The Impact, Use and Design of Game Awareness Widgets

By

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Abstract

Game designers create interface elements, called *Game Awareness Widgets*, to allow players to interact with games and to provide an awareness of what is happening in the game. Game awareness widgets are, therefore, extremely important parts of video games, which game designers carefully craft to best support players in a game and facilitate a desired play experience. Despite their importance Game Awareness Widgets have not been well studied and how they can best be designed. Through three separate studies this thesis exemplifies how game awareness widgets can be studied to uncover important new knowledge that can improve their design. These three studies contribute new information on how Game Awareness Widgets impact players, how players use them, and what current design practices are. The results of this thesis can help guide future research and provides important new knowledge to help designers build games that provide the best experience to players.

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List of Symbols, Nomenclature or Abbreviations

1. GAW – Game Awareness Widget
2. HCI – Human Computer Interaction
3. InfoViz – Information Visualization
4. UI – User Interface
5. Game world/game space – The virtual environment that gameplay takes place in
6. Game mechanics – The rules of a game that define the causalities of player actions as well as the end states of the game
7. Game interface – The UI of a game
8. Game play – The act of playing a game
9. Widget – Isolated UI components that have a specific interaction associated with them (e.g., buttons, clocks, graphs).

1 - Introduction

Entertainment and play are central parts of human culture. The global video game market alone is expected to reach $90 billion in revenue by 2020 and there are currently an estimated 2.5 billion self-identified *gamers* around the world [15]. Because so much time is spent with games, game designers are interested in how they can create interfaces that allow players to interact with games in the best way. Like other types of software, modern game designers provide players with *widgets*—interactive interface elements-— that are carefully crafted to best support play. While game designers and game researchers often put focus squarely on the design of characters, the game environment, and game mechanics (what can be done in a game), game interfaces and widgets have received somewhat less attention. Past research has shown that even subtle design decisions in elements of the interface can have an important impact on the experience players have while they are playing a game [11].

1.1 - **Graphical Awareness Widgets**

Widgets are interactive interface elements that are used to control systems and display information in software [12]. Widgets can be found in most game interfaces, with different widgets being responsible for providing particular information and/or interactions. For example, widgets such as buttons, checkboxes, and scroll bars are used in menu systems to allow players to setup and start games. Typically, widgets that are in the game but not part of gameplay are quite similar to those that can be found in other types of software interfaces (e.g., a word processor or a web browser). However, widgets that are actually part of the gameplay—in that they provide information needed to make decisions in the game or to control aspects of gameplay—are more varied in their functionality, style and purpose than what is often seen in other types of software interfaces (see Figure 1.1 for examples). These in-game widgets are defined as *game awareness widgets (*or *GAWs)*. GAWs assist players in performing in game actions and in maintaining an up-to-date awareness of the state of and actors in a game world, but are not part of the game world itself. This idea of *Game Awareness Widgets* extends the concept of *Awareness Widgets* as defined by preexisting Computer Supported Cooperative Work (CSCW) research [5]. Figure 1.1 provides examples of how game awareness widgets often parallel widgets found in other software such as social or productivity applications but have been carefully designed to provide a rich set of information relevant to gameplay. Game awareness widgets can provide an awareness of the player's characters (e.g., health bars to display health, a counter for lives, a decoration to display experience, etc.), awareness of other players (e.g., a blip on a map to show location, an animated icon to display state, etc.), and of the game state (e.g., a status bar to display progress towards a goal, an interactive list for available actions, etc.).

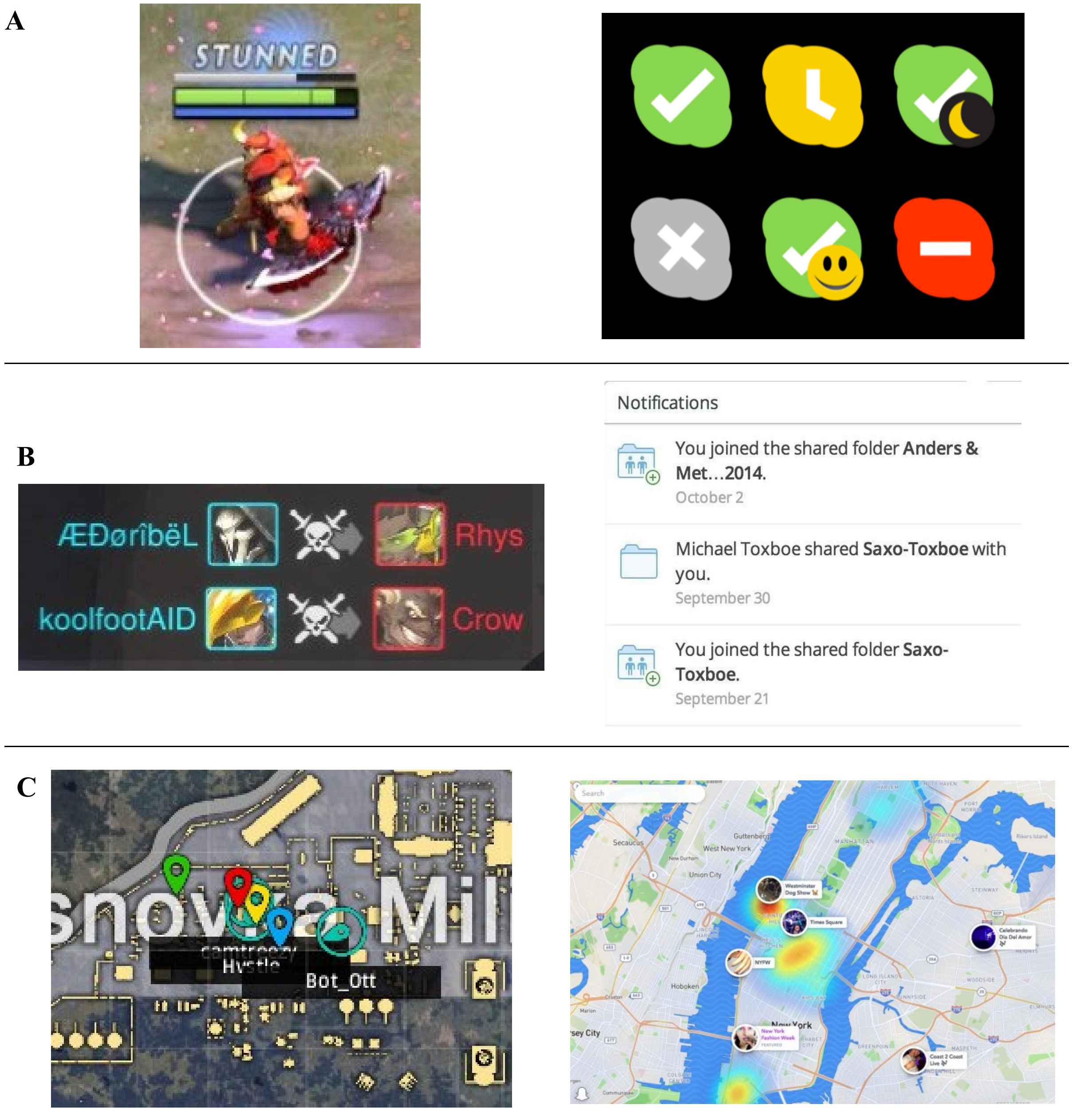

Figure 1.1: To demonstrate the differences and similarities between widgets found in online, multiplayer games and other software (i.e., social & productivity). A. Status indicators in *Dota 2* (left) and *Skype* (right). B. Event feeds in *Overwatch* (left) and *Dropbox* (right). C. Map displays in *Player Unknowns Battlegrounds* (left) and *Snapchat* (right).

1.2 - **Information Visualization**

Because widget design in video games is under-unexplored, designers often rely on the design guidelines from the field of information visualization (InfoViz) to provide a basis for understanding and informing the design of GAWs. InfoViz focuses on the visual representation of abstract data and the use of and interaction with visualized data. GAWs fit particularly well into many InfoViz guidelines because their core task is to present and communicate abstract date (i.e., data without a natural visual representation) to the player.

InfoViz research has a number of guidelines for mapping data to visual elements, accounting for the way that humans perceive visualizations. For example, it is because of information visualization research that we know horizontal bar graphs are easier to read that vertical ones [13]. The InfoViz community also addresses important visualization issues such as color blindness [7] and how to use animation effectively [9]. Many of these findings can also be applied to GAWs and thus act as a jumping board for research of GAWs and information displays in games. The articles presented in this thesis often rely heavily on InfoViz concepts and, thus, introduce them in their appropriate context.

1.3 - **Background & Research Questions**

Game designers and developers are faced with a variety of challenges. From designing the mechanics of a game, to writing a compelling story and creating a usable interface. Game mechanics, for example, affect everything from how users provide input (e.g., What button will they use to jump?) to how the game world works (e.g., How high should the character jump?) and what challenges and goals the player is presented with (e.g., Will the character die if they don't jump over the obstacle?) [10].

The Human-Computer Interaction (HCI) community has primarily focused on gameplay and game interface design which spans a wide range of topics. For example, gameplay alone includes how players play games (e.g., input control schemes), player experience[1] (e.g., if someone finds a game fun and why) and player behavior (i.e., what kind of decisions players make in games and why). Interface design, or more specifically game interface design, focuses on User Interface (UI) design itself. This includes anything from the menu a player sees when they load up a game to the widgets and colors used during gameplay. It is apparent that the well-studied aspects of game design (UI, mechanics and storytelling) have an important impact on player behavior, performance and experience; however, other subtle and less apparent aspects of a game can also

[1] Play experience, a common HCI concept, can be defined as the overall experience a player has in playing a game, which might include enjoyment, satisfaction, exhilaration, tension, etc.

impact players. For example, the type of controller a player is using has been shown to have a substantial influence on the player experience of a game [11].

One shortcoming in current research is a basic understanding of impact, use and design of the GAWs players interact with during gameplay. Despite the importance of play experience and the recognition that even small design choices can have a large impact upon it, very little work has yet focused specifically on game awareness widgets. As a starting point in this area, this thesis identifies three broad research questions that need to be investigated in order for game awareness widget design to be effectively designed for games:

1) *How do awareness widgets impact players during gameplay?*

   Games already implement a wide variety of GAWs. They are often added in order to fill a perceived need and iteratively designed to target a specific gameplay experience. However, the specifics of their relationship with players experience, player behavior and player performance are unknown. Without this information designer may waste effort exploring awareness widgets and designs that will not lead to a desired effect. For example, a game designer might manipulate how health information is displayed to players (by displaying that players have less health than they actually do), with the intention to instill an additional sense of urgency and tension. However, if such a manipulation isn't done effectively players might be overly passive and not engage in activities that might lead to experiencing tension.

2) *What motivates the use of game awareness widgets and how are they received by players?*

Part of successful design is an understanding of the need that the design is to satisfy an information need. Player needs for GAWs is poorly understood and game designers often provide generic solutions expecting players to adapt these tools to fit their needs. For example, Multiplayer Online Battle Arenas (.e.g *Dota 2*) often provide players with generic ping and annotation tools but these do not satisfy all needs expressed by players and could thus be easily misinterpreted when used for communicating with other players.

3) *How can game awareness widgets be designed to support specific gameplay experiences?*

   Game designers are often forced to use in-house knowledge or 'reinvent the wheel' to create GAWs. This can greatly limit the progression and innovation available to the field, in addition to leading to inefficiencies in all aspects of game design and development. The lack of centralized design patterns and/or frameworks results in many implementations making the same mistakes or lead to games having suboptimal experiences without a common basis for design knowledge. For example, many indie games have poor usability and design flaws limiting their success, which can be in part due to the limited availability of design knowledge that indie game designers have available and that they are able to incorporate into their game.

These three questions provide a logical progression to start building an understanding of game awareness widgets and how they can be designed.

First, given the current gap in current research, the impact that GAWs have on players must be identified. The main factors to measure the impact GAW designs can have are player experience, player behavior and player performance. The impacts and relationships between GAWs and any of these factors should guide the design and interpretation of future experiments.

Second, the use and emergent practices of GAWs by actual players should be studied to guide future designs and implementations and ensure their relevance to addressing player needs.

Third, and finally, current designs and implementations should be surveyed to ensure that designers and researchers are grounded in the current design practices of GAWs. These can be connected with relevant understanding to support a particular purpose.

1.4 - **Organization of the Thesis**

This thesis will first provide a brief overview of the current state of game research as well as introduce the topic of game awareness widgets. An exploration of the problem space will conclude with the identification of three main research problems, which provide an entry point for future research into game awareness widgets (Chapter 1). Chapter 2 examines RQ1 by contrasting a particular design decision for one type of GAW. By collecting and analyzing play data and surveying players using an experimental game developed by the author, Chapter 2 provides insight on how GAW design can impact play experience. The second article (Chapter 3) addresses RQ2 by observing and analyzing the interactions of players 'in the wild' with GAWs, by analyzing real gameplay in a popular online game. Again, this study included a survey of players to establish the perceived usefulness of the GAWs studied. Finally, RQ3 is addressed in Chapter 4 with the presentation of a design framework focusing on GAWs. This design framework is the result of a grounded theory analysis of existing GAWs and identifies current practices in the game industry. Because an analysis of all types of GAWs is not feasible, for this analysis we focused specifically on those for sharing information about teammates in co-operative games (e.g., teams where players are on the same team). Chapter 5 will conclude this thesis by unifying the three articles presented and readdressing the before mentioned research questions.

Since this thesis is based upon three separate articles, we sometimes depart from a unified referencing scheme to match the original publication format. For example, the way games are referenced is handled somewhat differently between articles. However, in all cases the formatting should be self-evident or further explained within each article. Reference lists are kept relative to the corresponding article, with a reference list for the introduction and conclusion of the thesis specifically found in Chapter 6. Figures and tables have been re-captioned to reflect the chapter in which they reside, references to them have been updated accordingly.

1.5 - **Contributions**

This article-based thesis is comprised of two published articles (Chapters 3 and 4) and 1 more article that at the time of this writing is in submission (Chapter 2). The primary contribution of this work is the conceptualization of game awareness widgets and a discussion of how game awareness widgets and their design can be improved. Finally, the articles also provide a demonstration of the application of existing research techniques to the topic of game awareness widgets.

2 - How Do Awareness Widgets Impact Players During Gameplay?

While GAWs are an important part of game interface design, the impact they have on players is poorly understood, and they are not often a focus of game design. This means that the design of GAWs could have unintended consequences and could contribute to the failure or success of a product. This research question focuses on the use of information communicated by GAWs. Considering different GAW designs, the specific GAW design may impact players in three ways. First, the GAW may provide information that the player uses to make a decision, impacting the players behavior. Second, if behavior is changed because of the information from a GAW, then player performance may be changed. Finally, if players behave differently in the game (by taking different actions) and they perform differently in the game because of those actions, it is likely, therefore, that the GAW can then impact their play experience.

To study the impact and effects that GAWs have on players, we first needed to focus on an appropriate and representative widget in which to research. Since the potential effects of GAW on player behavior are generally unknown the selected GAW should attempt to maximize the possible effects. General information visualization theory states that the effectiveness of information visualization depends on the data density [6] as well as its layout and representation [13], thus the selected widget should have a high data density and an effective representation. Additionally, the selected widget must visualize data in a manner that is flexible enough to allow it to act as the dependent variable (i.e., it must be able to represent several different conditions). Some visualizations are more flexible than others and can influence the user's perception of the data by manipulating itself [3]. One widget that fulfills these points are health bars which are thus selected as an appropriate widget for further study. Health bars are a common and ubiquitous GAW. They are often represented by simple bar graphs and thus have a high data density, a powerful representation and have already been manipulated in existing games to influence players.

The study presented in *Healthy Lies: The Effects of Misrepresenting Player Health Data on Experience, Behavior and Performance* implemented two health bars, one that accurately represents health and one that misrepresents it, in a custom-built game environment. In an online gameplay experiment on 125 participants the impact of these data visualizations was measured based on differences observed in player behavior, performance and experience.

Article 1

Jason Wuertz, Scott Bateman, and Max Birk. 2019. Healthy Lies: The Effects of Misrepresenting Player Health Data on Experience, Behavior and Performance. Conditionally accepted for the *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19). ACM, New York, NY, USA, 1978-2018.

2.1 - **Abstract**

Game designers use a variety of techniques that mislead players with the goal of inducing play experience. For example, designers may manipulate data displays of player health—showing they have less health than they actually do—to induce tension. While commonly used, players make decisions based on in-game data displays, raising the question of how misrepresentations impact behavior and performance, and whether this might have unintended consequences. To provide a better understanding of how data misrepresentation impacts play, we compare two versions of a game: one that displays health accurately and one that misrepresents health. Our results suggest that even subtle manipulations to data displays can have a measurable effect on behavior and performance, and these changes can help explain differences in experience. We show that data misrepresentation needs to be designed carefully to avoid unintended effects. Our work provides new directions for research into the effective design of misrepresentation in games.

CCS Concepts
Human-centered computing, User interface design, Human-centered computing, Information visualization, Applied computing, Computer games

Author Keywords
Game design; player experience; health bars; data misrepresentation; deception.

2.2 - **Introduction**

Modern video games often include many data displays that help communicate important information about the state of the game (e.g., time, progress or score) and the state of the player (e.g., identity, health, experience or abilities). Players make use of data displays in order to make decisions about what actions to take and what strategies to employ.

Game designers must carefully design how data displays communicate game data to ensure that they are usable, while aligning seamlessly with play mechanics, game theme, and story [18].

Data displays can also be a tool that designers use to support a particular play experience. Importantly, game designers do not only decide on what information to show, but exactly how to show it. Game designers sometimes change how data is typically displayed to induce a particular experience. For example, the health bar in *Assassin's Creed* (Ubisoft 2007) loses health quickly when players are closer to full health, and more slowly when a player has low health [26]—a manipulation that would have the effect of players interpreting their current situation as being more precarious than it actually is, raising the pressure and tension they feel.

