Immersive Wayfinding Cues for 3D Video Games

by

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Abstract

This thesis reviews how in-level wayfinding cues in video games can be harnessed to create immersive and enjoyable game experiences. It conducts an extensive literature review of game level design, and examines how modern games guide players to their destination. Many modern games rely heavily on incongruous visual cues and intrusive user-interface elements to push players through game environments. However, as these visual stimuli would not naturally occur within a game setting, they may reduce a player's spatial presence, immersion, and game enjoyment.

To increase player immersion, games can rely more heavily on environmentally appropriate, in-level wayfinding cues. Though some modern games do use in-level cues to guide players, there is little documentation on existing immersive wayfinding techniques. This thesis aims to fill the knowledge gap of video game wayfinding by outlining the importance of in-level cues, highlighting pre-existing in-level cues, and proposing new cues.

The new wayfinding hypotheses have been formulated from theories from various disciplines, including: perceptual and environmental psychology, fine art, design, urban design, and architecture. These hypotheses were then interpreted into game wayfinding cues, and implemented in testable game scenarios. The game scenarios, tested by research participants, demonstrated a variety of successes and potential to enhance game wayfinding.

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Introduction

Many contemporary games contain complex 3D environments through which players must navigate to reach their destination. These environments host the majority of the time spent in game, where gameplay elements can be implemented and story points can unfold.

Level designers focus on developing these environments. They aim to produce levels that are both navigable and fun, arranging in-game objects, topography, enemies, and items to create experiences which entice the players to move forward. However, the developers must also ensure that the environments feel as though they are naturally occurring, and not constructed by a designer with obvious goals (Byrne, 2005, 62).

The process of navigating through environments is often referred to as "wayfinding". Wayfinding is the practice of searching for and arriving at a destination within an environment. Paul Arthur and Romedi Passini suggest that the process of wayfinding can be simply defined as "spatial problem solving" (Arthur and Passini, 1992, 25). They suggest that there are three main processes involved with spatial problem solving:

1. "Decision making" (deciding on a navigation strategy),
2. "Decision execution", and
3. "Information processing" (gathering and processing the information from the previous two steps).

In addition to these three steps, Arthur and Passini assert that wayfinders perform several other processes associated with navigation. These can include:

- Recalling past experiences with other environments,
- Assessing the current environment and its characteristics,
- Investigating spatial cues or wayfinding information, and
- Weighing the cost/benefits of any paths forward.

Each of these processes aids in deciphering the environment, leading to a clearer, safer, and more efficient path forward.

Rudy Darken and John Sibert suggest that wayfinding cues, or directional cues, can have a large positive impact on wayfinding within digital environments (Darken and Sibert, 1996, E-1). Though digital worlds often attempt to mimic reality, navigation within a digital environment can be especially difficult, as they often have a reduced "field of view" and less detailed representations of spaces (Witmer et al., 1996, 416). As these troubles of virtual navigation can exist within videogames, it is the designer's job to ensure that the player is able to effectively maneuver through their environments with the use of in-game cues, and user interface (UI) or heads-up display (HUD) elements.

Though the field of level design has been a profession for some years, the scholarly documentation of the trade strategies is fairly thin. Bernd Kreimeier states that there is "little formal understanding" of level design practices (Kreimeier, 2002, 1). This is notably accurate when examining level wayfinding strategies for video games. Few published texts focus on wayfinding and directional cues or how they can be crafted effectively in video games. Documentation of the effectiveness of various in-game wayfinding cues is more abundantly available in online blogs, developer commentary, and other informal sources. Kreimeier suggests that level designers use their previously acquired knowledge when crafting new environments, but there is not an appropriate structure for passing this knowledge along to other designers (Kreimeier, 2002, 2). Much of the documentation on effective game wayfinding cues comes from anecdotal accounts by experienced game designers. There are no consolidated texts which outline pre-existing successful wayfinding strategies.

This thesis will fill the knowledge gap on video game wayfinding strategies that exists in game design studies. First, it reviews the state of the field, outlining basic strategies for game level design, and discusses the importance of using in-level wayfinding cues. It then documents pre-existing in-level wayfinding cues that exist in 3D games. These cues fall under the following general categories: Light, Breadcrumbs and Landmarks, Physical Barriers and Choke Points, Colour, High Ground, and Motion and Sound.

