of the characteristics and use of these player-created game cartography interfaces will be future work and much of this investigation has already begun. There are additional considerations around creator intent and player needs as some of these add-ons are considered "cheating" by their creators.

[9] http://wowinterface.com/downloads/info8162-ArtPad.html.
[10] https://www.wowace.com/projects/handynotes.
[11] http://www.wowinterface.com/downloads/info10777-DrawingBoard.html.
[12] http://www.zuggsoft.com/zmud/zmudinfo.htm.
[13] A list of interactive fiction mapping tools is available at http://www.ifarchive.org/indexes/if-archiveXmapping-tools.html.
[14] http://map.riftkit.net.
[15] https://tacnet.io.

8.4 Implications Beyond Game Design

The goal of this research is to provide a summative evaluation of game cartography interfaces and develop a framework that will foster discussion about them. While our aim is to support game designers and researchers in this way, there is potential for our framework to provide insights into how cartography interfaces and maps could be designed for physical world purposes. This includes cartography interfaces for crisis response, geographic information systems, and travel applications. More importantly, we seek to display how interface design in video games can be useful for the design of interfaces outside of games. The most direct application is in crisis response; specifically, the support of search and rescue operations and other collaborative mapping efforts.

8.4.1 Supporting Search and Rescue Mapping. In search and rescue practice, responders search within and navigate the environment, make sense of situations, and collaboratively plan operations [3, 4, 60, 109]. Responders use different types of maps (physical and digital) and marking systems to annotate key locations to keep track of operations. All the information collected in the field is communicated to other team members and command bases through maps [38, 104, 120]. This makes the map become the basis of collaboration and planning. It can be difficult to understand what information is still relevant and what parts of the search area are already explored, make sense of the retrieved information, and be aware of what each collaborator is working on [23, 57, 85, 121]. Collaborative video game cartography interfaces like those in *Arma III* [ARMA3] could be used to keep an active, real-time map of investigative efforts. In this way, we can use the interface properties of WAYPOINT SUPPORT and SYMBOL SUPPORT in crisis response mapping. This would help ground information in physical space, and support disaster reconnaissance [29, 119].

8.4.2 Supporting Collaborative Geographic Information Seeking and Retrieval. Current mapping technologies like Google Maps, Waze, and Apple Maps have limited affordance for tourism. Instead, they rely heavily on point-A-to-point-B or door-to-door service. Collaborative mapping technologies like those in video games have begun to afford these efforts by combining real-time iconography (e.g., vendors for certain kinds of items are represented by a turkey leg (food) or a medical cross (health items)). This set of affordances can be deployed when a distributed group searches for specific geospatial information. Something as simple as planning a road trip is currently somewhat challenging to keep track of—the large number of suggested stops, required stops, and places of curiosity. These challenges are profound, particularly when no interfaces or tools are provided and used to support these collaborative activities. In geographic information seeking, maps are commonly used to search and retrieve locations, landmarks, and points of interest. Future geographic information support systems can provide collaborative DRAWING SUPPORT interfaces to assist groups in identifying areas for exploration, tracking remote information, enabling awareness among group members, and building a common ground between collaborators [6, 8, 26, 50].

9 CONCLUSION

Game cartography interfaces have been developing quietly and with little notice since video games were created in the 1970s. The present research unites our fandom and our expertise as researchers of the socio-technical in order to provide actionable descriptions of game cartography interfaces. Our descriptions provide a rigorous catalog of affordances for game cartography interfaces based on their appearances over time. In addition to this catalog of affordances, we also provide a set of interface properties and high-level play activities promoted by those interface properties. In doing so, we hope to promote a discussion of map interfaces in general and outlined a number of potential spaces through which game cartography interfaces and geography-based collaborative activities can learn from one another.

The interaction between game and non-game interface design is already noticeable. Game cartography interfaces, especially after the creation of mapping platforms like MapQuest, Google Maps, Waze, and other forms of GPS-based map services, have begun to reflect the visual and afforded elements of mapping platforms used by everyday citizens. However, these game cartography interfaces also partially reflect the weaknesses of those platforms. Where game cartography interfaces experiment with these interfaces, and correct those weaknesses, is where more conversation needs to occur.

There are a number of problem areas that mapping platforms need to overcome [23]: incomplete or incorrect information [90, 91], problems of maps for indoor locations [49], 3D issues within 2D map interfaces, and the lack of available collaboration [3]. These issues are not only experimented with through the design of game cartography interfaces, but considered in ways that the world outside of video games needs to see. Our hope in providing our catalog, interface properties, and high-level play activities is to not only bridge these two fields of research and design, but to begin to unite their purposes. If current research focuses on understanding how people use their maps, then integrating how game cartography interfaces nudge users toward where they need to go whether they know they should go there or not would meet current research [97].