Manipulating a data display, like the one in Assassin's Creed, could have three main effects on players. First, as described above, play experience might be affected. Second, player behavior might change; since players use data displays to make decisions about what they do in the game, it seems likely that manipulating important data will also change what actions players take. Third, player performance might be affected; if players change their actions in games, these might lead to changes in performance (e.g., scoring more or less) and outcomes (e.g., winning more or less) in the game. Further, it is likely that changes in behavior and performance would change the experience that players have, in addition to the displays themselves influencing experience. While game designers are likely aware that manipulating data displays to induce play experience can have side effects on behavior and performance, exactly how such manipulations can and do affect behavior, performance and play experience has not been well studied.

While there exist many potential data misrepresentations that could be studied within games, we focus on the health bar for two main reasons. First, players have a basic mental model about how health bars work: *the amount of the bar that is filled represents how much health I have*. Second, there are real world examples of health bar manipulations in commercial games, but there is little information about how they impact game play.

In this work we provide a first study to explore how subtle manipulations on a common data display can have substantial and significant effects on player experience, behavior and performance. 125 participants played one of two versions of a game—the two versions of the game varied only in how health values were mapped to the health bar. The first version represents a typical health bar that follows a typical mapping, where the amount of the health bar filled corresponds directly to the amount of health the player has. The second version provided an experience enhancing mapping—similar to Assassin's Creed—that displays a greater loss of health when a player is near full health and a smaller loss of health when the player is at lower health.

Our work provides the following six contributions:

1. We provide a first systematic study of the use of misrepresentation in game-based data displays.
2. We show that even subtle manipulations of data displays have a measurable impact on player experience, player behavior, and player performance.
3. We describe what aspects of play experience data misrepresentations affect (tension and competence) and do not affect (enjoyment and experience of working hard).

4. We identify new ways that game designers can employ data misrepresentation (to balance play experience) and the potential implications for its use.
5. We provide a new and freely available game system that can be used as a testbed for future work in health mechanics and manipulation of data displays.
6. We identify new directions for research in both data misrepresentation and health mechanics.

2.3 - **Related Work**

2.3.1 Game Design and Play Experience

Many games can be viewed as a "series of interesting decisions", where the goal of the designer is to carefully balance what and how information is provided to a player (Sid Maier quoted in [2]). When considering the decisions that players must make, designers try to provide a desired play experience by ensuring that a game contains the right amount information to best balance challenge. Game designers, therefore, are interested in providing information that appropriately suits the mechanics, theme and challenge of a game [23]. However, the design of in-game information and data displays is an understudied area of research [32], and little is known about how they might affect play experience.

2.3.2 Assessing Player Experience

Play experience research has developed a number of concepts to help describe and evaluate experience including flow [25], fun [20] and motivation [23]. Because the amount of challenge has an impact on the outcomes of the game, most research has focused on showing how player performance predicts game enjoyment [27]. However, measuring play experience is complex as there are many related and complex factors that can affect the experience of challenge in games [9]. For example, recent work has examined how expertise [19], the alignment of skills between competitors [14], the type of controller used [7] and social settings [6] influence player experience. This suggests that continued research into the many factors that contribute to and affect play experience is necessary.

Among the existing instruments in player experience research we describe the Intrinsic Motivation Inventory (IMI) [21], since it is used in our work. IMI measures the constructs of enjoyment (feeling joy), effort (trying hard and being cognitively invested), perceived competence (feeling mastery over a task) and tension (feeling pressure or tension). IMI is commonly used in player experience research via questionnaire [23].

2.3.3 Representing and Misrepresenting Data

2.3.3.1 **Misrepresentation and Deception in HCI**

Recently, Adar et al. explored the use of "benevolent deception" in HCI [1]. They describe deception as the intentional mismatch between a person's perception of a system and the actual system state (e.g., a progress bar that shows 90% complete when it is not the case). This can be achieved via "... an explicit or implicit claim, omission of information, or system action." Distinguishing between malevolent deception (e.g., tricking people into performing an undesirable action) from altruistic deception (i.e., deception that improves user experience), they highlight that in any situation where there is a mismatch between a person's desire (e.g., their expectations) and reality (e.g., skill required to complete an action) there is an opportunity to use deception.

2.3.3.2 **Manipulating Gameplay to Influence Play Experience**

Games have a long history of manipulating gameplay in order to influence experience. For example, in the *Mario Kart* series (Nintendo) it is well known that the chance of receiving power-ups is dependent on position in the race; trailing players receive the most helpful items, while players in front receive the least helpful. Techniques like this are referred to as dynamic difficulty adjustment, which aim to align player skill with game challenge [3,4,24]. However, game designers have employed other heuristics to help relax certain mechanics to provide players with an improved experience. *Gears of War 3* (Epic Games 2011) provides players new to the multiplayer mode damage bonuses that are reduced after the first few kills. *Far Cry 4* (Ubisoft 2014) reduces Non-Player Characters (i.e., computer controlled characters) accuracy and damage the closer they are to a player, which encourages players to enter close and exciting encounters. Games researchers have also evaluated several different approaches for improving play experience through manipulating different aspects of gameplay. For example, several projects have looked at various aspects of balancing between players of different skill levels in a range of game genres through subtle assistance [5,10,29]. Evaluations of these techniques have shown consistent positive benefits on play experience (e.g., subjective ratings of fun [5,10]), and that they do not harm other aspects of gameplay such as skill development [15]. Importantly in much of this work, users were unaware that assistance was being used to help or hinder performance in the game. Interestingly, when assistance for player balancing has been disclosed to players it did not harm their experience. Depping et al. [13] used attribution theory to explain this result, highlighting that players tend to take credit for their successes (e.g., "I won because I played well") and blame external factors when they fail (e.g., "The controls are too difficult").

2.3.3.3 **Misrepresentation of Data in Games**

Studies that examine the misrepresentation of data to influence experience have been explored less frequently. Recently work has examined the manipulation of player position on leaderboards. Finding that manipulating success increases player perception of competence, autonomy enjoyment, presence and positive affect as compared to failure, and these manipulations were not highly detectable by players [9]. Another study demonstrated that describing others on leaderboards as being "a similar player" led players to perform better in the game [11].

2.3.3.4 **Misrepresenting Data and Data Displays in Games**

In-game data displays (such as health, mana or experience bars) are often used to provide the player with important information, and as such are an important part of making decisions in games [30].

In general, it is well-understood in information visualization that distortion in data graphics is not desirable [28]. Tufte's well-known concept of the "lie factor" suggest the size of the effect shown in a data display should be directly proportional to the size of the effect in the actual data [28]. As described above, however, game designers often manipulate aspects of game design to provide a desired play experience, suggesting this general guideline is not always followed in the context of games. Indeed, there are several examples where games do not consistently display data with the goals of improving play experience. In both *Assassin's Creed* (Ubisoft 2007) and *Doom*

(Bethesda Softworks 2016) health is lost more quickly when the health bar is full but lost more slowly when health is low. We hypothesize that this is done to raise the experience of tension in the game. However, no previous work has explored the manipulation of data displays and how it might affect player experience, performance and actions in the game.

Of further interest is that since player experience is often the focus of games research it is important to establish what contributes to it. Because players make decisions based on the information the game provides them with, it is likely that behavior is changed when data misrepresentation is used and that this may lead to a change in performance. Further, it could be that both behavior and performance might help explain any change to experience.

2.4 - **Study of Health Data Manipulation**

To provide a better understanding about how manipulations to game data can affect player behavior, performance and experience we conducted a between-subject experiment analyzing the play and subjective experience of 125 participants. Participants played one of two versions of the game we built, called *Redline.* The two versions of Redline differed only in how they presented health data. The two types of health bars are: a *typical* health bar that directly maps the character's health to the length of the bar; or, an *experience-enhancing* health bar that subtly manipulates how health data is mapped to the bar in an effort to raise the tension experienced by players.

2.4.1 Apparatus

Redline is a 3D, voxel-styled, top-down firefighting game developed in Unity 5.6 that runs in a web browser using WebGL[2].

2.4.2 Gameplay

In Redline players control a male or female firefighter in-training from a top-down view and navigate around a small home to extinguish flames with water (see Figure 2.1). The goal of the game is to extinguish all flames on a level before reaching zero health (and needing to be rescued by fellow firefighters) or before the 60-second onscreen timer elapses.

Redline uses standard keyboard and mouse controls. The movement of the avatar is controlled via WASD or arrow keys. The avatar faces in the direction of the mouse pointer and clicking and holding the left mouse button sprays water in that direction. Water spray has a limited reach.

[2] Source can be found at: https://github.com/hcilab/redline

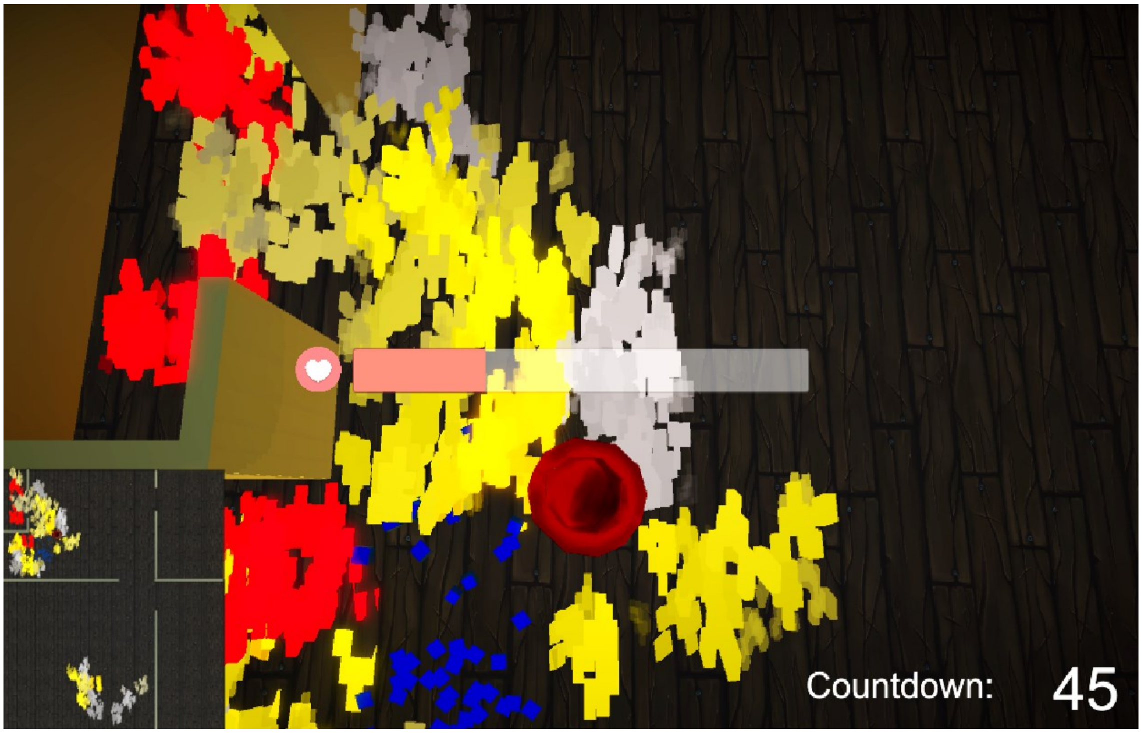

Figure 2.1: Game play screen of Redline. The firefighter's helmet can be seen spraying blue water. The interface components including the health bar (above the player), the mini-map (lower-left corner) and count-down timer (lower-right corner) are shown.

2.4.2.1 **Strategy**

Each level varies in the placement, number and intensity of flames (see Figure 2.2). Flames grow over time and spread over the map. Flames have four levels of intensity: progressing in both intensity and hue from light gray smoke onto yellow flame, orange flame, and dark red flame. Players receive damage when they are within a minimum distance to the flame, which scales up the closer the avatar is to the flame. The darker the flame the more health they remove from a player. Spraying water on the flames lowers its intensity until it is fully extinguished. However, to extinguish a flame, a player must be close to it. The closer they are the faster they are able to put out a fire, but the more health they will lose.

The distance needed to hit a flame with water is the same distance at which the player takes damage. This, together with the 60-second timer and mechanic that spreads fire, provides a time pressure on players to act quickly, but to not be overly aggressive. *Players, therefore, must constantly be working to strike a balance between extinguishing as many of the darker flames as possible, while maintaining a safe position (i.e., extinguishing the fast spreading flames as quickly as possible, while minimizing the amount of health lost).* If players are overly aggressive they will lose too much health and not be able to put out all the flames. If players are not aggressive enough they will not be able to extinguish the flames before the timer elapses. An optimal strategy is one that minimizes health loss and the spread of the flames.

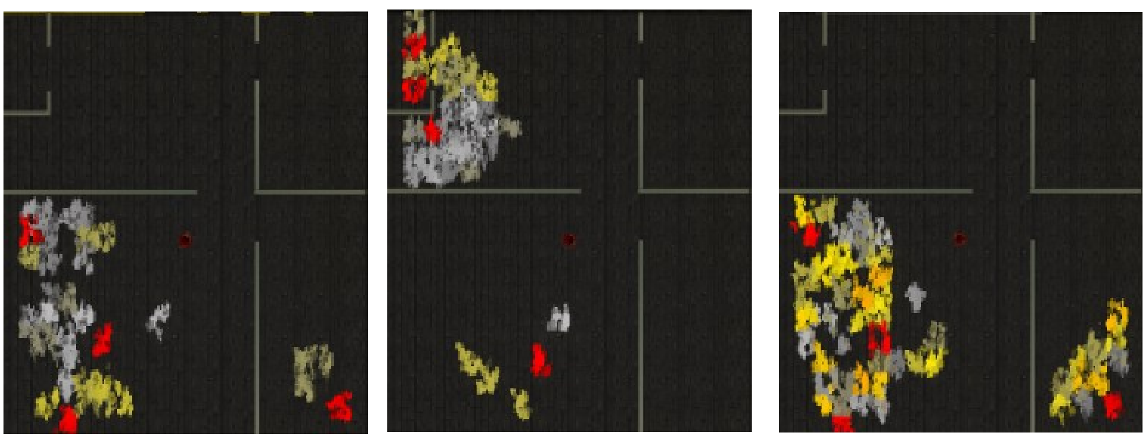

Figure 2.2: Maps demonstrating different levels and game states. Left: Testing level 1 at the beginning of the level; Center: Testing level 2 at the beginning of the level; Right: Testing level 2 after the flames spread without player action for 20 secs.

2.4.2.2 **Health Bar Display**

Health is monitored by a large health bar displayed over the avatar. Health is mapped in one of two ways, as described in more detail below (see Figure 2.2). When health is full the bar is green and transitions to red as the bar approaches empty. To provide reinforcement when the avatar loses health, the health bar shakes to make the loss more visually salient. When starting a level players start with a total of 1000 health points.

2.4.2.3 **Health Bar Versions**

Our game has two versions of the health bar, that are presented in two otherwise identical versions of the game. The two health bar versions are a linear, *typical* health bar and an *experience enhancing* bar. The typical health bar provides a direct mapping between health remaining and the size of the bar (e.g., when at 75% health remaining, the bar is 75% full). The experience enhancing bar provides a subtle manipulation of how health data is mapped to the bar, initially exaggerating health loss when the player has full health and gradually slowing the health loss as the bar approaches zero health (Figure 2.2). We call this an "experience enhancing" bar because we were inspired by games that manipulate data like health to create a target game experience.

With our experience enhancing bar we aimed to raise the amount of tension experienced by players, since this bar shows lower health throughout the game making play feel extra challenging and situations more serious than they would with the typical bar. We wanted the health manipulations created by the experience enhancing bar to be subtle so that they would not be easily perceived by players, allowing us to evaluate how even small manipulations might impact play.

Through play testing and piloting, we established the following formula for mapping health data to the length of the bar displayed:

$$L_n = \frac{(f(n) - 1) \times \frac{f(n) + 2}{2}}{(\rho - 1) \times \frac{\rho + 2}{2}}$$

Where L is the length of the bar, and n is the percentage of health remaining. We then defined $f(n) = n \times 10 + 1$ and $\rho = 11$ so that $L_{0\%} = 0\%$ and $L_{100\%} = 100\%$. Figure 2.2 and Figure 2.3 show how health is displayed in practice.

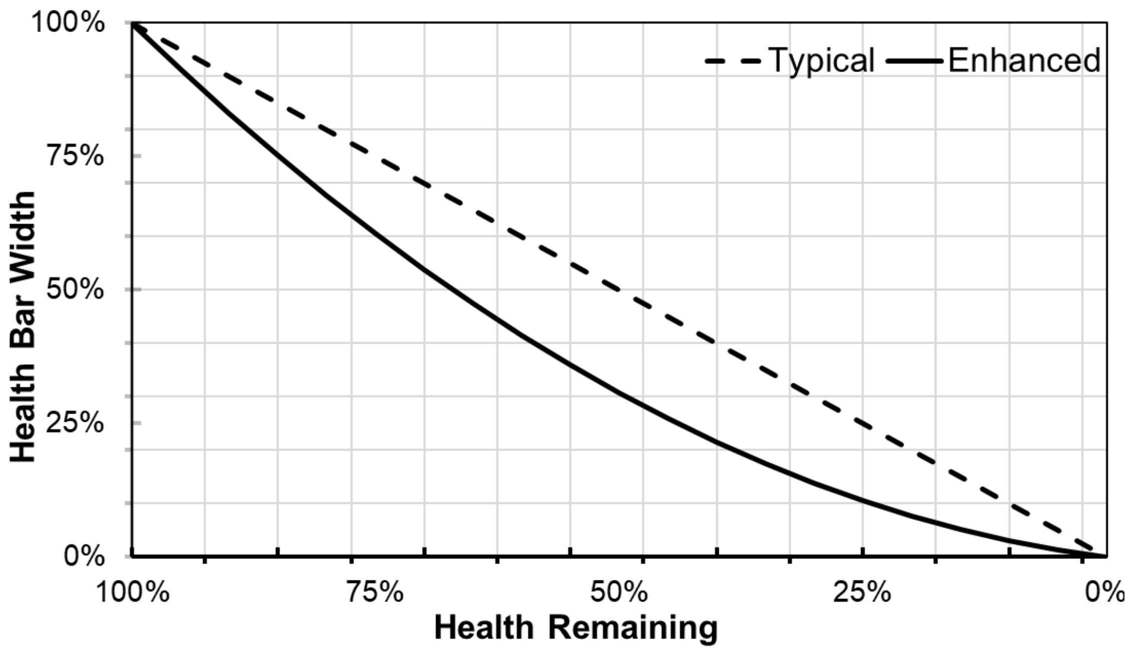

Figure 2.3 Comparison of effect (width) displayed in Typical and Experience Enhanced (Enhanced) Health Bars as a function of actual health remaining in the game.