This thesis then proposes new wayfinding cues that can be used within videogames. The new cues are derived from a variety of disciplines, including perceptual and environmental psychology, fine art, architecture, design, and urban design. Supporting evidence for each new strategy is presented and interpreted, establishing a theoretical base for each cue. These cues will then be tested within a laboratory setting. In a laboratory we can observe how wayfinders interact with the proposed cues and analyze the cues for effectiveness. The new cues fall under the following categories: Material Lines, Implied Lines, Shorelines, Complexity, Symmetry, Density, Mystery, Nature, Change Blindness, Figure-Ground Contrast, and Region Contrast.

The thesis's appendix includes supplementary information on the various discussed topics. It contains supporting images and information for both current wayfinding strategies, and the new proposed cues. It also expands heavily upon the process of designing testing environments, the test structure of the research trials, documents associated with the research participation, and other non-essential supportive information. The information in the main body will refer to appendix content with the appropriate figure number or appendix heading for easy locating.

Ultimately, this thesis communicates the importance of providing effective in-game wayfinding cues, and provides an extensive toolkit of new and pre-existing wayfinding cues for the creation of immersive game levels. Game environments that relay wayfinding information through immersive, environmentally appropriate in-game cues, can create more efficient and enjoyable game level experiences.

Chapter 1 – Level Design, Immersion, and Wayfinding

Basic Strategies of Level Design

Environment Structure and Limitations

Prior to establishing a system for game wayfinding, developers must structure their environments, creating both *primary paths* and *secondary paths*. A level's primary, main, or critical path is the direct route that can be taken to reach an environment' goals. The secondary paths are hallways, rooms or other areas that offer additional content to explore and enjoy without physically advancing down the main path. In some cases, the secondary paths may provide an alternate route for advancing through the level, feeding back into the primary path at vital locations.

Fiel and Scattergood suggest that it is important to create environments that appear as though the players can reach their goals through multiple different pathways. Players prefer when they have an active choice in navigational tasks and are not pushed down a predetermined route. "The art of level design is to make players think that they have infinite choices when they have only a few." (Fiel and Scattergood, 2005, 29). By providing players with various pathways to explore and navigate, often taking the form of secondary paths, the game world is suggesting that the players have a choice in their paths forward. However in most cases, these alternate paths will ultimately feed back into the primary path at important story or game points.

When developers create paths that do not lead to the goal, with the intent of creating the illusion of size and choice, Fiel and Scattergood state that they must ensure that these pathways properly reward the player's exploration (Fiel and Scattergood, 2005, 46). The rewards that the player receives for following secondary paths can take the form of items, information, interesting environments and interactions, or other features. This will encourage exploration of the environments, expanding play time and the player's willingness to search the game's environments. If the developers aim to have a highly explicit wayfinding method for their game, it is important that the players are able to differentiate between the primary and secondary paths of the game. This will allow players to explore freely, while maintaining confidence in wayfinding towards the ultimate goal.

Players given the option of extraneous exploration can have varying responses to secondary paths. Shbeeb and Skinner suggest that certain players, particularly those who fall under the Bartle-type "Explorer", who are aware of the critical path, will often avoid it. They will prioritize traveling down all possible secondary pathways before advancing. These "wrong" choices are intentional, as they allow the player to conduct a more comprehensive search of their surroundings prior to advancing the story (Shbeeb and Skinner, 2012, 3). This behaviour is likely associated with an awareness that certain games will physically block players from returning to previous game sections. Players who push themselves down the main path too quickly risk missing features that are nested off the primary path.

It is not uncommon for games to both acknowledge and encourage exploratory behaviour within secondary areas, rewarding players who explore the game's environments in depth. Author James Newman cites modern *Super Mario* titles as games which provide players with rewards for exploring beyond a level's apparent boundaries (Newman, 2013, 116). Many other games feature collectible items or rewards for straying from the main path, or for traversing dangerous, yet not vital terrain. See *Halo 3*'s skull system for an example of this. Supplementing the main game experience with rewarding exploration may increase both game enjoyment and game length.

However, environments cannot be endlessly expansive, so the level's use of space must be restricted, while simultaneously portraying a real world. Designers use a variety of techniques to create the illusion that the environment is extensive, while the space is actually quite confined. This allows environments to operate within the technical limitations inherent to optimized games. Indoor environments manufacture the illusion of size by featuring doors or gateways which falsely appear to be operable. Outdoor scenarios use rivers, mountains, and other physical features to prevent the player from travelling too far in a certain direction. While it is possible for all of a game's doors, landscapes and geography to be accessible, environments are artificially restricted for several reasons: secondary areas can weaken the critical path, cause 'render bloat', and confuse the player (Byrne, 2005, 291). As game levels should "flow" and lead the player to their destinations (Bates, 2004, 110), excessive secondary paths that have not been populated with navigational information will ensure the player's confusion, and prevent a flow towards the level's destination.