In our framework, games that afford users to mark up their maps with SYMBOL SUPPORT allow users to mark places of interest or places that look interesting either by seeing them far off or on the map itself. This affordance can be replicated using cameras and mapping applications. The use of SYMBOL SUPPORT in products like Google Maps could allow businesses to learn where residents of a city are going or a tourist to learn about hidden, out-of-the-way spots. TEXT SUPPORT and DRAWING SUPPORT, while ripe for vandalism, can provide collaborators, advertisers, and independent citizens with a means through which to offer custom directions, note landmarks of interest, and provide explanations for direction styles that call for odd pieces of data like "turn left at that crooked tree after the burnt-down barn." WAYPOINT SUPPORT and ALIGNMENT ASSISTANCE allow designers to witness automated mapping technologies in order to understand their potential for mapping platforms. Finally, the use of all these affordances in virtual spaces for collaboration and coordination allow researchers to witness how untrained fans and players use these technologies to navigate complex environments in real time.

This research is a first step in the process of the following:

(1) bridging video game mapping systems with those used outside of games and
(2) providing vocabulary to discuss them.

We based this work on a single video game (*The Legend of Zelda: Breath of the Wild* [LZ:BW]) that used tourism as the basis of its interface. It spoke to our needs as crisis response researchers in that it provides more useful tools for situation maps than much of the research on these tools has provided. Future research within this space should deepen this relationship by asking not only game-players to coordinate with these systems, but emergency response professionals as well.

APPENDIX

A GAME DATA

Game and property state for each game in the Ludography. The Symbol Support column describes the number of symbols available, along with further details on what they are. There are three special cases of Map Construction: the *Etrian Odyssey* series [EO1, EO2, EO3, EO4, EO5, EON] allows the player to use a *manual* map or provide an *automap* as a game configuration setting. In *Firewatch* [FW], the map is *revealed* at the start, but certain game activities *trigger* paths that are added automatically. In *Metroid: Samus Returns* [M:SR], an *automap* is provided, but other game mechanics can reveal portions of the map that have not yet been visited (*triggered*).

Game	Symbol support: degree (types)	Text support	Waypoint support	Drawing support	Alignment assistance	Map const.
[AC1]	N/A	N/A	Single	N/A	N/A	Triggered
[AC2]	N/A	N/A	Single	N/A	N/A	Triggered
[AL]	Place ping: many (context-dependent)	N/A	Multiple	N/A	None	Revealed
[ARMA3]	Place symbols: many	Attach memo	Multiple	Lines	Grid provided	Revealed
[AS]	N/A	N/A	N/A	Freehand	None	Revealed
[BoI:RB]	N/A	N/A	Draw	freehand	None	Automap
[C:LoS]	N/A	N/A	Draw	Freehand	None	Automap
[Civ4]	Place symbol: 1 (pin)	Attach memo	Single	N/A	Snap-to-grid	Automap
[DE:HR]	Place symbol: 1 (memo)	Attach memo	N/A	Freehand	None	Revealed
[DP]	N/A	N/A	Draw	Freehand	Snap-to-grid	Revealed
[Doom2]	Place symbol: 1 (numbers)	N/A	N/A	N/A	None	Automap
[Dota2]	Place symbol: 2 (towers; enemies)	N/A	Single	freehand	None	Revealed
[EO1]	Place symbol: many (memo; icons)	Attach memo	Multiple	paint grid / lines	Snap-to-grid	Automap OR manual
[EO2]	Place symbol: many (memo; icons)	Attach memo	Multiple	paint grid / lines	Snap-to-grid	Automap OR manual
[EO3]	Place symbol: many (memo; icons)	Attach memo	Multiple	paint grid / lines	Snap-to-grid	Automap OR manual
[EO4]	Place symbol: many (memo; icons)	Attach memo	Multiple	paint grid / lines	Snap-to-grid	Automap OR manual
[EO5]	Place symbol: many (memo; icons)	Attach memo	Multiple	paint grid / lines	Snap-to-grid	Automap OR manual
[EON]	Place symbol: many (memo; icons)	Attach memo	Multiple	paint grid / lines	Snap-to-grid	automap OR manual