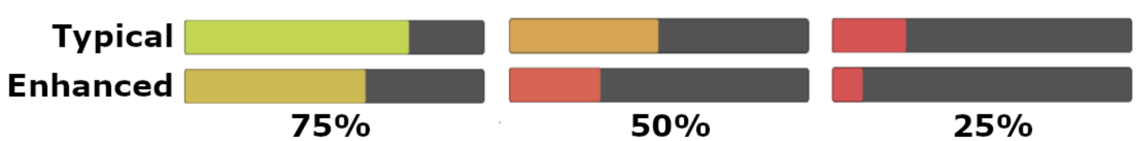

Figure 2.4. Example Health Bars from the two versions of the game (typical and experience enhanced) at set amount of actual in-game health: 75%, 50%, and 25%.

2.4.2.4 **Levels**

In our experimental system we designed two sets of levels. The first set, the tutorial set, consisted of 7 levels that progress steadily in challenge, allowing players to get comfortable with the game controls. For example, the first tutorial level required a player to extinguish a small fire that appeared directly in front of them. By the seventh tutorial level, players must extinguish two small fires in separate rooms.

The second set of levels, the testing levels, consisted of 4 levels that were substantially more difficult than the tutorial levels. These levels were designed to require players to monitor their health closely to make effective decisions. All four levels started with two large fires that varied only in their positioning around the game map. Through playtesting we found this approach allowed some degree of control, but that the levels played quite differently.

To provide reinforcement on the outcome of levels, a simple level summary screen is displayed after each level. When players are successful they are rewarded with a congratulatory message (e.g., "Way to go!"), and when they fail they are provided with a message that highlights their failure in a playful way while providing encouragement (e.g., Upon running out of health the following message is provided: "Get out of there, you are going to get hurt! Keep trying!"). Whether a player is successful or not, the game progresses to the next level.

2.4.3 Study Participants and Deployment

In our study we report on the analysis of 125 participants (*36.8% female, 0.8% other; mean-age = 33.91, SD = 8.04*) who we recruited from Amazon Mechanical Turk. A total of 179 US-based, adult participants from Amazon Mechanical Turk (MTurk) completed our study. We removed 31% before analysis for the following reason: (1) We set minimum computer hardware requirements (e.g., CPU speed and memory) on our HIT, which we determined through testing our game on various platforms. However, during initial analysis we determined that many participants likely experienced poor performance in the game, despite completing the study, which was determined by logging the frames-per-second (FPS) throughout the study. (2) To ensure that a minimal level of playability was met, we initially removed 47 participants from analysis, who had successfully completed the study, but who did not have at least 60% of their gameplay at a framerate of 15 FPS. We eliminated 2 participants that did not meet the following criteria: they filled in more than 2 surveys with zero variance between items or showed ratings of ±3SD in more than 2 questionnaires. (3) We eliminated 5 participants who only produced questionnaire responses but no game play data. In the end we had 125 participants: 62 who used the typical health bar, and 63 who used the experience enhancing health bar.

2.4.4 Procedure

Upon accepting the HIT (the MTurk task), participants accessed a website that guided them through the study. The website initially assigned participants into one of the two between-subject conditions. Participants were first presented an informed consent form, followed by a demographic questionnaire, and then given a brief tutorial that introduced the game through a series of annotated still shots (including the story, goal, controls, and how information is displayed—e.g., timer and health bar). Finally, players completed two gameplay sessions, which were each followed by play experience questionnaires. The final questionnaire of the experiment allowed participants to provide subjective ratings on aspects of the health bar they used. Upon completion of the final questionnaire, participants were provided a completion code that they submitted to receive payment of $5 USD. The entire experiment required approximately 30 minutes to complete.

We organized our experiment around two game play sessions. The first was arranged to get players up to basic competency with the game, while the second aimed to have them to recognize the need for a strategy to be successful. The first of the two gameplay sessions required participants to play the 7 tutorial levels and the first two of the four testing levels. Upon completion of play session one, players completed the play experience questionnaires for the first time. The second gameplay session followed, which consisted of playing all four levels of the testing set twice (8 levels in all). Through playtesting we had established that playing the testing levels multiple times was important to allow players to learn the strategies, get accustomed to the controls, and recognize the importance of monitoring the game data (health and time). The goal was to get players to a basic level of competency for the final four testing levels of the experiment.

2.4.5 Performance, Behavior, and Experience Measures

In-game metrics were used to measure performance and behavior, while questionnaire data was used to assess experience.

2.4.5.1 **Performance**

To assess performance, we collected *health* at the completion of each level, *win rate*—how often the player extinguished all fires on each level, *timeout rate*—how often the player ran out time before extinguishing all fires, and *death* rate—how often the player ran out of health before all fires were extinguished. In our initial analysis we observed that death rate and win rate are highly negatively correlated (r=.75). Therefore, we omitted win rate from all further analysis.

2.4.5.2 **Behavior**

To assess the constant balance players made between moving towards a fire to extinguish it and preserving health, we collected the following measures every second of the game: *health lost*—the count of health points lost—and the number of fires in the character's *proximity*—counted as the fires that damage the player (min.=0, max.=25 fires). Higher levels of proximity and health loss would indicate more aggressive behavior; i.e., players would expose themselves to a high number of fires in an effort to extinguish more fires, faster. Therefore, we present health loss and proximity as indicator variables of aggressive play.

2.4.5.3 **Player Experience**

We used a validated scale to assess experience and deployed a series of questions regarding the usability and utility of the health bars.

We measured intrinsic motivation using the Intrinsic Motivation Inventory (IMI, [21]). The IMI measures the agreement to 18-items using a 7-point Likert scale. The instrument measures the following four constructs: *enjoyment*—"I enjoyed this game very much"; *effort*—"I put a lot of effort into this game"; *competence*—" I am pretty skilled at the game"; *tension*—"I felt tense playing the game".

To assess the usability and utility of both health bars, we presented participants with seven items (see Table 2.2) after the experiment was completed. Participants rated their agreement for each item using a 7-point Likert scale.

2.4.6 Analysis

All data was analyzed using SPSS 25 and Hayes' PROCESS-macro for SPSS (see [16] for details). For analyzing the health bar items, we used the Mann-Whitney U test for independent samples. To determine the strength of relationships between variables we used regression analysis. To investigate the effect of health bar manipulation on performance and experience, we performed ANCOVAs with age and gender entered as covariates.

To investigate the effect of health bar manipulation on the relationship between performance and experience we used moderation analysis; see Hayes for a detailed description of moderation analysis [17].

Because level completion time varies widely (M=41.13, SD=14.12) as a result of skill, strategy, and outcome (i.e., timeout, win, loss) we initially sought a way to compare play regardless of time spent in a level. To account for temporal difference between participants, we divided each level into one of ten temporal bins—averaging values for a metric (i.e., proximity and health loss) per bin. This resulted in 10 bins for each level (bin 1=1-10% of the level completed, bin 2 = 11-20%, ..., bin 10 = 91-100%). We investigated the effect of health bar manipulation on behavior using a mixed ANOVA with health bar condition entered as a between subject factor and temporal bin as the within-subject factor, for proximity and health lost.

Descriptive statistics for performance measures (i.e., health, win-rate, loss-rate, and timeout rate), the average scores for all four IMI constructs, the individual performance measures (i.e., proximity and health), and aggression metrics (health lost and proximity) by bin can be found in Table 2.4.

2.4.7 Research Questions

We organize our results around the following research questions that we established progressively through our analysis:

RQ1. Did participants realize that the health bar was manipulated or use the health bars differently?

RQ2. Does health bar manipulation alter experience and/or performance?

RQ3. Does performance predict experience?

RQ4. Does health bar effect the relationship between performance and experience differently?

RQ5. Can changes in experience between conditions be explained through differences in behavior?

2.5 - **Results**

Below we present the results of our analyses organized by research questions. We further describe the specific statistical methods used where appropriate.

2.5.1 RQ1. Did participants realize that the health bar was manipulated or use the health bars differently?

First, we were interested in how health bars were perceived by our participants. Obvious differences between both health bars would defy our intention to create a subtle manipulation with the aim to alter play experience. Our results suggest that there is no noticeable difference between the bars—see Table 2.2Table 2.1 for descriptive statistics and Mann-Whitney U test results.

Participants were only told that we were assessing player experience in a game, and when asked to describe what the purpose of the experiment was only 2/125 participants mentioned the health bars.

	Typical	Enhanced	
	M *(SD)*	M *(SD)*	p
1. The health bar helped me achieve my goal in the game	4.76 *(1.89)*	4.68 *(1.63)*	.504
2. The health bar helped me be effective in playing the game	5 *(1.77)*	4.67 *(1.73)*	.215
3. I was aware of my health levels while I was playing	6.4 *(.86)*	6.05 *(1.28)*	.074
4. I found the color of the health bar more useful than it's fullness	3.15 *(1.73)*	3.40 *(1.88)*	.527
5. I found the health bar confusing	1.92 *(1.49)*	1.79 *(1.19)*	.819
6. I found the health bar distracting	2.55 *(1.99)*	2.78 *(1.84)*	.257
7. I did not notice the health bar	1.44 *(.92)*	1.52 *(.759)*	.251

Table 2.1. Mean and standard deviation by health bar item and p-values from Mann-Whitney U tests for independent samples.

2.5.2 RQ2. Does health bar manipulation alter experience and/or performance?

Table 2.3 provides a summary of descriptive statistics for performance, behavior and experience by health bar condition.

Performing individual ANCOVAs on the experience measures controlling for age and gender, our results show higher levels of competence in the typical health bar condition (M=5.17) compared to the experience enhancing health bar condition (M=4.59), $F_{1,123}$=4.596, p<.05, $\eta_p^2 = .037$. Experienced tension is decreased in the typical health bar condition (M=3.37) compared to the experience enhancing bar condition (M=4.02), $F_{1,123}$=4.991, p<.05, $\eta_p^2 = .04$. There were no significant differences for enjoyment (p=.17) or invested effort (p=.80).

Investigating performance data using ANCOVAs we entered age and gender as covariates, our results show that participants in the typical health condition have less health on average (*M*=628.75) compared to the experience enhancing health bar condition (*M*=663.54), $F_{1,121}$=7.758, p<.01, $\eta_p^2 = .06$. There were no differences in the outcome for the performance rate (death rate: p=.793; timeout rate: p=.287).

	Typical		Enhanced	
	M	*SD*	*M*	*SD*
	Performance			
Victory	0.51	0.42	0.46	0.43
Death	0.33	0.34	0.32	0.38
Time-out	0.17	0.23	0.22	0.33
Health Points	628.75	68.76	663.55	71.08
	Behaviour			
Proximity	2.11	0.40	2.16	0.90
Health loss	24.08	4.86	24.56	11.11
	Experience			
Enjoyment	4.94	1.52	4.55	1.47
Effort	5.94	1.31	5.86	0.90
Competence	5.17	1.93	4.59	1.84
Tension	3.37	1.81	4.02	1.54

Table 2.2. Descriptive statistics for performance, behavior, and experience by health bar condition.

Taken together, these results show that subtle manipulations of in-game data affect experience (i.e., competence, and tension) and performance (i.e., health). However, the relation between performance and experience remains unexplored.

2.5.3 RQ3. Does performance predict experience?

To investigate the effect of performance on experience, we performed two separate regression analysis for each experience variable (i.e., tension and competence) as the outcome variable and the three performance measures (i.e., death rate, timeout rate, and health points) as predictors.

Our results show that performance data predicts experience of tension ($F_{3,121}$=3.246, p<.05, R^2=.052). The individual coefficients show that death rate (β=1.19, p<.01) and timeout rate (β=1.05, p<.05) predict tension, while health points do not predict tension in our model (p=.45). Predicting competence by the three performance measures using regression analysis reveals the same pattern, $F_{3,121}$=31.26, p<.001, R^2=.42. The individual coefficients show that death rate (β=3.19, p<.001) and timeout rate (β=2.43, p<.001) predict competence, while health points do not predict experience of competence (p=.884).

Our results confirm that performance affects experience—a result that doesn't necessarily come as a surprise but provides further insights into the exact composition of experience in the context of our study. Specifically, we see that there is a very strong effect of performance on competence (R^2=.42) and a small effect on tension (R^2=.052). It remains, however, unclear how subtle manipulation of displaying health information affects the relationship between performance and experience.

2.5.4 RQ4. Does the manipulation of health information affect the relationship between performance and experience differently?

We have established that performance predicts experience and that experience and performance can be altered through the manipulation of displaying health. To investigate the effects of health bar manipulation (M) on the relationship between performance (X) and experience (Y), we conducted a moderation analysis (model=1, [17]) controlling for age and gender.

Predicting tension by death rate moderated by health bar manipulation, our results show a significant model (p<.005, R^2 =.15), with significant results of condition on tension (p<.05) and a significant interaction between condition and death rate (p<.005). The conditional effects show an increase of tension over death rate for the typical health bar condition (p<.005), but no increase for the experience enhancing condition (p=.59); see Figure 2.5.

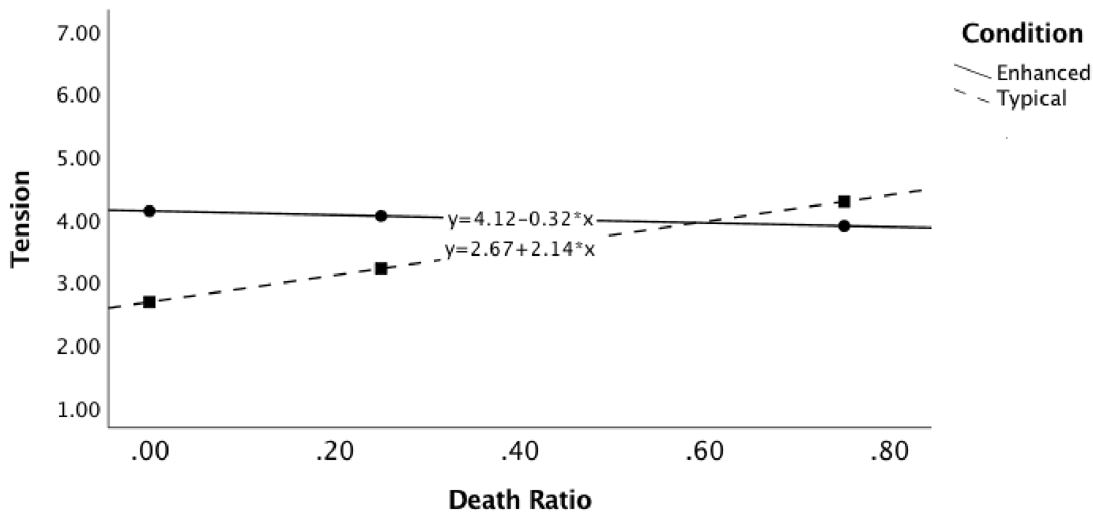

Figure 2.5. Moderation analysis for the relationship between tension and death rate, moderated by experience condition (typical, enhanced).

There were no significant moderation effects for health points (p=.36) or timeout rate (p=.56) predicting tension moderated by time, and no significant moderation effects for health points (p=.21), death rate (p=.39), or timeout rate (p=.83) predicting competence moderated by time.

The results suggest that enhancing the experience indeed results in a more stable experience of tension independent of a players' death rate.

2.5.5 RQ5. Can changes in experience between conditions be explained through differences in behavior?

Because our results indicated that participants were making use of health bars and that these did bring about change in experience and performance, we decided to look at our aggressiveness metrics over time. Table 2.4 shows a summary of the Proximity and Health Lost metrics for each temporal bin and health bar. The number of bins was iteratively decided on in an attempt to minimize noise.

		Bins									
		1-10%	*11-20%*	*21-30%*	*31-40%*	*41-50%*	*51-60%*	*61-70%*	*71-80%*	*81-90%*	*91-100%*
		Proximity									
Typical	*M*	1.998	2.630	2.731	2.399	2.160	2.118	1.898	2.088	2.032	1.563
	SD	0.814	1.035	1.244	1.121	1.507	0.816	1.107	1.255	1.519	2.405
Enhanced	*M*	1.838	2.521	2.401	2.066	2.387	1.989	2.014	1.972	2.153	2.266
	SD	0.945	1.165	0.968	0.925	0.843	0.796	0.661	1.001	0.857	1.208
		Health Loss									
Typical	*M*	10.927	26.137	28.800	29.050	24.299	24.519	22.143	25.067	27.600	22.300
	SD	6.303	12.117	22.035	13.880	16.229	15.212	17.116	15.683	17.937	38.953
Enhanced	*M*	10.725	22.757	28.883	23.480	27.886	24.258	24.821	25.037	27.358	30.440
	SD	7.732	14.780	14.024	13.409	11.181	10.639	8.487	10.985	14.217	17.425

Table 2.3. Mean and standard deviation for proximity and health loss by bin and health bar.

A mixed ANOVA with health bar as the between-subject factor and the 10 temporal bins as the within-subject factor revealed that there was no between-subject effect of health bar display on proximity, $F_{1,121}$=0.011, p=.916. However, our analysis showed that proximity varies between temporal bins, $F_{9,1089}$=9.11, p<.001, η_p^2=.07. Testing the interaction between the health bar condition and the 10 temporal bins, our results show an interaction effect for proximity, $F_{9,1089}$=3.715, p<.001, η_p^2=.03. Bonferroni corrected pairwise comparisons reveal that proximity between health bar conditions differentiates in the 10th bin (p = .008). See Figure 2.6.