To aid in proper navigation, Beram suggests that the primary path and secondary paths should be visually distinguishable. The primary path should be far more visually complex and detailed than the secondary pathway, clearly marking the most efficient route through the environment. As the secondary paths are not required to complete the level, they should not be "too flashy" (Beram, 2001). As will be discussed below, this lower attention to detail in the secondary area may be reflected in the player's decreased attention towards that area. This could have a positive impact on the player's wayfinding within that environment. Time spent by the developer on these additional areas, which a large percentage of players may not see, may be better spent developing the core of the game. By reducing the complexity of the secondary paths, developers are reducing their labour output on extraneous areas, and visually communicating an area's importance. However, inconsistency in environment detail may lead to visual incongruity and obvious indications of the developer's intent.

Naturally-Occurring Cues

As discussed above, the illusion of size is often used in place of additional secondary areas. The developer can provide the appearance of supplementary content, lending the environment greater realism, without its actual implementation. A common example of this includes lining hallways with fake doors (Byrne, 2005, 291). Byrne suggests that implementing doors which are either high or low in resolution is the best way to communicate a door's functionality. Doors with higher detail represent accessibility. Doors with lower detail represent inaccessibility. Alternatively, an image of a door handle could be used on the fake door, with the real door featuring a modeled 3D handle (Byrne, 2005, 293).

Though the illusion of space can effectively portray an exaggerated scale, illusion created through inconsistent or unconvincing strategies will fail to maintain game immersion. *Immersion*, discussed in greater detail below, is the positive experience of being totally engrossed in a medium. The player may cease to succumb to the illusion of a game, losing immersion, once they understand that these doors merely exist for aesthetic purposes. Breda asserts that it is not necessarily the player's inability to open certain doors that breaks immersion, it is the knowledge that nothing lies behind these doors (Breda, 2008).

Though the inaccessibility of doorways or paths should be clearly communicated to the player, there are likely better tactics for doing so than altering its resolution or detail. To maintain some sense of realism, developers should visually communicate that an area is inaccessible due to the physical state of the entrance. Inaccessible doors should be barricaded, broken, blocked, locked, etc. Path restrictions should be visually communicated by some feature that would naturally restrict movement, be a naturally-occurring feature, and be immediately understandable. I would define naturally-occurring visual cues as: physical features of a game environment that are visually and contextually consistent with the surrounding area. A naturally-occurring visual cue could be a pile of rubble within a dishevelled building, or a row of well-maintained hedges in an ornate garden. Doors with altered resolution are not naturally-occurring cues, and could break immersion by reminding the player of the artificiality of the game world.

If the player is able to readily identify which doors are accessible through naturally-occurring visual cues, this can aid in both game immersion and wayfinding. This aligns with Bates' suggestion that games must provide feedback to the player's inputs (Bates, 2004, 18). Areas which should be accessible to the player, but are not, should have visual, physical, audio, or tactile feedback to justify their inaccessibility; for example, if a door is inaccessible, it should represent this physically with a broken handle, or an appearance which reflects its inaccessible state.

Richard Rouse states that the failure to visually or auditorily communicate a door's accessibility is poor game design. The player should not have to continually engage in experimentation to determine which areas of the game are accessible (Rouse, 2004, chapter 23). Once a visual cue has been established as a physical barrier to the player, it should be used again whenever applicable; for example, if the player learns that a barred door cannot be opened, all future barred doors should be inaccessible, unless otherwise established. This aids in building the game's *visual language*. This idea will be discussed further below. If it is not possible to communicate accessibility through an obvious visual state, because of environment aesthetics, then alternative forms of feedback should be used. Auditory cues of a lock mechanism could be played when the player attempts to interact with the door. This would provide justification as to why the door is inaccessible. However, this sound should be accompanied by a distinct visual trait on this door, such as a red blinking light on the door console, or a padlock. This will enable players to associate that distinct visual feature with inaccessibility, allowing them to make much quicker wayfinding decisions through visual cues.