[EQ]	Place symbol: many	Text on map	Single	freehand / lines	Grid provided	Automap
[ES:A]	N/A	Text on map	N/A	N/A	None	Automap
[ES:S]	N/A	N/A	Single	N/A	None	Automap
[FBR]	Place ping: 1	none	Single	N/A	None	Revealed
[FFXI]	Place symbol: 1 (pin)	Attach memo	Single	N/A	Grid provided	Revealed
[FO3]	N/A	N/A	Single	N/A	None	Automap
[FO4]	N/A	N/A	Single	N/A	None	Automap
[FW]	N/A	N/A	N/A	N/A	N/A	Revealed AND triggered
[GW2]	Place ping: 2 (personal; team)	Attach memo	Multiple	N/A	None	Automap
[H:ZD]	N/A	N/A	Single	N/A	N/A	Triggered
[LZ:BW]	Place symbol: many (colored pins; icons)	N/A	Multiple	N/A	Straight lines	Triggered
[LZ:PH]	N/A	N/A	Draw	Freehand	None	Triggered
[LZ:ST]	N/A	N/A	Draw	Freehand	None	Triggered
[LoG1]	Place symbol: 1 (memo)	Attach memo	N/A	N/A	Snap-to-grid	Automap
[LoG2]	Place symbol: many (icons)	Attach memo	N/A	N/A	Snap-to-grid	Automap
[LoL]	Place ping: many	N/A	Multiple	N/A	None	Revealed
[M:SR]	Place symbol: many (colored pins)	N/A	Multiple	N/A	Snap-to-grid	Automap AND triggered
[MH:W]	Place ping: 1	N/A	N/A	N/A	None	Triggered
[Miasm]	None	N/A	N/A	Lines	Straight lines	Manual
[PS1]	Place symbol: 1 (pin)	N/A	Single	N/A	None	Triggered
[PS2]	Place symbol: 1 (pin)	N/A	Single	N/A	None	Triggered
[PS:T]	None	Attach memo	N/A	N/A	None	Automap
[Rust]	None	N/A	N/A	Freehand	None	Automap
[SC2k]	None	Attach memo	N/A	N/A	None	Revealed
[SH:SM]	None	N/A	N/A	Freehand	None	Revealed
[SS1]	None	Attach memo	N/A	N/A	None	Automap
[SS2]	Place symbol: 1 (memo)	Attach memo	N/A	N/A	None	Automap
[SotS]	None	Attach memo	N/A	N/A	Snap-to-room	Automap
[T2]	None	Attach memo	N/A	N/A	None	Revealed
[Tibia]	Place symbol: many (icons)	Attach memo	Multiple	N/A	None	Automap
[UE]	Place symbol: 1 (memo)	Attach memo	N/A	N/A	Snap-to-room	Automap

[UU]	None	Attach memo	N/A	N/A	None	Automap
[Wiz8]	None	Attach memo	N/A	N/A	None	Automap
[Z:D]	Place symbol: 2 (circles)	Attach memo	N/A	N/A	Snap-to-room	Revealed

B GAME SAMPLING SOURCES

Sources that served to identify games with cartography interfaces and develop an understanding of game map history that drove sampling for the corpus.

Title	Type	Link
Why has "writing/notes on game maps" not become more prevalent? : truegaming	Forum	https://www.reddit.com/r/truegaming/comments/1i1m62/why_has_writingnotes_on_game_map s_not_become_more/
How is everyone using stamps?	Forum	https://www.gamefaqs.com/boards/189707-the-legend-of-zelda-breath-of-the-wild/75147234
RPS Asks: Maps In Games?	Forum	https://www.rockpapershotgun.com/2009/12/01/rps-asks-maps-in-games/
Life on the Grid	Blog post	https://www.filfre.net/2019/01/life-on-the-grid/
Map Annotation System (Concept)	Wiki	https://www.giantbomb.com/map-annotation-system/3015-6495/
Cartography (Concept)	Wiki	https://www.giantbomb.com/cartography/3015-4197/
Treasure Map (Object)	Wiki	https://www.giantbomb.com/treasure-map/3055-5638/
Map (Object)	Wiki	https://www.giantbomb.com/map/3055-660/
Cloth Map (Concept)	Wiki	https://www.giantbomb.com/cloth-map/3015-3006/
Breath of the Wild: The Best Game Ever	Video review	https://www.youtube.com/watch?v=ZLRedgWqejo
How Big is the Map?	Video series	https://www.youtube.com/channel/UC-CVWg-9oatigOFK_Hb6c5A
The Polygon Show	Podcast	https://www.polygon.com/the-polygon-show
The Joystiq Podcast	Podcast	(Now defunct; only available as an archive: https://archive.org/details/JoystiqPodcastComplete)
RadioRadar+	Podcast	http://rss.talkradar.wordpress.com
The CRPG Book Project	Book	[86]
Masters of Doom	Book	[61]
Replay: The History of Video Games	Book	[33]
The Secret History of Mac Gaming	Book	[73]
Stay Awhile and Listen: Book 1	Book	[28]
Super Mario: How Nintendo Conquered America	Book	[95]
The Unofficial NES/Famicom: A Visual Compendium	Book	[35]
The Unofficial SNES/Super Famicom: A Visual Compendium	Book	[36]

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