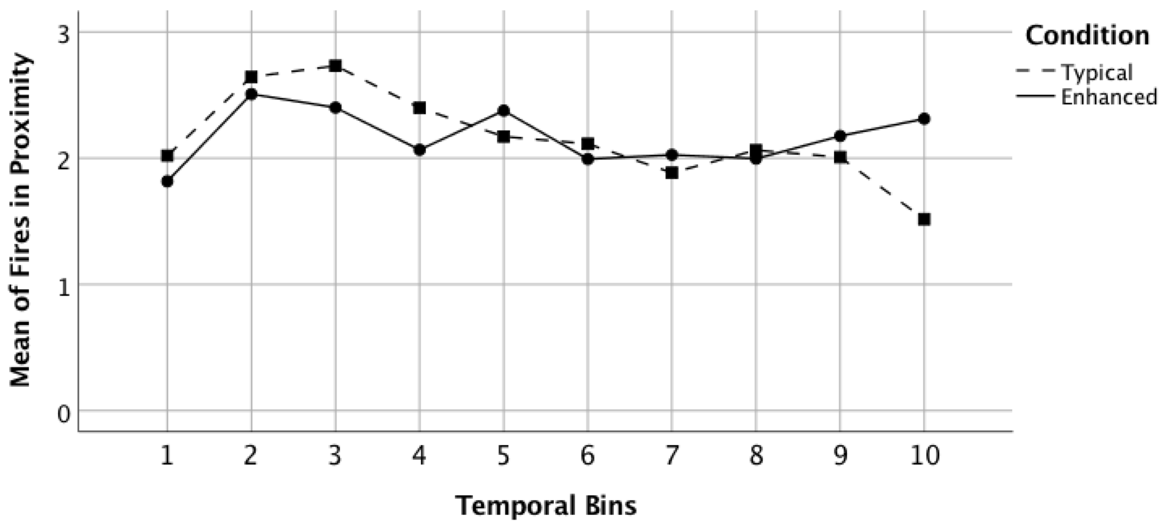

Figure 2.6. Line chart of the mean of fires in proximity to the player by temporal bin and condition.

We performed the same mixed ANOVA analysis on the amount of health lost—players start each game with 1000 health points. Health bar was entered as the between-subject factor and the 10 temporal bins as the within-subject factor. Our results reveal that there was no between-subject effect of health bar display on health loss, $F_{1,121}$=0.154, p=.695. However, our analysis showed that health loss varies between temporal bins, $F_{9,1089}$=4.034, p<.001, η_p^2=.03. Testing the interaction between the health bar condition and the 10 temporal bins, our results show an interaction effect for proximity, $F_{9,1089}$=2.54, p<.001, η_p^2=.02. Bonferroni corrected pairwise comparisons reveal that health lost between health bar conditions differentiates in the 4th bin (*p=.027*) and marginally in the 10th bin (*p=.065*). See Figure 2.7.

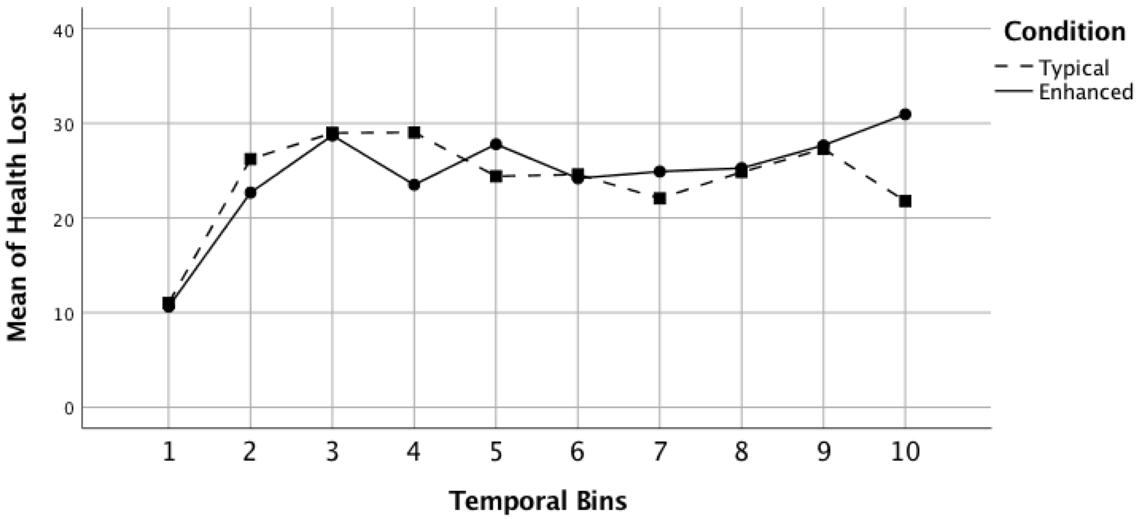

Figure 2.7. Line chart of health loss mean by temporal bin and condition.

Combined, the interaction effects suggest that players are more aggressive in the early game with the typical health bar but are more aggressive towards the end of levels with the experience enhancing health bar.

2.5.6 Summary of Results

Our analyses lead to the following main findings:

1. *The experience enhancing bar works*. Experience (competence and tension) and performance (amount of health) are affected by our data display manipulation.
2. *Players didn't notice the misrepresentation of health data,* and no differences were observed in the utility of the bars.
3. *Performance help predicts experience.* Our results show that the death rate and timeout rate are predictors for competence and tension.
4. *The experience enhancing bar resulted in a more consistent experience of tension regardless of game outcome.* With the typical health bar, players would experience higher levels of tension only when they performed poorly (i.e., had a higher death

rate). However, with the experience enhancing bar players experienced tension independent of how they were performing in the game.

5. *The experience enhancing bar led to change in behavior.* Players with the experience enhanced health bar are more aggressive towards the end of levels compared with the typical health bar.

2.6 - **Discussion**

2.6.1 Explanation of Results

While our game was designed to require the use of the health bar, players did not notice any manipulations with the bar and did not feel it was a key to playing or being effective in the game. Even though the manipulation was not spotted, the effects on experience, performance, and behavior were measurable and showed differences as a result of our health bar manipulation.

Our results suggest that the manipulation of data displays of health affects competence and tension as primary measures of intrinsic motivation, but not enjoyment and effort. The strong relation to competence makes intuitive sense, because measures of health are a common indicator of play performance. For example, the fighting game *Tekken* (Namco, 1994), highlights a player's success as a “flawless victory” when a player does not lose any health or *Street Fighter 2* (Capcom, 1991) gives score based on the amount of health remaining.

We can also show that health manipulation affects tension; a result that confirms what designers have intuitively applied before—decreasing health faster early on, but then keeping the player on low health for a while increases the tension experienced. Interestingly, our manipulation has no direct effect on enjoyment and effort, suggesting that health bar manipulations can be used effectively to alter the overall “feel” of a game without necessarily affecting players’ enjoyment or their willingness to work harder to achieve a given goal.

While it might not be surprising that manipulating health will change play experience given our game design, it is surprising how effective it was given our rather simple and small manipulation.

After establishing that death rate and timeout rate strongly predict competence (R^2=.42), and to a lesser extent tension (R^2=.052), we investigated the effect of health bar manipulation on experience (i.e., tension, competence). Interestingly, health information only affects the experience of tension—it is stable with the enhanced health bar and shows a positive relation between death rate and tension in the typical health bar condition. These findings have implications for game design by showing that game designers can manipulate the display of health information to keep a game tense, independent of how a player performs. This result is particularly important because it suggests that through the simple manipulation of how data is displayed, the overall experience can be altered and used to balance experience between players. In fighting games, for example, balancing is often done by applying handicaps to players, i.e., the stronger player has less health than the weaker player. Our results suggest that to keep the game interesting for advanced players the actual amount of health does not need to be reduced, but that it could be enough to simply change how health is displayed in the bar.

We designed our game to influence behavior—players have to balance how close they get to flames. In general, players can get close to flames to try and extinguish them as quickly as possible and trade in health in the process, or they can try to be more careful, taking time to position themselves to best extinguish a fire while minimizing health loss. Our data suggests that players with the experience enhancing bar charged into the fire in the last seconds but stayed slightly more conservative over the course of a level—players in the typical health bar condition showed the opposite pattern. While the direct effect on behavior requires further investigation, our results suggest that health bar manipulation induces a more conservative play style. The passive play style led players to increased aggression in later stages of a level. From a game designer's perspective, being able to form assumptions about how players will behave depending on their health information is important. For example, consider the design of dynamically generated content. Generating encounters using a health bar that punishes engagement with intense health loss might result in a more intense experience and be ideal for later levels. However, the same approach might be a bad choice for early tutorial levels, because players would play too conservatively. Our behavioral findings suggest that designers need to carefully consider when and why players would show aggressive behavior and how it relates to the intent of design.

In summary, our results show that health bar manipulation affects experience, performance, and behavior, and provides new game design insights and possibilities. Designers can leverage data display misrepresentation as an unobtrusive technique that has relevant effects on players through a subtle and simple manipulation.

2.6.2 Implications for Designers

Our game was specifically designed to study the effects of data display manipulation on play. As such, we crafted our game in a way that required players to make use of the information in the bar. However, our bar does align closely with bars in commercial games (*Doom* and *Assassin's Creed*). Like our game, these games require players to monitor health, avoid death, and make decisions about actions to take. These similarities suggest that experience enhancing bars like ours could be applicable to a wide variety of games.

2.6.2.1 **Designing for Emotional Complexity**

While high tension and lower competence might be thought of as negative or undesirable outcomes, designers might try to induce these experiences to engage players and create a feeling of depth of play, while still targeting an overall fun play experience (or not). Recently, researchers have highlighted how the focus on "positive" affect alone might miss out on the opportunities that the interplay between positive and negative emotions might offer [8,22]. Our work recognizes this view and our findings can help designers achieve a desired play experience through data manipulation.

Competence is related to the experience of overcoming challenge and tied to our perception of difficulty; i.e., a player who struggles to overcome a challenge will likely perceive the challenge as being difficult in relation to their own ability. The balance between challenge and ability and their effect on experience is most famously captured in Csikszentmihalyi's notion of flow [49]. The concept of flow suggests that we experience deep engagement when challenge and ability align. In our work we show that we can artificially manipulate competence, which has implications for the perceived difficulty of the game. Future work should assess how perceived difficulty—changed by data manipulations—can influence flow.

In many ways data display misrepresentation offers an attractive option to fine tune play experience. Considering that during the development cycle technical dependencies make it more and more difficult to introduce changes, tools such as these are important for game designers, because they allow the introduction of adjustments to overall play experience with few dependencies.

2.6.2.2 **Fostering Player Experience through Health Bars**

Most health bars in games are strongly connected to the concept of competence—they represent how well a player is doing in relation to their environment and indicate the player's ability to survive difficult encounters. The health bars in Redline also falls in the category, since it is one of the main ways players receive feedback it can be seen as an indicator of competence.

Health bars, however, can be used in ways other than for assessing competence. For example, to promote choice and different play styles, in *Borderlands 2* (Gearbox Software, 2012) the actual health of a player is augmented through the players choice of a shield. The kind of shield players equip affects the play style of the player—some shields allow the player to play more aggressively and to enter melee fights, while other shields give lots of bonus but don't protect the player well resulting in a more passive play style. Through choosing a shield players can alter the experience they are having and express their personal preferences.

Another way health bars can be used is to enhance the experience of connectedness with other players. Many games like *World of Warcraft* (Blizzard 2004) or *Team Fortress* (Valve 2007) feature healing characters (e.g., priests, shamans, or medics) that can recharge the health of teammates. Players need to interact with each other to maximize their play experience resulting in stronger connections and enhanced play experience through health related interactions between players.

As the above examples show, health plays a central role for creating valuable experiences in many games. Investigating how health is used to foster different experiences and how health bar manipulations can be used to alter these experiences are relevant questions for future research.

2.6.3 Considerations for Manipulating Data Displays

While our study did not solicit player opinion on the use of misrepresentation, our experience enhancing bar design was based on examples from well-known and popular commercial games (*Assassin's Creed* and *Doom*). The fact that misrepresentations are already in use, and that some are much more apparent than what we tested, suggests that players are at least generally aware of this, and open to it. Recent findings in hidden manipulations of input for the purpose of player balancing (e.g., [5,10,29]) support the idea of players being receptive to the idea of misrepresentations as long as it has a positive impact on experience. Our work, however, does allow us to comment on at least two situations where designers must be careful with the use of misrepresentation.

First, with the growing popularity of e-sports and competitive gaming, some players have on increased focus on optimizing behavior and performance. In these situations, the design of widgets and data displays are often done with a focus to maximizing usability and accuracy [31]. We see our own experience enhancing health bar design as being potentially problematic in such situations. Since the experience enhancing bar changes the effect size in the bar for different amounts of health, we suspect that this could lead to inaccuracy in reading data in situations where precise and time-sensitive decisions must be made.

Second, and related to the last point, is that manipulations may have a negative impact on learning and adoption of expert behavior. We believe this could be the case with our experience enhancing bar. The experience enhancing bar may have led players to behave less aggressively early in levels, and more aggressively later on. If so, this behavior is suboptimal for our game. This is because fires in the game grow over time, this suggests that players are better to be aggressive earlier in a level and extinguish as many fires as possible to reduce the total amount of work required, rather than later in a level when fires have a chance to grow (causing more health loss and increased time to be extinguished). This observation is an important lesson, while our health bar did increase the tension experienced (as designed), it may have had a negative effect on learning. Overall, these examples show that it is critical for designers to consider both performance and behavior – and not just experience – when designing misrepresentations in data displays or other aspects of game play.

2.6.4 Limitations

Although our findings have opened several new directions for future research, our work has several limitations that should be investigated to better understand the generalizability of our results. First, we have only compared two different health bars. It is not clear how different mappings, that have different representations (e.g., diegetic representations) or different health mechanics (e.g., discrete rather than continuous health) might affect our results. Further, we do not know whether our approach might work in different types of games (e.g., fighting games), or whether social/multiplayer settings might influence the effects we saw.

While we took care in choosing simple health bars that are representative, future research that replicates and extends our findings in various scenarios will be needed and valuable to the informed and effective uptake of data misrepresentation.

2.7 - **Conclusion**

In this paper, we have described a first study of data display misrepresentations in games. Our work has provided new findings that demonstrate that simple, subtle data misrepresentation can meaningfully alter play experience. What is extremely promising from our findings is that this type of display manipulation may allow designers to help provide a more stable play experience for players across a wide range of skill levels. While we highlight that designers must remember that small manipulations can impact player behavior and performance, our findings suggest that they do not necessarily have an impact on enjoyment or willingness to work towards goals. For designers our work means that there is a tool that can be used to alter the feel of the game, and it can be readily applied even late in development because it does not impact many other aspects of play. While our findings immediately inform designers, we have also identified future research possibilities on the implication of subtle manipulation of data displays on player experience, performance, and behavior.

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3 - What Motivates the Use of Game Awareness Widgets and How are They Received by Players?

One potential problem for the successful design of GAWs is that designs are often based on a vague understanding of what users need and want. Studying the actual use of GAW in the wild has not been often done, partially because access to the data and analysis techniques for this type of research have been lacking. To address this gap, data sources and techniques must be identified to study the use of and interactions with GAWs in real world game play.

This work focuses on one of the most frequently studied groupware communication tools: virtual gestures. Virtual gestures take the place of pointing and gesturing towards objects and locations in face-to-face collaborations and are meant to facilitate communication by replacing their real-world equivalent commonly used by people to share information. Because extensive research from the field of computer supported cooperative work on gesturing tools exists and because gesturing tools are an important part of many multiplayer games they are a highly suitable GAW to study.

This study is comprised of two connected projects: an interaction analysis on game play as well as a survey of players. The analysis aimed to understand the behavior and motivation of players as they use these tools in the wild (i.e., in part of actual games). Interaction analysis has been used before to study the behavior of people in groups and their interactions with others and systems [4]. It involves the careful study and observation of subjects and results in the extraction and categorization of interaction events. These events can be interactions between users and the system or between the users themselves. The categorization is achieved via frequent iteration over the events and eventually allows for the categorical study of these previously elusive events. The second part of this study involved a survey of 167 participants to understand the perceived usefulness of annotation tools in the game. It focused the degree to which players view gesturing tools (widgets) as important for coordinating with teammates to win matches and communicate.

Article 2

Jason Wuertz, Scott Bateman, and Anthony Tang. 2017. Why Players use Pings and Annotations in *Dota 2*. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (CHI '17). ACM, New York, NY, USA, 1978-2018. DOI: https://doi.org/10.1145/3025453.3025967

3.1 - **Abstract**

Groupware research has long focused on representing gestures as a means to facilitate collaboration. However, this work has not led to wide support of gesturing in commercial groupware systems. In contrast, *Dota 2*, a popular MOBA game, provides two frequently-used gesturing tools: *annotations* – freely drawn lines on top of the gamespace – and *pings* – a combination of animation and sound indicating a point of interest. While gesturing tools are important for quickly coordinating with teammates in *Dota 2*, there is little information about how and why people use them. To gather this information, we performed two complementary studies: an interaction analysis of eight game replays, and a survey of 167 experienced players. Our findings include: six distinct motivations for the use of gesturing tools; when and how frequently gesture motivations occur during games; and, that players find pings an essential tool for winning, but not annotations. Our findings provide new directions for the design of gesturing tools in groupware and online games.

Author Keywords

Dota 2; Pings; Annotations; motivation; gestures; MOBAs; online games; groupware; communication tools.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

3.2 - **Introduction**

Groupware research has long focused on how to best design tools that facilitate collaboration. One important focus has been on the best way to support gestures – pointing or motioning with the body to communicate – because it is an easy yet effective way to rapidly share information, often used in face-to-face collaboration [12]. While many types of groupware do not natively support gesturing (e.g., Skype or Google Docs), recent online multiplayer games (notably Multiplayer Online Battle Arenas, called *MOBAs*) provide rich support for gestures. MOBAs, such as *Dota 2*, often provide two gesturing tools frequently seen in past groupware research (e.g., [2,3,4,5,11,13,14,15]): *annotations* – freely drawn lines on top of the gamespace that last a few seconds – and *pings* – a combination of animation and sound that indicates a single point of interest.

While MOBA players learn about pings and annotations early on, and use them frequently, no work has yet looked at *why and how people use gesturing tools in a MOBA*, and to what degree they view them as important for coordinating with teammates to win matches. This information is important for groupware and game designers to understand when gestures are needed. *Dota 2* provides a concrete context where such gestures are used today.