Bioware's *Dragon Age: Inquisition* displays an effective uses of movement restricting naturally-occurring cues. The game features various natural entities to corral the player and prevent them from venturing beyond the bounds of the environments. In addition to structures like walls that physically block movement, and slopes that are too steep to climb (which slow the player to a trudge as the grade becomes too great), Bioware uses both bodies of water and winds to contain player movement. When nearing the edge of the map in an environment such as the Hissing Wastes, the player is greeted by a gusting sandstorm. As the sandstorm becomes too severe, the player's avatar slows their pace and shields their eyes. The player's companions cease to follow player into the storm, and verbally suggest turning around. Continuing to trudge on, the player will eventually be presented with the world map, signaling that this is the edge of the territory, and venturing farther would exit the current area. This system provides both visual and auditory feedback to the player's attempts to move past the game's boundaries, communicated through a naturally-occurring, environmentally appropriate phenomenon.

Bodies of water, fresh or salt, are also used as physical barriers in *Dragon Age: Inquisition*. As the character enters into the water above their head, a gasp or yelp can be heard. The screen quickly cuts to black, and returns as the player's avatar is picking themselves up off the shore. Though swimming is likely in the protagonist's list of skills, the character's heavy armour and weaponry make drowning in water a very believable scenario. Again, this is an organically occurring physical barrier that provides feedback when the player interacts with it. Once the players have discovered that certain cues indicate accessibility, or inaccessibility, these cues should be used consistently in this manner throughout the game to outline the boundaries of the game map.

Bioware's environmental features are a natural substitute to excessive *invisible walls*. Invisible walls are restrictive barriers that are not visually supported by any structure or entity. Nearly all games will feature invisible walls at the edge of maps to prevent the player from travelling beyond the physical scope of the level. In these scenarios, it is the developer's responsibility to stop the player, with environment features, from ever reaching this wall. Encountering invisible walls in a game can be a very jarring experience, as the player's movement is stifled, but no physical barriers are present. Though invisible walls do exist in *Dragon Age: Inquisition*, Bioware implements clever uses of natural features that help to organically communicate that the player should not/cannot go any farther in a direction. With these environment features, the game is providing clear wayfinding information, while preventing the use of invisible walls.

Visual Language

Games that consistently maintain visual communication with the player, using environment features to inform wayfinding decisions, are establishing the game's "visual language" (Rogers, 2010, 236). After a player learns that they are unable to swim through deep waters, or ascend a certain grade of hill, the game has established visual communication of its environment's boundaries, making navigation much more efficient. However, the designer must ensure that the visual cues for accessibility and inaccessibility are consistent throughout the game. When an item or geographical feature is used to communicate an area's accessibility, the feature's properties should be maintained when it is used in the future. The features in the environment, and the player's experiences with these features, are priming the player's wayfinding expectations. If the game is inconsistent in its visual cues for accessibility, it may interrupt the player's immersion.

Consistency in visual language is notably important for communicating the accessibility of traversable terrain. If the player is able to ascend a certain grade of hill at one point in the game, all other hills of the same or lesser grade should also be accessible. If hills of the same grade vary in their accessibility, the player will be reminded of the artificial restrictions imposed by the game developer (Newman, 2013, 119; Fiel and Scattergood, 2005, 46). Perhaps more importantly, inconsistency in the environment's visual language could also lead to a confusing and frustrating wayfinding experience.

When the player's schemas of the environment and its features are challenged by game's systems, the game's limitations intrude on the player's immersion. This "intrusion of the simulation" (Newman, 2013, 119) means the game is unable to uphold the illusion of a believable game world. Breda states that game features such as invisible walls can also be challenges to immersion (Breda, 2008). If a game's visual language is inconsistent, these inconsistencies should be supported by the game's story; for example, if the developer lets the player cross a body of water that previously blocked progress, this should be supported by evidence from the game. The character could receive a swimming upgrade, access to a boat, or the terrain could be physically altered to represent its new accessibility.

Creating a visual language that the player can understand is important for multiple reasons: it maintains a consistent aesthetic, it visually communicates the functionality of the game's environment, and it enhances the player's ability to wayfind. A consistent visual language will enable the player to readily and consistently identify the accessible pathways within the game. If the developer introduces physical features or objects that are inconsistent with the game's visual language, the player will likely never be certain of which way they can or cannot go. Experiencing inconsistencies in the environment's affordances and visual cues may reduce the player's immersion and enjoyment of the game.