We conducted two studies to provide this basic understanding. First, we conducted an interaction analysis of eight *Dota 2* game replays, identifying why gestures were created. We found six distinct motivations for gesturing: *planning, warning, resource, conflict, help,* and *emoting*. By examining production time, we found that the motivations for gestures change as a match progresses – from primarily warnings early in matches to primarily planning later on. We also observed that pings are used heavily, but annotations were used much less often. Second, to confirm our identified motivations, and to understand the perceived utility and importance of gesturing tools, we conducted an online survey of 167 experienced players. Players reported that pings are a critical tool for winning matches, while annotations are the least important among surveyed tools. The survey also supported and clarified the motivations identified in the first study.

The results of our studies provide new information about why people use gestures in a popular MOBA, along with new findings about when, how often they are used and their subjective importance. Our work provides new directions for the design of gesturing tools; highlighting that although pings are used frequently, they can be improved by allowing them to convey intent, minimizing ambiguity.

3.3 - **Background: MOBAS and Dota 2**

Dota 2, like other MOBAs, is played on a static map by two teams of five. Each team battles for control over resources in order to advance towards and destroy the other team's base. Each player controls one of 112 possible characters, each with unique abilities and strengths. To increase the odds of success, players must master the nuanced game-mechanics and synergize with their teammates playstyles.

In most MOBAs, players can only see a region of the map in detail at any given time, depending on where their camera is currently set. This means that many actions occur around the map at any given time that are not directly visible, increasing the need for information sharing. *Dota 2*'s interface also provides a *minimap* that displays the entire map in low detail, but makes important information salient (e.g., the location of players and other enemies on the map); see Figure 3.1, center.

Figure 3.1. Communication tools in Dota 2: (left) caution pings; (center) an annotation on the minimap; (right) the chat wheel.

MOBAs provide an array of communication tools that attempt to facilitate and streamline team communications. For the purpose of this note, we select several representative examples from different MOBAs; however, this is not an exhaustive list of all communication tools in the genre.

Text chat – text chat is universally available in MOBAs. Text chat allows players to send free text messages.

Chat wheel – some games (e.g., *Dota 2*, Strife) allow preset text phrases to be entered with shortcut keys and/or using the mouse to select phrases from a pie menu (see Figure 3.1, right).

Pings - a combination of animation and sound that indicates a single point of interest. *Dota 2*, has two ping types created by holding a shortcut key and clicking on an open position on the map: exclamation pings (alt + left clicking) appear as an exclamation mark; and, caution pings (ctrl + alt + left clicking) appear as an 'X' (see Figure 3.1, left). While the meaning of pings is not specific, exclamation pings are context sensitive, with different effects depending on the object that was clicked. For example, an exclamation ping over an enemy tower produces a unique sound and a sword icon. Pings appear on both the gamespace and the minimap.

Annotations – players can create free hand annotations on the minimap, which allows the creation of more detailed gestures to teammates (ctrl + click and drag on the minimap). Annotations and drawings only last for a few seconds and can only be seen on the minimap. See Figure 3.1, center.

3.4 - **Related Work Gestures in Groupware & Games**

The more relevant information a team shares, the more likely it is to succeed [16]. Hence, groupware research has focused on providing tools that facilitate communication and increase group awareness [4]. Such tools include gesturing support, which has been shown to facilitate shared work [1,2,5,7]. Gestures can be represented in a variety of ways, including telepointers [4,5], push-pins [3], freely drawn annotations [6, 11] or representations of collaborators' arms [11,13]. Toups et al. studied communication mechanics in games, and identified several ways that games support gestures (including pings) and ways that players approximate gestures when they are not supported by a gesturing tool [14].

Recent work has found that League of Legends (*LoL*) players want and need to collaborate in "every aspect of the game" to have fun and to be successful [9]. Similarly, a recent study of Portal 2, a game with a rich set of gesturing tools, found that the tools were critical to coordinating actions [15]. Work has also recognized the importance of gestures in MOBAs; a large-scale analysis found that using pings correlated with several metrics of player performance [10]. While research has recognized the importance of gesturing tools to support teamwork in games, no work has yet examined why, when and how gesturing tools are used.

3.5 - **Studies of Gesturing in Dota 2**

3.5.1 Study 1: Analysis of Game Replays

Our first study focused on identifying the communicative intent behind gesture tool use in *Dota 2*.

3.5.1.1 **Data and Analysis**

Public *Dota 2* game replays can be downloaded and replayed in the game's client, allowing full exploration of the entire game state at any time during a match. Eight replays were selected from recent amateur matches to cover a range of match lengths and skill levels (5 normal skill matches; 3 high skill matches). Normal matches covers 75% of players (see: http://de.dota2.com/2013/12/ matchmaking-2/).

We used the iterative nature of Interaction Analysis to create content codes for labeling gesture events [8]. Events (annotations or pings) were identified and recorded with contextual details (e.g. creation time, a communicative intent category, map location, etc.). A new category was created when an event did not fit an existing category. Often this would include discussion and re-watching the event multiple times to ensure accuracy and minimize redundant categories.

3.5.1.2 **Overall Results**

Our analysis resulted in 756 gesture events in total (mean: 94.5 events/match; sd. 37.6; min: 31; max: 159). Overall, we found that pings were used extremely frequently, accounting for 729 of the events, while annotations accounted for just 27 events over 8 matches. Matches varied in length between 23 and 56 mins. (mean: 35.3 mins/match; sd: 9.4). Because of this we present data related to time as a normalized value (the percentage of time passed to the end of the match). Based on normalized time, the majority of gestures occur just after the midpoint of matches (after 52.33% of the match has elapsed).

3.5.1.3 **Results: Communicative Intents (Gesturing Motivations)**

Our analysis resulted in the six communicative intents (referred to as *motivations*) listed below (with the percentage of total events observed). 751 of the 756 events were categorized into the six motivations. Five events were initially omitted, but categorized later (see Discussion).

Planning (37.2%): Indicates a goal, path or objective that the player plans on pursuing or wants others to achieve or perform. For example, a player pings an enemy tower to tell teammates to attack it.

Warning (37%): When players notice that a teammate is in that an enemy is unaccounted for (i.e., missing), that an area of the map is unsafe, or that an enemy is searching for engagement they may produce warning events.

Resource (8.0%): Makes teammates aware of a resources that are available, such as wards, neutral stacks or runes.

Conflict (8.7%): Draws attention to areas of conflict. For example, a player is ambushed by enemies so they notify their teammates of the ensuing conflict.

Help (1.0%): Sometimes players know that they will require help to complete a task (such as safely farming in a lane), they will request help from other teammates. For example, if a player knows they will need healing from a teammate in the future, they may request help from a healer.

Frustration (*Emoting*) (8.1%): Players often experience frustration, as a result of their own mistakes, the mistakes of teammates, or due to conflict with teammates or enemies. We also observed ignoring warnings and reckless playstyle as causes for frustration in players. Frustration is commonly expressed by creating (spamming) pings in rapid succession. *Note*: Study 1 only uncovered Frustration as a motivation. However, the results of Study 2, caused us to broaden Frustration to *Emoting*. See Discussion for a description.

3.5.1.4 **Results Based on Analysis of Motivations**

Overall, we observed relatively few uses of the annotation tool; 27 events overall, with coverage in only three of six categories: planning (21 events), warning (4), emoting (2). Figure 3.2 shows the average count of each motivation type by normalized production time in the match. We can see that most motivations remain relatively stable throughout the match averaging between 0-1.5 uses. However, both warning and planning rise sharply mid-match, with warnings peaking just before the midpoint and planning just after.

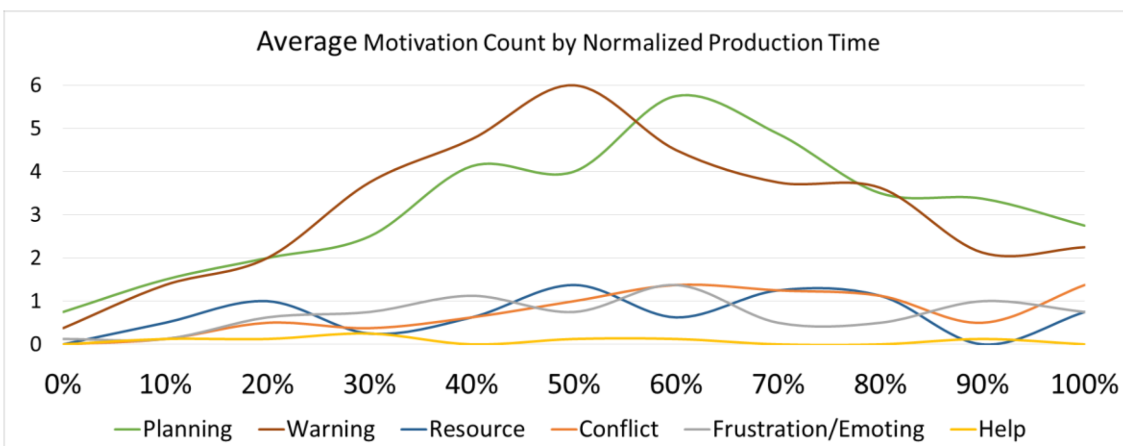

Figure 3.2 Average Motivation Count by Normalized Production Time

3.5.2 Study 2: Survey

3.5.2.1 **Design and Participants**

Our online survey collected player's perceived importance of gesturing tools to winning as compared to other available communication tools, the utility of annotation and pings for expressing our six identified motivations from Study 1, and to identify any other motivations for ping and annotations together. To simplify the survey, all of our questions asked participants to consider pings and annotations together.

We advertised our survey on the online forums r/dota2 (reddit) and the LiquidDota forum, in addition to the authors' Twitter accounts. 179 respondents could optionally be entered into a draw for one of five 20USD Steam gift cards.

Participants were from 40 different countries – the top 3 countries were US (47), UK (28), Canada (16) – 63% spoke English as a first language, had an average age of 20.5 (sd. 4.9, min. 14, max. 39), and were predominantly male (175 male; 4 female). Participants were very experienced, the average number of time in game was 2406 hours (s.d. 1757, min. 227, max. 11,050); only 22 participants reported playing fewer than 10 hours/week.

3.5.2.2 **Data and Analysis**

Our survey asked a series of Likert-style (on a 5-point scale). Response data was analyzed using a Friedman test and pairwise comparisons were conducted using Wilcoxan, with Bonferonni adjustments. Participant responses to optional free-text questions are used selectively to support findings.

3.5.2.3 **Results**

There was an effect of communication tool type on participants rating of the tool helping them win (see Figure 3.3); $\chi^2(3) = 62.734$, $p < .001$. Overall, participants rated pings, text chat and the chat wheel significantly more helpful for winning than annotations (all $p < .001$), but there were no other differences between the communication tools.

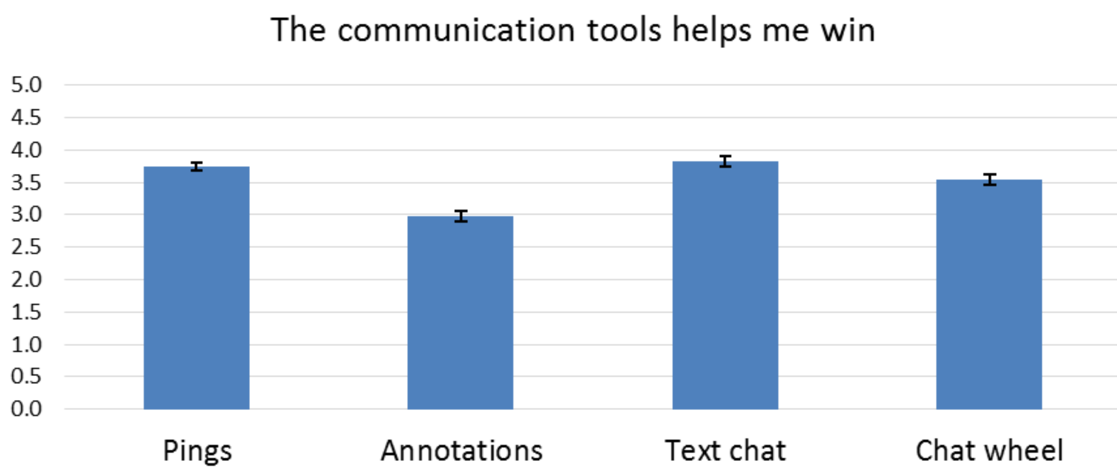

Figure 3.3. Agreement ratings for the utility of different communications for winning matches.

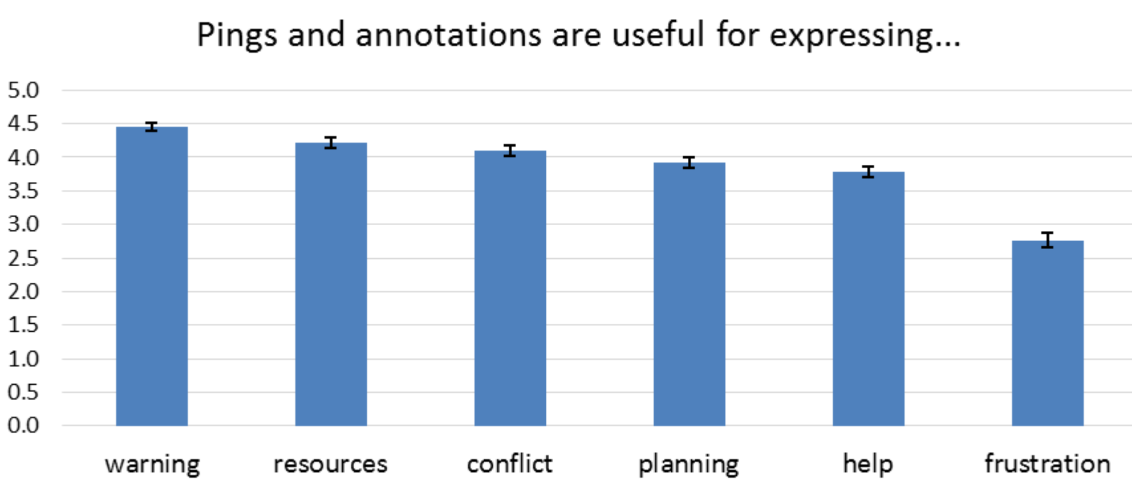

Figure 3.4. Agreement with the usefulness of tools for expressing six different motivations identified in Study 1.

There was a significant difference between the usefulness of gesturing tools for communicative intents (see Figure 3.4); $\chi^2(6) = 185.934$, $p < .001$). Overall, there was a difference between all motivation types (p<.001) with the exception of there being no difference between danger and resources, and planning and conflicts. This means that participants felt that pings and annotations are most useful for communicating warnings and resources, followed by planning and conflicts. They were rated least useful for expressing frustration.

We also asked participants to describe why they use pings and annotations. Of the 179 participants, 44 described uses. Two authors looked at these individually and agreed that most mapped to our categories; for example, "Notify a teammate of who to target" maps to 'planning'. However, 10 uses did not fit in our motivation. For example, one participant would cheer for teammates using pings: "Awe at execution of skill or luck in an event." Participants also described using pings and annotations for "flaming" and for "comedic value". These comments led us to broaden Frustration to Emoting (see Discussion).

3.6 - **Discussion**

3.6.1 Frustration becomes Emoting

Study 1 originally uncovered only 'Frustration' as a motivation. However, after Study 2, we broadened this category to include other types of 'Emoting' including the expression of joy, praise, pride, playfulness or to flame. This resulted in the only 5 (0.6%) events for which we could not find a category in Study 1, to be recoded as Emoting. For example, these five events included two instances of players expressing pride in making big plays by pinging rapidly, and two instances of a player drawing penises on the minimap; a relatively common act that is meant to be playful.

3.6.2 Why Are Pings More Popular than Annotations?

We were surprised that annotations were not used more frequently; however, we can speculate about two possible reasons for their lack of use, which should be investigated in future work. First, pings are likely enough in many situations. Although, pings carry low information content, drawing attention to a single point only [14], the addition of contextual use (e.g., different behavior for pings when clicking objects like towers) and player's deep knowledge and experience with the game might allow pings to carry much more information that can be inferred rapidly by players. Second, annotations take more time and effort to create. Annotations must be created on the minimap; targeting, clicking and dragging the mouse on this small area can be challenging and might take too much time in the heat of a battle. Further, unlike pings (which appear on the gamespace), annotations only appear on the minimap; meaning they are much less visible.

To address these limitations, we believe that annotations might be used more often if they were more salient and more easily created. For example, annotations could be created and viewed directly on the gamespace rather than the minimap. There is some evidence that such a change could work, as *Dota 2* provides exactly this in widely used tools for commentators and casters to describe matches to spectators.

3.6.3 Why Do Motivations Occur at Different Times?

The results relating to production time for the different motivations provide valuable new information regarding the dynamics and different stages of matches. During the early stages of a *Dota 2* match players actively engage in well understood activities (e.g., laning, jungling, etc.); however, in the middle of the match players start to form a game plan to try and gain the upper hand. Initially, teammates try to jockey for an advantage (e.g., by pushing lanes, trying to gank enemies), which results in warning pings being created. As this is happening, teams start to plan offensive and defensive tactics, leading to planning pings. This opens up interesting direction for work that looks at how communications can help explain game behavior and dynamics in MOBAs and other games.

3.6.4 Enriching Gestures with More Information

Games like *Smite* and *LoL* have recognized that providing a pre-defined type with pings can make them more effective; via an interface similar to the chat wheel, called the ping wheel. Four ping types are provided: danger, enemy missing, on my way, and assistance. At least two of these, map clearly to our motivations (danger & missing >warning, assistance > help). The other messages are available in *Dota 2* through the chat wheel, which allows reports of "missing" with a general location (e.g., "top" or "bottom"), and on my way. However, we have identified six motivations and each of these motivations might warrant its own ping wheel (e.g., the planning chat wheel could have pings for "attack", "push", "gank", "hide"). We will explore this in our future work.

Deictic references (the combination of speech and gestures to communicate detail quickly) are common in collaboration [12]. Ping wheels enable a form of deixis;

however, it is also likely that voice and pings are often used together in *Dota 2*. Studying voice chat and their use in combination with pings and annotations was not possible through our study methodology, and would be a complex undertaking. Therefore, our work focused exclusively on non-verbal tools. Future work should start to examine the use of voice in MOBAs and how it is combined with gesturing and other communication tools.

3.7 - **Conclusions**

Our two studies were the first to identify six distinct communicative intents for the use of gesturing tools (planning, warning, resource, conflict, help, and emoting). We found that use of pings for most motivation types are fairly stable throughout matches, with the exception of warning and planning gestures, which peak around the middle of matches. We also found that players clearly view pings as an important tool; players used them extremely frequently and rated them as important to winning. However, annotations were neither used frequently nor felt to be particularly helpful for winning.

Based on these results we have suggested several promising directions for the improvement and future study of gesturing tools in *Dota 2* and MOBAs. Given the success and importance of gesturing tools in MOBAs, other genres, such as MMOs and FPSs, might consider them as new ways to support collaboration. Further, we believe that groupware research more generally might learn from some of the communication tools that have successfully been employed in MOBAs (and other games), and provide designers with new directions to support collaborative work tasks.

3.8 - **References**

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4 - How Can Game Awareness Widgets Be Designed To Support Specific Gameplay Experiences?

In order to be effective, game awareness widgets must provide players with the right information at the right time. Providing too much or too little information can be the difference between a challenging, fun experience and a frustrating or boring experience. However, there are no guidelines or techniques to guarantee that a widget design will achieve these goals. While game designers can learn from trying to duplicate existing widget in other games, the reason why a particular design might work in a particular context and not in another would be difficult to uncover because there is theoretical basis or common vocabulary that underlies the design of widgets.

To address this the published work *A Design Framework for Awareness Cues in Distributed Multiplayer Games* presents the results of a survey of 99 awareness cues from 24 different multiplayer games. It introduces a palette for game designers that wish to build new GAWs and target certain play needs and experiences. To achieve this, a grounded theory analysis was performed on the extracted GAWs. The application of grounded theory is a common technique for the creation of frameworks from existing implementations. It involves the survey and classification of existing interfaces. These classifications can then be used to find structures and design patterns in the data.

Article 3:

Jason Wuertz, Sultan A. Alharthi, William A. Hamilton, Scott Bateman, Carl Gutwin, Anthony Tang, Zachary Toups, and Jessica Hammer. 2018. A Design Framework for Awareness Cues in Distributed Multiplayer Games. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI '18). ACM, New York, NY, USA, Paper 243, 14 pages. DOI: https://doi.org/10.1145/3173574.3173817

4.1 - **Abstract**

In the physical world, teammates develop situation awareness about each other's location, status, and actions through cues such as gaze direction and ambient noise. To support situation awareness, distributed multiplayer games provide awareness cues—information that games automatically make available to players to support cooperative gameplay. The design of awareness cues can be extremely complex, impacting how players experience games and work with teammates. Despite the importance of awareness cues, designers have little beyond experiential knowledge to guide their design. In this work, we describe a design framework for awareness cues, providing insight into what information they provide, how they communicate this information, and how design choices can impact play experience. Our research, based on a grounded theory analysis of current games, is the first to provide a characterization of awareness cues, providing a palette for game designers to improve design practice and a starting point for deeper research into collaborative play.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords
Awareness cues, situation awareness, workspace awareness, game design, distributed, multiplayer games

4.2 - **Introduction**

Teams working together in the physical world develop situation awareness [13, 14] about teammate location, status, and actions through cues such as body language, gaze direction, and ambient noise [29, 31, 61]. *Distributed games* help players coordinate by providing *awareness cues*—information that systems automatically make available to collaborators to support cooperative actions [44]. Distributed games are played together by players on separate devices typically arranged so that players cannot see each other's' screens. Thus, it is primarily through awareness cues that teammates' status, characteristics, actions, experience, etc. are represented and understood. Because *game worlds*, the virtual worlds that players experience as the interface to games [35], are artificial and lack the sensory cues that make coordination as natural as it is in the physical world, awareness cues must be designed to provide the right information at the right time. Game designers have additional latitude to create detailed and complex representations of actions and events that occurred in past, present and future, and are not limited only to approximating cues that exist in the physical world.

Since teammates in distributed games are largely experienced through awareness cues, the principal challenge for game designers is to create tools that will provide the right information at the right time [62]. The design tension is to balance this information with ensuring that the game remains challenging, so giving a player omniscience is undesirable. If a game designer provides too little information, coordination will be cumbersome, awkward, and slow; if they provide too much information, cues could be overwhelming, difficult to learn, and distract from gameplay. On the other hand, some games opt to purposely limit awareness cues to increase uncertainty and realism, and some even provide this as a separate game mode (e.g., *Left 4 Dead 2 (L4D2)* [G21], *Rainbow Six: Siege* [G19]). In contrast, other games try to raise the ceiling on performance by providing many rich awareness cues and tools, which can be initially overwhelming and increase the game's learning curve (e.g., *League of Legends* (*LoL*) [G17], *Dota 2* [G23]). Despite the importance of awareness cues in distributed games, there is currently little information about what information game designers provide, how it can be provided, and what trade-offs might exist with particular designs. Using a grounded theory approach, we examined 24 games, selected for maximum variability, from which we identified and analyzed 100 awareness cues. Our research provides a characterization of the range of awareness cues currently in use through game mechanics, interface components, and other information displays. We do this by first articulating the information made available through awareness cues to teammates. Second, we describe the essential design dimensions of awareness cues and how they make teammate information available. Third, we discuss potential consequences for games and play experience when particular design choices are made.

While prior work has considered synchronous verbal communications [8,56,67] and cooperative communication mechanics (game mechanics invoked by players to communicate with one another) [37,60,64,70], our work focuses on the understudied tools and techniques that games use to support coordination, which are made available to players without explicit effort.

Building on previous work in awareness, this work makes two main contributions. First, we provide a palette for game designers and researchers to identify and devise new awareness cues depending on the game experience they want to target. We expect that users of games (players and viewers) influence how cues should be designed and also consider how players adapt their play experience through cues. Second, we provide a starting point for future research and for informed design practices around awareness cues in online games, and in groupware more broadly.

4.3 - **Organization**

We first synthesize background on awareness and related awareness frameworks to motivating the present work, then describe our grounded theory approach and our search and selection strategy. We then present our design framework that classifies cues by the information they provide and how they convey that information, discuss how the framework aids designers in explaining their cues and surfacing them for analysis, and identify implications for designers and researchers.

Our work uses games, game mechanics, and game interfaces as primary data sources, which form a Ludography. Games that are discussed but are not a part of the dataset appear in References. When games from the Ludography are cited they are prefixed with a "G" (e.g., [G6]).

4.4 - **Related Work**

In this section we provide background on awareness, with a focus on games. We then discuss prior frameworks and identify the gap that we address—an improved understanding of awareness cues in distributed multiplayer games.

4.4.1 Awareness and Awareness Cues

Awareness provides people with knowledge about the state of the changing environment around them [24]. *Situation awareness* is the ability to understand a complex situation and predict its future states in order to make decisions [13]. A high level of situation awareness supports decision making, enabling an actor to identify one or more correct courses of action. In distributed teams, awareness of teammates' status and activities is critical to coordinate activity and avoid interference [14]. To maximize performance, teams organize their activities and synchronize their effort [46, 49].

As teams develop *shared mental models* [19], they are able to improve their situation awareness [13, 14], which allows them to coordinate more efficiently [66]. This occurs because as teams become more efficient, they reduce their reliance on verbal communication [39, 65], shifting to a mode of implicit coordination [15, 16, 63]. Successful implicit coordination means that team members can communicate less and readily make use of cues from their working environment.

Although team or group awareness is easily maintained in co-located collaborative environments, it is more difficult in remote collaboration [26]. Hence, groupware research has focused on interface techniques that facilitate communication and increase group awareness [24]; i.e., awareness cues. In our work, we use the definition for awareness cues put forward by Oulasvrita who described them as ... *any signal or symbol or mark in the user interface—typically textual, graphical, or auditory—the content of which is produced (or influenced), in real time, by the actions or properties of a remote person.* [44]

4.4.2 Awareness in Cooperative Games

Cooperative play engages two or more players in challenges that require them to work together to defeat a common opponent or the game system (e.g., *L4D2* [G21], *Portal 2* [G22]) [18, 38, 72]. Players want and need the ability to collaborate and share relevant information to have fun and to succeed [17, 36]. Players communicate through many channels: verbally through voice [56] or text chat; or using specialized tools such as virtual gestures, pings, or annotations [60, 70]. Prior research has investigated how such communication channels are used in games [60, 70], how they provide a shared awareness of teammates [8], and what other communication channels exist in cooperative games [60]. However, there is little work investigating how awareness cues that are automatically shared by the game support cooperative play.

4.4.3 Prior Awareness Frameworks

Because of the importance of awareness in remote collaboration, there has been substantial research into frameworks that describe its nature and characteristics [8, 24–27]. For example, studies have investigated team awareness in collaborative environments, including shared workspaces [12, 24, 25, 46], software development teams [26, 54], and gaming [8, 43, 58].

In co-located and distributed collaborative environments, people need to gather information from the environment around them and make sense of it to maintain situation awareness. In these collaborative environments, several tools and widgets are used to help maintain awareness [26]. Research on workspace awareness has proliferated in the field of computer-supported cooperative work and helped address several coordination challenges [24, 26]. This prior research provides insights into how to design tools to support awareness and collaboration.

Gutwin and Greenberg define *Workspace Awareness* (WA) *as the up-to-the-moment understanding of another person's interaction with the shared workspace* [25, p. 412]. They proposed a framework that provides designers with a common understanding of how to support awareness and foster collaborative activities. The framework is structured around three questions: *WHO* we are working with; *WHAT* they are doing; and *WHERE* they are working. WA supports successful collaboration and helps reduce the effort needed to coordinate tasks and resources. We focus specifically on distributed multiplayer games, which are a form of workspace.

Cheung et al. [8] classified awareness cues in co-located games. Co-location allows players to, for example, look at one another's screens or overhear one another to gain and maintain awareness. However, this is not possible in distributed games as remote players cannot view others' displays. Thus, these cues need to be designed specially for remote players in order to provide them with needed awareness information.

4.5 - **A Framework of Gamespace Awareness**

While the existing WA literature is extensive, Teruel et al. found that gameplay involved a superset of activities from those observed in group work [58]. Seeking to unify WA with observed game activities, including social and group dynamics, they developed the *Gamespace Awareness* (GA) framework through a thematic analysis of previous workspace awareness research. GA frames existing awareness research in the awareness questions introduced by games and considerably expands on Gutwin's WA framework. Furthermore, GA includes social and group dynamic awareness (group membership, group awareness, roles and communication awareness) necessary for multiplayer games. We use GA as a reference frame for understanding and classifying awareness cues.

One shortcoming of GA is that it does not specifically identify *how* awareness can be provided in cooperative games. Therefore, we develop a design framework to describe how to develop cues that encode and represent awareness information.

4.5.1 Methodology

We conducted a grounded theory study of cooperative games to identify and characterize the range of awareness cues currently used in these games. Grounded theory is a set of qualitative practices aimed at exploring and characterizing a new domain by developing a related set of codes from data [21, 22]. It is a common methodology for extracting structured frameworks from video game components and mechanics [60, 68]. In grounded theory, researchers build up codings and characterizations from a series of rounds of data collections and open coding, followed by structuring. The proposed framework was the result of a fairly standard Glaserian approach to grounded theory [20–22]. This is in similar style to previous studies (e.g., [60,69]). Our process involved three phases, with frequent iterations both within and between phases:

> **Phase 1**: finding and selecting distributed, cooperative games via an iterative inclusion criteria;
>
> **Phase 2**: initial observations and open coding; and
>
> **Phase 3**: revising the coding scheme to develop axial codes.

During each phase, the researchers engaged in discussions to explore the relationship between the examples and their codes, the emergent concepts, and the initial awareness cues.

4.5.1.1 **Phase 1: Finding and Selecting Games**

Our iterative process started with a collection of games researchers were familiar with. However, not all distributed games included awareness cues, so discussion and iteration was required. Games with awareness cues were recorded in a spreadsheet that was updated frequently during discussions. These discussions also resulted in a set of inclusion criteria that were applied to the existing list as well as future additions to determine if games fit the dataset:

- the game must include a cooperative play mode;
- the game must automatically render a player's state or perception to another cooperating player (i.e., information should come from a teammate not an enemy); and
- the game must be designed for distributed play.

Since our goal was to maximize variability in the set, we excluded new games that were similar to ones in our existing set. Our final data set includes 24 games, drawn from a range of genres, including first-person shooters (FPS), multiplayer online battle arenas (MOBAs), real-time strategy (RTS), and role-playing games (RPGs). Co-located cooperative games were excluded to focus on awareness cues that were designed without any additional local context.

After initial coding (Phase 3) researchers often returned to this phase seeking out specific types of cues that were hypothesized about as potential codes and dimensions emerged. This also resulted in the following natural stop criteria:

- the absence of games that demonstrate new awareness cues
- existing axial codes and design dimensions did not suggest new potential cues that we did not have in our dataset

4.5.1.2 **Phase 2: Initial Observations and Awareness Information**

As games were added to the dataset, each was evaluated for any awareness cues that it might provide. Data were drawn from personal play experiences and observations of players, both in-person and through gameplay videos from Internet sources (e.g., Let's

Play videos on YouTube and Twitch). As games were added to the dataset, we identified awareness cues and collected the following details: game name, genre, player count, co-op / competitive mode(s), awareness cue description, screenshot, and comments.

For each cue, we identified whether and how each addressed awareness questions, such as: *WHO* players are playing with, *WHAT* they are doing, *WHERE* they are in the game world, and *HOW* these events would occur. As more games were added, we began to see saturation in the dataset: new games were not adding new insights. Consequently, the final dataset contained 100 cues from 24 games. While there are other games that fit the inclusion criteria, we expect there to be substantial overlap.

4.5.1.3 **Phase 3: Axial Coding and Design Dimension Classification**

Through a series of discussions, we iteratively identified potential design dimensions. At each stage, we conceptually decomposed the cues using descriptive labels, and determined their positions on each dimension. We refined these dimensions until we had eliminated redundant dimensions, and the dimensions remained relatively stable as we added new games to the set. During this process, we noted any implications and trade-offs we identified based on the awareness interpretations of the cues and their design dimensions.

4.6 - **The Design Framework for Awareness Cues**

Awareness cues encode information that games make available to players to support cooperative gameplay. Awareness cues address individual questions (e.g., *WHERE* is my teammate? *WHAT* are they doing?), and are often combined into larger tools and widgets such as character embodiments[3], hit point (HP) bars, usernames, and user icons (Figure 4.1).

While work has been done to provide a unified [58] framing of awareness in games, existing frameworks provide little insight into the design of tools that support awareness. To fill this gap, we present a framework for awareness cues in distributed games. To understand awareness cues and the proposed design framework, we consider two perspectives:

1. what information awareness cues provide; and,
2. the design dimensions behind these awareness cues.

For the former, we consider how cues answer questions related to awareness (e.g., state of my teammates); for the latter, we develop a set of properties that describe interface elements of cues (e.g., animated icons with status information). Our discussion of current awareness tools in games is not exhaustive and should be seen as an exploration of common tools in games and the awareness information they communicate.

4.6.1 The Information Provided by Awareness Cues

Prior research on WA [24] and GA [58] identified four types of information that team members use when collaborating:

WHO? – Presence and identity

WHAT? – Status and tasks and social structure

[3] Embodiments are how players exhibit agency in gameworlds (e.g., avatars or cursors) [2, 53]

WHERE? – Location, positioning, and gaze

HOW? – Communicating the way important events occur

In the following sections we use this organizational framework to provide an overview of the awareness information provided by current distributed multiplayer games. For each question, we indicate the range of ways that the information is conveyed, introduce game design factors that relate to that awareness element, and discuss temporal aspects to the questions.

4.6.1.1 **WHO? – Presence and Identity**

In traditional groupware systems, identity information is relatively static; while team composition may change as people come and go, individual members' names and capabilities do not. Many distributed multiplayer games are fundamentally different: although players may be continuously present, their embodiment (i.e., their in-game avatar) may go in and out of existence in the game world multiple times during a single play session as they die and respawn. Thus, *WHO* information is characterized both by identity of the player as well as the avatar the player embodies.

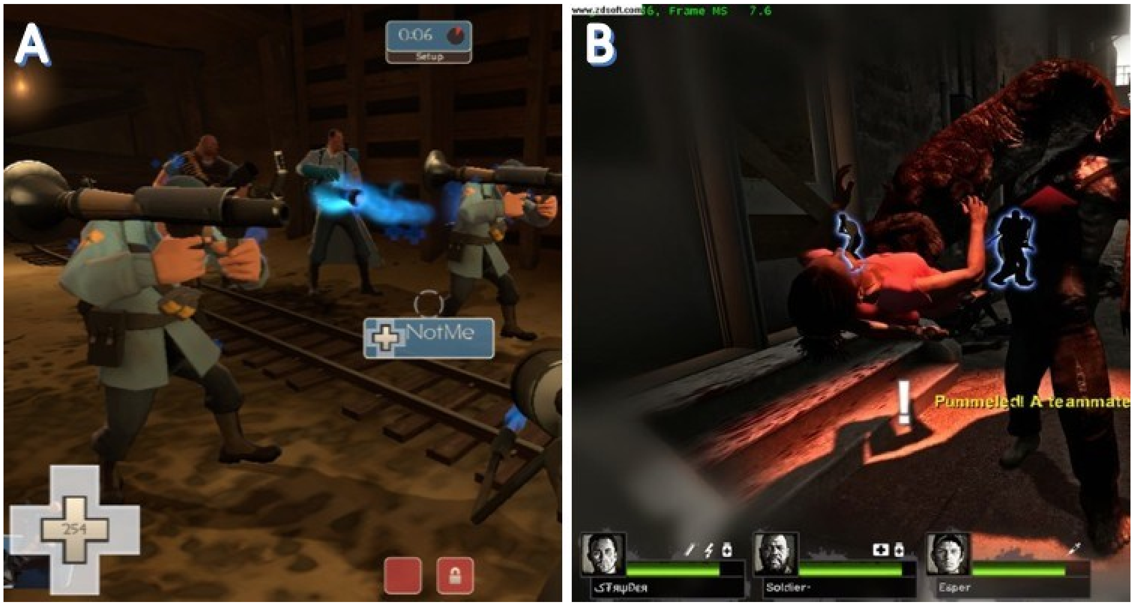

Figure 4.1 Two examples of *WHO* information (among others). A: Diegetic presence and identity information through embodiments in *Team Fortress 2* [G20]. From the perspective shown, the player can tell what classes teammates are playing, what weapons they are using, and the health of the character in the crosshairs. B: X-Ray vision of teammates in *L4D2* [G21] demonstrates how games solve the problem of obstructed vision of teammate embodiments.