Immersion

The goal of this thesis is to document existing strategies for wayfinding cues in video games, their benefits, and to suggest new innovative strategies. Use of in-level wayfinding cues can increase the players' enjoyment of a game. Specifically, by increasing the use of visually-consistent, environmentally-appropriate visual cues, and by decreasing reliance on thematically inconsistent visual cues and wayfinding features, player's immersion can be enhanced.

Janet Murray describes *immersion* as:

> …a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus… (McMahan, 2007, 68)

The key feature of this definition is the total absorption of our attention and perception. Those who are immersed are totally engaged, with their attention focussed within the immersed medium. The experience of immersion is commonly associated with entertainment media, such as games, movies, or books. It can be felt through a variety of vastly different experiences.

Stephen Bitgood defines immersion as "…the illusion of 'feeling in a specific time and place.'" (Bitgood, 2013, 59) This suggests that one of the vital components of feeling immersion is experiencing *presence*, that is, a connection with a space and time that you are not physically occupying. The medium in which the participant becomes immersed presents the participant with an artificial world in which they can lose themselves. This artificial world could be established through the pages of a book, portrayed in a movie, or fully realized in a video game.

Very few forms of media create more convincing and well-realized worlds than video games. Video games feature affordances that no other media can match: characters that can be directly controlled by the player, and worlds that can be explored, manipulated and affected through the player's actions. Video games must exploit these advantages and separate themselves from other media and their limitations. Specifically in the context of video games, Bob Bates describes immersion as "…what happens when you make the moment–to-moment experience so compelling that the player is drawn completely into the game and the real world disappears." (Bates, 2004, 21) Similarly, Skalski and Tamborini suggest that game worlds can create the sense of immersion by removing the player from their current real-world location, and placing them inside of convincing digital worlds (Skalski and Tamborini, 2006, 229). Immersion is such an important game feature that Bates suggests that a game's success is partially reliant on its immersive potential (Bates, 2004, 22). As such, whenever possible, game developers should actively strive to make games a more immersive experience.

Importance of Immersion

Though creating an absorbing experience may be reason enough to pursue a game's immersive potential, immersion may also increase a player's enjoyment of the game. Wirth et al. suggest that the experience of spatial presence, one of the primary components of immersion, is associated with an increased enjoyment of video games and other media (Wirth et al., 5). Skalski and Tamborini echo this, suggesting that there is a strong connection between presence and enjoyment of a medium (Skalski and Tamborini, 2006, 235). Kremers asserts that keeping the player immersed will keep them happy, and willing to continue playing. The immersion of players is one of the primary goals of level design (Kremers, 2009, 147).

The experience of presence and immersion may be enjoyable in itself. However, Klimmt and Vorderer suggest that immersion is enjoyable because it enables escapism. Those who want to escape the trials of daily life may experience a greater sense of escape if they can immerse themselves in another world (Klimmt and Vorderer, 2003, 355). Additionally, while in a state of immersion, the player will also become more susceptible to information communicated by the game, and have an enhanced learning experience (Kremers, 2009, 415-417). This may aid the player in understanding the game's systems.

Presence

The factor of immersion that is most relevant to this thesis is *presence*. Skalsi and Tamborini define presence as the perception of "nonmediation." Participants place themselves within the medium without actively paying attention to the enabling structures of the medium, inhabiting the space that is being portrayed (Skalski and Tamborini, 2006, 226-227). By inhabiting this space, the participant also experiences a shift in cognitive functioning to more appropriately fit the artificial environment (Wirth et al., 8). We become so absorbed in the medium that our thought processes change to fit the digital scenario in which we find ourselves. Ultimately, the player is able to experience a "sense of being there" in a virtual environment, with the technologies required to experience the medium (the gaming system, controller, screen, etc.) fading from the player's attention (Breda, 2008; Wirth et al., 4).

Although technology enables and produces presence, its involvement in the experience must not be obvious to the player. In addition to the physical technologies required for playing the game, other in-game features may stifle the experience of presence. Incongruous visual cues, inconsistent visual language, or heavy use of user interface wayfinding elements add another layer of obstacles to the realism of the game world.

To reduce the strain on our suspension of disbelief, developers should use naturally-occurring wayfinding cues to guide players to their destinations. Instead of guiding players with incongruous cues, such as arrows that are floating in space, developers can harness lighting, landmarks, motion, or high ground, to steadily pull the player through the environment. These naturally-occurring visual cues may be vital for presence: psychologist Jamie Madigan states that the experience of presence relies partly on the perception of media spaces as “real” (Madigan, 2010). Games should support environmental realism whenever possible. By using environmentally appropriate wayfinding cues, a game’s realism is improved, and barriers to experiencing presence are removed.