Presence and identity of players is typically shown in nondiegetic displays, such as a list view, which shows the identity of teammates and sometimes also shows information about their embodiments (i.e. dead or alive). Some games show this team list in a fixed location on the interface [G3, G6, G7, G21] (as seen at the bottom of Figure 4.1.B), while others allow this information to be called up on demand (i.e. holding Tab in *Overwatch* shows Figure 4.2.B).

A player's embodiment in the game is the primary way that others perceive the player's (and the avatar's) presence. WHO information about presence can be shown diegetically[4] by their existence. Additional information about the character's abilities and roles is also often shown diegetically (e.g., via the character model or adornments on the avatar). Finally, the player controlling the embodiment is often shown using a text label above the avatar. Since players can change their avatar through a gameplay session, tracking this WHO information is a critical part of successful team coordination. This embodiment-based display of WHO information can be limited by the player's field of view, distance, or occlusion. In a departure from the physical world, game designers address this problem in two ways: with markers on or over an embodiment (e.g., Tribes: Ascend [G13], Team Fortress 2 [G20]), or sometimes by showing outlines of teammates through game world obstacles (e.g., Figure 4.1.B).

WHO information can also be found elsewhere in the interface. A radar view that primarily shows locations (as described below) also implicitly indicates which teammates' embodiments remain in the game. Some games identify fellow teammates using unique icons. We also see authorship awareness in some places. For example, some games show an icon in the interface or above the avatar to indicate who is talking.

[4] "The narrative presented by a cinematographic film or literary work; the fictional time, place, characters, and events which constitute the universe of the narrative." [45].

4.6.1.2 **WHAT? – Status, and Tasks & Social Structure**

Status

As with identity, games are typically concerned with the in-game embodiment's status, rather than that of the player.

Embodiments in games have several attributes that vary during a game (e.g., HP, powers, equipment), and these elements are often part of a game's awareness displays. Many games present multiple pieces of status information as augmentations around or above a player's avatar. For example, *Realm of the Mad God (RotMG)* [G24] displays an HP bar below embodiments, a line of icons indicating positive or negative effects currently in place for the embodiment (e.g., powerups, detriments), and numbers showing the rate of HP and mana regeneration (Figure 4.3.D). Although previous work has shown that people are able to interpret a large number of these augmentations [53], *RotMG* is a good example of how visual effects can quickly clutter the display when there are many embodiments in view.

Status information can also be conveyed through automatic chat messages. For example, when an *Overwatch* embodiment reaches a critical health level and the player requests healing by pressing a button, a "Critical Health!" phrase is automatically added to the usual "I need healing!" chat message. We consider this an awareness cue as it automatically supplies extra information about this teammate to another player.

Some status information is also presented about the players. Nickname display is shown in most games and is often part of the avatar or player-list augmentation (e.g., Figures 4.1.A; 4.3.C; 4.3.D); player experience is less common, but is important in some games because experience level determines how players will form their strategy. One example of this is the “level borders” decoration in the *Overwatch* [G6] player list: as players demonstrate skill, their portrait is given additional levels of decoration (e.g., Figure 4.3.B).

Tasks and social structure

Maintaining awareness of other players’ actions, activities, and intentions is a critical part of successful teamwork. Much has been written in CSCW about how coordination depends on an understanding of what others are doing—for example, the idea of social protocols that act as access-control mechanisms over shared resources [23]. Information about what others are doing can include a character’s low-level activity (e.g., their movements and detailed actions), their higher-level activity (e.g., the task they have taken on in the game), or their plans for the future (e.g., a division of labor for a future group activity). Given the importance of this type of awareness information, and the many examples of augmentations and external widgets for showing other kinds of awareness, it is somewhat surprising to see how reliant games are on in-view representations of activity, and voice communication [56, 67]. That is, the primary vehicles for conveying information about what a person is doing are in the embodiment itself, and through the player’s spoken messages.

There is, of course, much that can be conveyed about activity through an embodiment—for example, where an embodiment is (and where they are going) in the game world gives strong clues as to a player’s destination and task (particularly in games that are oriented around location-based objectives); similarly, what equipment they are holding (e.g., a sniper rifle) and what they are doing with that equipment (e.g., shooting) clearly shows their current activity. In addition, many games’

Figure 4.2 A: Characteristic visual effects of different embodiment actions in *LoL* [G17]. B: Character icons in *Overwatch* [G6]: the borders represent player experience wheel silver icons represent skill. C: Automatically amended chat messages in *Overwatch* [G6] indicating of the severity of a player's request.

visual representations of embodiment actions and equipment are often highly recognizable—for example, the weapons used in *Team Fortress 2* [G20] are large and visually obvious (Figure 4.1.A); similarly, many actions have characteristic visual effects, such as a smoke trail from firing a rocket, or a particle effect from casting a spell (Figure 4.2.A). However, relying on embodiments to convey awareness information has the limitation that characters must be in view. Additionally, some games provide an awareness of the capabilities of teammates. For example, in *Dota 2* [G23] players can see detailed information regarding the spells and abilities of their teammates.

Some games provide a kind of automatic commentary in the team chat channel that provides information about others' activities. For example, many games produce text or voice notifications when teammates have reached a new level of achievement (e.g., "NickFury8 is on a scoring streak!" or "NickFury8 has levelled up!") [G14, G17, G23].

However, the automatic display of information about activities, tasks, and future plans is still limited, which means that many games must rely on players talking to each other through verbal channels (voice or chat) about what they are doing. It may be that planning and executing coordinated group strategies in games are complicated enough that automatic displays cannot provide enough information, and so human communication is necessary. This is an area where experienced teams rely on practice and prior planning—that is, if a team already knows what to do when executing a group action (because they have practiced it many times), people are much less dependent on up-to-the-moment displays of others' activities. Such a change represents a shift toward implicit coordination [15, 16, 63].

4.6.1.3 **WHERE – Location, Positioning and Gaze**

Conveying other players' locations in the game world is primarily accomplished in one of three ways: first, within the field of view of the player; second, through radar (or bird's eye) views[5]; and, third, through abstract widgets such as icons on a compass. For example, in PlayerUnknown's Battlegrounds [G7] players can see map markers for their teammates in a compass at the top of the screen (see Figure 4.5.C).

Some games make a considerable effort to increase the visibility of location information—for instance, by highlighting or outlining embodiments so they are visible

[5] Radar views show the relative locations of cooperating players (and, usually, enemies). Some are combined with a mini-map showing topology and/or points of interest.

through obstructions (e.g. Figure 4.1.B), or by simply indicating their location via icons when a straight view of them is impossible. Additionally, games may display

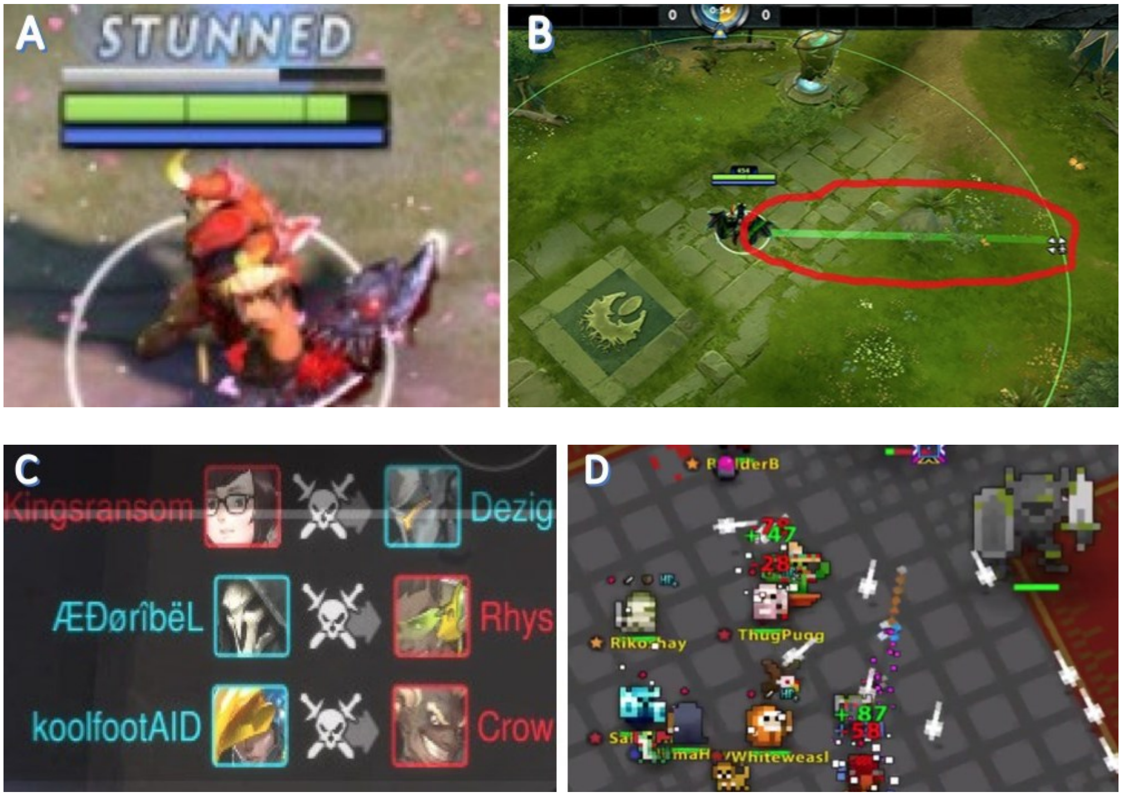

Figure 4.3 A: "Stun bar" showing when an effect will finish in Dota2 [G23]. B: A visualization of the future range of a spell in Dota2 [G23]. C: "Kill feeds" in Overwatch [G6]. D: Status awareness cues over embodiments in Realm of the Mad God [G24].

icons on the edge of the screen when the other players' embodiments are outside of one's viewport. Beyond this, some games append distance information about other players next to the icons or names. Another common widget used in multiplayer games represents an abstract "birds eye view" of the environment in which other players' embodiments are represented by icons or glyphs.

4.6.1.4 HOW – Communicating the Way Important Events Occur

HOW actions and events are being accomplished or were accomplished in the game world can be critical information. In particular, we note that many games are not sufficiently complex to warrant *HOW* information. Awareness cues can provide immediate notifications (e.g., kill feeds in Figure 4.3.C), but if they persist they can also convey information about past events. Whether a *HOW* cue that persists provides present or past awareness depends on when the player notices it.

One common example is the kill feeds common in player versus player games. These provide a log of player deaths and often how the death occurred (Figure 4.3.C). In such games, it is critical for players to maintain an awareness of task history, which aids understanding of teammates' current capabilities (for example, if a teammate has just killed an enemy that has a special ability, this ability will not be available to the opponents for some time). This kind of *HOW* awareness is most common in adversarial games where maintaining an awareness of how your teammates have been affected by enemies (and vice versa) is important.

4.6.1.5 Temporal Component: Past, Present, and Future Awareness

Situation awareness requires the integration of past and present events in order to predict future events [13,14]; thus, it is necessary to maintain an awareness of all three temporal states (past, present, and future). Indeed, all of the awareness elements discussed above have temporal components.

Historical traces and change awareness have been explored in other areas for many years (e.g., [1, 30, 55]). Some games represent the past through persistence of changes to the game world. This is integral to construction-based games like *Minecraft* [40] (where the purpose of the game is to change the world), but has also been used in other game genres such as shooters, many of which make certain effects of acting in the world persistent (e.g., in the *Halo* series [G8], bullets create holes in walls and battle traces such as blood spatters persist for several minutes). These persistent visuals can be used by other players to determine what has occurred in a particular location (and can also be repurposed as an emergent CCM—such as firing a bullet to mark a particular location). Second, several games provide indications of future activity, including displays such as effect timers and spawn timers. For example, *Dota2* [G23] shows “stun bars” that indicate the time when a stun effect will wear off (Figure 4.3.A); several other games use similar spawn timers (both for teammates and monsters) and almost all player-versus-player games inform the team of how long a teammate will be dead before respawning.

Third, games often provide automatic chat messages that provide information about past and future events. Kill feeds are nearly ubiquitous in player-versus-player games (Figure 4.3.C) as are voice prompts and/or head-up display (HUD)[6] messages reporting on the state of the current match (e.g., “Only 15 kills remaining!” [G6] as a team nears a quota to win).

4.7 - **Design of Awareness Cues**

After a designer decides what awareness information to include, they must decide how that information should be represented. Above, we presented what information games

[6] The HUD is an information overlay through which the player experiences the game.

share in order to support situation awareness, with examples. Awareness tools and widgets are often made up of several awareness cues working together or providing complementary information. For example, Figure 4.3.A shows how multiple cues can be combined. In this case it consists of text, a progress bar, an embodiment animation and an icon animation.

Rather than exhaustively list individual awareness cues and relate them to widgets, our analysis instead allows us to characterize the design space of awareness cues. This presentation allows game designers to better understand and differentiate awareness cues, and to identify how different decisions in the space can lead to different designs. Further, this decomposition supports critical practice around design and facilitate the invention of new cues and widgets.

We identified two sets of decisions that must be made when information is represented as a cue. First, awareness information must be encoded (i.e., decisions must be made about the cue can be represented). Second, decisions must be made about how a cue can be composed (i.e., how individual cues are combined, displayed and accessed).

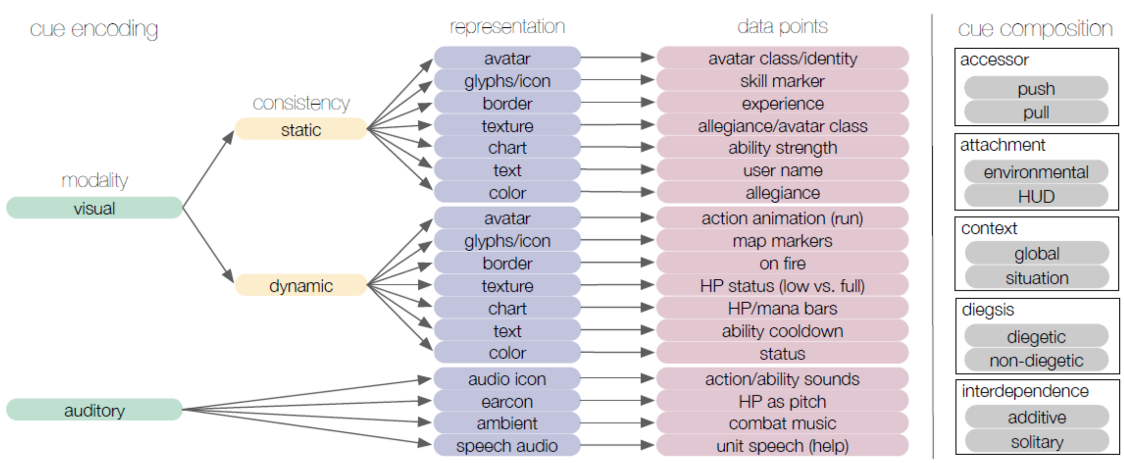

Figure 4.4 A thematic tree describing the framework for awareness cues in multiplayer games. See Table 4.1 below for an application to example cues.

Figure	Encoding				Composition			
	Modality	Consistency	Representation	Accessor	Attachment	Context	Diegsis	Interdependence
2.B	Visual	Dynamic	Icon	Pull	HUD	Global	Non-diegetic	Solitary
3.A	Visual	Dynamic	Chart	Push	Environmental	Situational	Non-diegetic	Additive
3.A	Visual	Dynamic	Avatar	Push	Environmental	Situational	Diegetic	Solitary
5.B	Visual	Dynamic	Chart	Push	Environmental	Global	Non-diegetic	Solitary

Table 4.1 Example awareness cues categorized using the framework. Figure 4.2.B shows a team list accessed via holding Tab in *Overwatch* [G6]. Figure 4.3.A shows a progress bar and embodiment animation respectively. Figure 4.5.B a HP bar found in *Dota 2* [G23]

4.7.1 Cue Encoding

Cue encoding refers to how game designers represent awareness information to be accessed by a player. Our analysis resulted in three decision points in that must be made to encode awareness information as a specific representation, and five further properties of cue composition. Figure 4.4 displays a thematic tree connected to specific exemplar data points. Also, Table 4.1 provides illustrative examples from our figures described by their cue encodings.

4.7.1.1 **Modalities**

Refers to the two main sensory channels through which players can receive cue information: visual and auditory. Many designers (and HCI researchers) are likely familiar with the notion of representing information visually; however, we also found many uses of auditory cues that may be somewhat less familiar (see Figure 4.4). Visual and auditory cues are often used together and are often so tightly coupled that they might be considered a single cue. It should be noted that while it may also be possible to use haptics to encode awareness information (e.g., a vibrating controller to denote when a player bumps you), we did not encounter any instances.

4.7.1.2 **Consistency**

Refers to whether a visual cue changes or not. Visual cues can be static or dynamic cues. Static cues do not change during a game session. For example, a player's username would usually be static throughout a match. Dynamic cues change during the course of gameplay. For example, it is common for HP bars to increase and decrease depending on ingame events. Auditory cues by their nature are dynamic, in that they have a short duration; their pitches and envelopes [4, 5] are modulated to encode information (as described below).

Figure 4.5 A: Avatar allegiance is shown by the characters clothing color in *FIFA 17* [G11]. The arrow is pointing to a diegetic representation of status, low health/injury in this case. B: The dynamic nature of HP bars found in *Dota 2* [G23]. C: In *PUBG* [G7] squad-mate HP bars, activity icons (parachuting) and waypoint colors are shown on the left while the center-top of the players screen shows a compass with the directions of their teammates waypoints. D: Player perception indication in *Overwatch* [G6] via a on-fire border animation. In this case it shows that the player is performing well.

4.7.2 Representation

Refers to the specific design that encodes awareness information. Similar to information visualization problems designers are presented with a variety of channels [42] that can encode and communicate different types of data. While there are potentially other possible encodings, Figure 4.4 contains the specific representation found through our analysis.

While some representations are straightforward and familiar, (e.g., color, text, icons), others warrant further explanation. Avatar cues refer to a player's in-game embodiment. For example, an animation showing an embodiment reloading her weapon. Glyphs refer to specifically designed visual representations. For example, a triangular wedge glyph on a mini-map is a frequent representation of the location and the direction that players are facing. Charts are most frequently seen as simple bar charts to represent health. Borders are graphics surrounding other icons, glyphs or avatars. They often represent a secondary attribute of the thing they surround.

While speech and ambient audio cues are straightforward, audio icons and earcons require more explanation. Audio icons are short sounds that correspond directly to an action event [4,5] (e.g., a teammate moving close by is represented by a unique character-specific footstep sound in *Overwatch* [G6]). Earcons are abstract sounds whose characteristics are varied corresponding to the underlying data they represent, so they can be used to build complex notifications [4, 5]. Learning to identify and make effective use of audio representations is challenging, but useful, for players [34].

4.7.3 Cue Composition

While cue encoding (described above) concerns itself with the auditory and visual representations of awareness information, cue composition describes how the cues fit into the game experience. It should be noted that some encoding combinations and compositions are unlikely or impossible. A non-diegetic, dynamic avatar awareness cue makes little sense. For example, it is unclear how (or why) one would make a game embodiment move without it being considered part of the embodiment's narrative experience of the game world.

4.7.3.1 **Cue Accessor**

Refers to the means by which a player can access an awareness cue. Cues can be either ***push*** or ***pull***. Pull cues refer to cues that are not initially available, but can be made visible or triggered through some input action by a player (e.g., players view the Overwatch [G6] scoreboard, Figure 4.2.B, by holding the TAB key). By using pull accessors, designers can enable access to a large amount of information that would not be otherwise feasible to display.

Push cues are information that is provided without player input. Here designers must balance the needs of players. Information that players must be aware off constantly or that has important time constraints may best be pushed to players, while information that is less critical can be pulled. Oftentimes games combine cues that push coarse information and allow more fine-grained details to be pulled through interaction (e.g., seeing a player's character name over their avatar, mousing over it provides more detailed status). Pushed awareness cues are very common, and include passive displays such as HP bars, usernames, or the avatars themselves.

4.7.3.2 **Cue Context**

Refers to the time at which a cue is visible or available, and its duration. For many sufficiently complex games making all information available at all times would be overwhelming and provide little utility. Designers typically limit cue availability, allowing only certain cues to persist for the entire game, while other cues are made available based on particular events occurring. Cues that are ***global*** are available at all times; these cues tend to persist and can be accessed at all times. Global cues typically contain information that needs to be frequently accessed, or critical information that could be needed at any time (e.g., HP bars, team lists).

Situational cues provide information after certain events, because it is superfluous (and even distracting) until those events occur. Typically, situational cues are ephemeral and only persist while the information is relevant. For example, stun animations in *Dota 2* [G23] are situational as they are only shown when a teammate is in a stunned state (Figure 4.3.A).

4.7.3.3 **Cue Diegesis**

Describes how the awareness cue relates to the narrative game world [32]. If an awareness cue is perceivable by in-game characters (as if the embodiment were a living entity in the game world) it is ***diegetic***. If the cue is instead part of the interface or non-visible to the characters, then it is ***non-diegetic***. A common example of diegetic cues are speech audio uttered by an in-game character (e.g., in *L4D2* [G21], characters automatically announce to teammates when they find a stash of ammo: “Ammo Here!”). However, cues that are placed in the environment (i.e., attached to an in-game object; see *Cue Attachment* below) are not necessarily diegetic (e.g., a stun bar in *Dota 2* [G23] is placed over the head of an avatar but is not perceivable by characters). Using diegetic cues can increase the feel of realism in a game, but a cue must make sense within the theme and narrative of the game.

4.7.3.4 **Cue Interdependence**

Describes the relationships that individual cues can have. ***Solitary*** cues exist independently of other cues, providing a sole source of information. For example, HP bars provide information on their own. However, individual cues are often combined making them ***additive*** cues. Figure 4.5.D shows the "On Fire" border around the identity avatar of the player in *Overwatch*. This cue would not make much sense without the identity cue it surrounds.

Cues frequently provide important information and aid in the interpretation of another related cue. For example, Figure 4.5.B shows how a numeric representation of a player's HP enhances the already-present HP bar below it. Individual cues that provide redundant information are considered additive, since this dual representation of the information frequently changes the nature of the cue (for example, by making the awareness information more salient).

4.7.3.5 **Cue Attachment**

Refers to the placement of cues relative to the interface: they may either be connected to the ***HUD*** (so, relative to the screen) or embedded in the game world through ***environmental*** cues. Environmental cues can make critical information fast and easy to access (especially in time-sensitive situations; e.g., HP bars during a team fight). However, cue placement must be done carefully, while players can learn to recognize and understand a larger number of cues attached to in-game objects or characters, these can become distracting and can be overwhelming for novices [2, 53]. Designers often leverage the HUD as a means to offload some of this information. HUD cues are a part of the interface and are typically in a fixed location. Diegetic cues may appear in the HUD or the environment [32]. Diegetic HUDs will only appear when the player's embodiment in the game world would have the same experience (common in FPS games where embodiments can wear head-mounted displays).

4.8 - **Discussion**

Our framework provides a toolbox for game designers to tackle common awareness challenges in multiplayer games. In this section we discuss the implications of the design framework for several design tensions faced by game designers: fun vs. challenge, novices vs. experts, and streamers vs. their audiences. Further, we discuss these implications in relation to game designers and games researchers.

4.8.1 User Characteristics

Players and viewers (collectively users) bring different concerns for the game designer. We describe how these characteristics impact and are impacted by awareness cue design.

4.8.1.1 **Novices and Experts**

A hallmark of experts in a domain is "chunking," the ability to recognize underlying patterns in an apparently chaotic situation [6]. Complex awareness cues that are impenetrable to novices can be not only interpreted by experts, but interpreted quickly and efficiently. Novices, on the other hand, may be aware of the cue but not able to interpret its meaning; they may get little practice with situational cues that arise infrequently, and they may not realize that they can activate cues accessed through a pull accessor. Designers must consider how to train novices in the effective use of awareness cues and scaffold their transition to expertise.

4.8.1.2 **Viewers as Stakeholders**

Many players learn to play new games by watching videos and live streams [7, 50]. However, other viewers in the same audience may already be experts. In designing cues, designers must therefore consider how they can be interpreted by game viewers at varying levels of expertise as well as by players. Since viewers cannot control where the player is looking or what cues they choose to display, environmental and pull cues may introduce particular challenges for streaming gameplay. At the same time, cue designs that make for good viewing are not necessarily the ones that make for high-quality play.

4.8.1.3 **Game Literacy**

Games within a genre often share conventions for conveying information, such as HP bars. Understanding and reproducing these conventions is part of what it means to be literate in games [52]. However, these conventional/generic design patterns may or may not serve the designer's goal for a specific game. Our framework allows designers to analyze and characterize existing patterns of awareness cues, and to identify the most productive axes along which to diverge from a conventional approach.

4.8.1.4 **Cue Modality**

Our framework enumerates different representations of awareness cues, such as visual, auditory, and haptic. Game designers must choose not only in which modality to provide awareness cues, but also how many. Providing cues in all available channels can accommodate the broadest range of play styles, such as players who prefer to play with the sound off or who do not have haptic controllers. However, information provided across multiple modalities can generate unnecessary cognitive load, at the same time, and requiring players to customize the modality in which they access awareness cues could be overwhelming and frustrating unless it is carefully designed [41, 48].

4.8.1.5 **Tolerance for Uncertainty**

One function of awareness cues is to manage the level of uncertainty in the game by making certain information salient or showing the player that there is information they don't know [10, 59]. However, different people have different levels of tolerance for uncertainty [33]. A level of uncertainty that is satisfying for one player may be anxiety-provoking for another. Designers must consider whether their awareness cues are useful or frustrating for players.

4.8.1.6 **Player Goals and Motivation**

Research on player motivation shows that different players in the same game may have different goals and find different activities satisfying (e.g. [47, 71]). Players may also play for a range of social reasons, such as connecting to real-world or online friends, retaining an online streaming audience, or practicing for professional competition. Awareness cues that address some players' goals may interfere with or even demotivate others. However, unlike with game roles, it is difficult to identify a given player's motivation—particularly as players may play the same game for different reasons on different days. Finally, players' goals may sometimes be transgressive or anti-social [9].

These motivational differences should be taken into account when designing awareness cues.

4.8.2 Adapting the Play Experience

Awareness cues are a key consideration in how players approach the play experience, heavily influencing how difficult a game is. Players may deactivate or add awareness cues to their game clients to change the experience.

4.8.2.1 **Adjusting Difficulty**

Many games can be played at different levels of difficulty, whether manually adjusted by the player or automatically by the game [51]. Awareness cues are one method for performing difficulty adjustments. For example, many FPS games contain "hard-core" modes in which the amount of awareness information is decreased. Our framework allows designers to articulate the dimensions of the awareness cues that can be manipulated to adjust game difficulty, and to define and study which dimensions they expect to have the highest impact.

4.8.2.2 **Interface and Awareness Mods**

Players often customize their user interface experience in games using modifications, or mods [57]. For example, many World of Warcraft [G3] mods take diegetic game information and convert it to a non-diegetic form, while simultaneously taking environmental information and placing it in a HUD. These choices help players perform their in-game roles more effectively. Designers must therefore consider not only how their awareness cues are designed, but what data they are exposing for players to design their own cues with. Player-generated awareness cues are designed by players to serve player goals, and can therefore serve as implicit sources of data about what player needs are not being met by the designers' choices.

4.8.2.3 **Asymmetric Gameplay**

In asymmetric games, different players take on different game roles or capacities [11, 28]. For example, in many games players can serve as tank[7], DPS[8], or healer[9] [69]. A given piece of information may be much more valuable to the player of one role than another, such as which enemy is doing the most damage or which ally has the lowest health. Designing cues targeted at the responsibilities a given player faces can decrease the amount of clutter and increase the amount of relevant awareness information available. Since the amount of relevant information available to players impacts their chances of success [66] awareness cues must take game roles into account; different player roles may need the same awareness cues expressed differently, or need different cues entirely.

4.8.3 Implications for Game Designers

We demonstrate that our awareness framework ties to awareness-related problems that game designers already face, such as supporting new players and designing for uncertainty. Our framework allows designers to describe their existing problems more

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[7] A character with many hit points that protects other characters.

[8] A character with high damage per second focused on damaging enemies.

[9] A character that focuses on restoring the restoring of others.

effectively, and see how these problems relate to one another. This can help game designers identify design tradeoffs and how they might affect different stakeholders. Our framework can also help designers iterate and identify design directions that they might otherwise not consider. Using concepts from our framework, they can more carefully articulate the underlying rather than only the apparent differences between alternative implementations of awareness cues. Consideration of awareness cue design can be incorporated into existing ideation or production methods.

4.8.4 Implications for Researchers

Our work has implications for researchers who want to use games as settings in which to study team coordination or other issues related to awareness. First, our framework can help researchers select appropriate games to use as probes or in studies by providing a way to articulate the awareness cues featured in the game. Second, our work can also inform the design of experimental materials for the study of awareness in games or other CSCW software.

Because we propose a common language for describing awareness cues, we can now articulate differences and similarities between studies allowing us to more effectively survey and combine knowledge from different sources.

4.9 - **Conclusions and Future Work**

In this paper we have provided a framework for awareness cues in distributed multiplayer games. In order to effectively collaborate during gameplay, players need information about teammates' identity, location, activities, status, and more. The amount of team awareness information available to players influences the difficulty of coordination and, therefore, play. This means that design choices regarding what, when, and how awareness information is made available directly influence the way players experience the game.

We see this paper as setting out a research agenda for awareness cues in distributed multiplayer games, improving the relevance of our work to both designers and researchers.

First, existing team awareness cues build on common design patterns, both within a particular game genre and across different genres. From this basic language for awareness cues, we can begin to describe the existing set of design patterns for awareness cues that already exist. Game design patterns are useful to facilitate and analyze designs [3], and can also be used to identify negative space in a design space: places where patterns ought to exist but do not. Game design patterns can therefore improve existing distributed awareness cues as well as driving discovery of new patterns and designs.

We can use these patterns to analyze, improve, and push forward specific aspects of games. One clear axis is looking at different categories of games—either looking at specific genres such as MOBAs, or looking at games that share common features, such as turn-based play. Another direction is to compare different categories of players, for example understanding what awareness cues are associated with different player roles or how they are deployed differently for experts and novices. Finally, we can look at different types of information, such as how nominal versus continuous information is deployed.

Second, we can extend our framework beyond team awareness. When players make decisions, they need to understand their teammates, but, their decisions also incorporate information about themselves, their adversaries, the environment, nonplayer characters (NPCs) and the game system.

Finally, we expect to bring this work full circle, by applying these insights in other types of distributed workspaces. Specifically, we expect fast-response organizations, like disaster responders, to benefit from this work. Further, we expect other types of groupware (e.g., distributed document editing) can use our work to identify new awareness cues.

The present research contributes to our knowledge of how team members work together, and how teamwork can be supported. We expect our framework to be of value to game designers and researchers, and hope that, through this work, we discover new ways to support team coordination.

4.10 - **Acknowledgements**

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5 - Conclusion

Awareness widgets are essential parts of many games and are important in the design of video games. However, little previous research exists providing information about how game awareness widgets impact players during gameplay, how players use and perceive the widgets and how game designers can design these widgets. This thesis addresses this gap by identifying and focusing on three exploratory research questions:

1. How do awareness widgets impact players during gameplay?
2. What motivates the use of game awareness widgets and how are they received by players?
3. How can game awareness widgets be designed to support specific gameplay experiences?

Together these research questions act as a multipronged exploration of the problem space. Chapter 2 provides a new understanding of the impacts of game awareness widgets establishing the importance of research in this direction. The Chapter 3 aims to provide details on what motivates the use of game awareness widgets and how players perceive them. Finally, Chapter 4 furthers design knowledge by surveying existing designs to provide a common grounding for future designs and research into game awareness widgets. Studying these three research questions also provides a clear demonstration on how to uncover other important aspects, usage contexts and relevant issues that may arise.

Each chapter presented in this thesis addresses one of the broad research questions listed above and demonstrates the application of existing techniques to the problem space and provides contextual contributions in their respective areas. The results presented by the articles can be used by game designers and researchers alike to guide future implementations and experimentation of game awareness widgets. This work is a stepping stone for future explorations into game awareness widgets. As a result, the articles presented in this thesis have been well received by the larger HCI and Game User Research communities, and have already been used in other research (e.g., [8, 1, 2]).

5.1 - **Do Awareness Widgets Impact Players During Gameplay?**

The data presented by awareness widgets was found to have significant impacts on player behavior and performance in gameplay. This can be used to help explain the effects of awareness widgets on player experience. This means that the design of the interface and perception of data presented by that interface significantly impact not only the reception of the game (player experience), but how players play the game (behavior and performance). This carries important implications for researchers and designers alike since even subtle changes in GAW design can be used to influence play experience, inadvertently or otherwise.

5.2 - **What Motivates The Use Of Game Awareness Widgets And How Are They Received By Players?**

The results of the Chapter 3 demonstrate that it is important to understand that the motivation a player has for using a widget in the first place can help determine the design and future evolution of that tool. Observing how players use and appropriate tools for other purposes can help identify user needs and new design opportunities. Tools that players don't find useful will simply not be used. Therefore, it is not accurate for a game designer to think that if they build a tool, players will use it. This suggests that other parts of game play (such as the game's mechanics) will contribute to whether and how players might use GAWs.

5.3 - **How Can Game Awareness Widgets Be Designed to Support Specific Gameplay Experiences?**

Game awareness widgets have existed for many years and existing design patterns and knowledge should be used to inform the design of future widgets. In that spirit a survey of existing widgets in the context of implicit team awareness has resulted in a first design framework for game awareness widgets. This design framework outlines the available modalities and visualizations available to designers as they create new GAWs. Furthermore, the framework includes a list of important design considerations that need to be accounted for in the creation of GAWs.

5.4 - **Applications of the Findings**

The primary contributions of each chapter in this thesis can combined into a comprehensive starting point for the design and research of GAWs. The chapters provide a comprehensive picture of *what* it is GAWs do, *why* players use them and *how* they are designed. This work also provides designers with details on how they can target certain player experiences. For example, Chapter 2 shows that the game experience of players (the experience of tension) was more consistent across skill levels when data was misrepresented, opening up new avenues for game balancing to create a more fair and fun experience for players of all skill levels. The results also outline shortcomings and dangers of certain designs that should be investigated further in future research. For example, Chapter 3 suggests that pings have detailed semantics despite having low expressivity and that annotation tools have a low priority for players. Chapter 3 also demonstrates that the design of GAWs can and should be informed by player practices. The chapters also present and discuss a variety of directions and areas for future academic work. They lay the groundwork for further research into GAWs and their impact. The application of techniques, such as Interaction Analysis and Grounded Theory, strengthen the tools available to researchers to conduct this work. Further, research questions are also presented by the chapters, for example the specificity of the experiments must be addressed in order to refine the models proposed by them and ensure that they apply across games.

Together the three articles in this thesis represent an important contribution to the area of Human-Computer Interaction and game development. They provide valuable, novel insight into a new direction for continued research into game awareness widget design.

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7 - Curriculum Vitae

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Montreal International Gaming Summit (MIGS'18)
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2018 CHI Conference on Human Factors in Computing Systems (CHI '18)
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