Suspension of Disbelief

In addition to presence, our suspension of disbelief can aid in creating an immersive game experience (Breda, 2008). Suspension of disbelief is important to all forms of entertainment, allowing users to look past a medium’s inconsistencies and barriers to immersion. Examples include: accepting the impossible stunts in a movie, supernatural elements in a book, or visual bugs in a video game. Wirth et al. suggest that actions as simple as feeling a book’s pages while reading, or seeing the method of interaction with a medium (mouse and keyboard, controller, screen, etc.), can distract the user from the experience (Wirth et al., 31). However, as participants in a medium, we choose to overlook certain features of the experience, disengaging our critical eye to better interact with the experience and increase our enjoyment (Breda, 2008). We cease our “deconstruction” of the experience, and immerse ourselves in its content (Glicksohn and Berkovich-Ohana, 2012, 104).

Klimmt and Vorderer suggest that when viewing media, we can take one of two levels of involvement: high involvement or low involvement (Klimmt and Vorderer, 2003, 347). These levels of involvement can directly impact our suspension of disbelief. High involvement in a medium is “…a fascinated, emotionally and cognitively engaged way of enjoying the presentation…” (Klimmt and Vorderer, 2003, 347). High involvement players would be more likely to suspend their disbelief, and disengage their critical analysis of the medium. This permits a greater acceptance of structures and technologies that modify our gaming experiences, such as user interfaces, heads-up displays, or the technology we need to interact with games. Those with low involvement have “…a distant, analytical way of witnessing the events presented by the medium…” (Klimmt and Vorderer, 2003, 347). They will be unable to overlook the flaws within the medium, and unwilling to overcome the barriers to immersion.

Flow

Flow is another aspect of immersion. As defined by Mihaly Csikszentmihalyi, flow is “the state in which ‘individuals are so involved in an activity that nothing else seems to matter’ ” (Breda, 2008). While in a flow state, the participant is totally involved in the current task (Bitgood, 2013, 60; Breda, 2008). Unlike presence, flow is established through the participant’s experience with the medium, not with the realism of the medium’s world. The experience of flow is reliant on several factors: a clear set of goals, immediate feedback, and a challenge/skill balance (Csikszentmihalyi, 1997, 29-31). One final requirement for flow, as suggested by Barry P. Smith, is that those in flow must be participating in the activity for its own sake. Experience of flow must occur through “autotelic” activities (Smith, 2012, 104).

Various games and sports are effective channels for entering flow, as they contain rules and goals, both of which are well defined, and enable the player to act without contemplation (Csikszentmihalyi, 1997, 29). Those experiencing flow are aware that they are making progress, and of how well they are doing. Activities that enable flow confirm to the participants that they are advancing as a direct result of their efforts (Csikszentmihalyi, 1997, 30).

With the above criteria in mind, we see that video games are great enablers of flow. They feature extensive, well defined rules, governed by the affordances and restrictions of gameplay. The goals of the game are often well defined, established and continually reinforced through the story, and permanently accessible in the quest log. They constantly supply the player with information on their progress, providing a persistent stream of data on character statuses, quest progression, location, etc. Games excel at providing immediate feedback for the player's actions: we can actively see our target's health total dropping, or our settlement's net income soar. Most gamers would identify their game time as autotelic. And finally, most games aim to create an appropriate skill/challenge balance.

One of the more important aspects of flow is the delicate balance between the participant's skill and the challenge of the task. Tasks that are too difficult or too easy relative to the participant's skill may cause him or her to fall out of flow (Csikszentmihalyi, 1997, 30; Westcott-Baker and Weber, 2012, 129). Game difficulty is usually established through the encounter design, platforming difficulty, enemy difficulty, resource scarcity etc. Many games actually let the player adjust the difficulty of the game at any point during play (Smith, 2012, 106). This allows the players to reduce, or increase the difficulty of a challenge to better fit their skills. As the potential of flow is mostly reliant on the creation of a skill/challenge balance, and not the maintenance of a consistent environment, this thesis will not focus on flow creation. Extensive documentation of flow and how it corresponds to games can be found in titles such as *Video Game Play and Consciousness* by Westcott-Baker and Weber.

Realism and Mental Models

In addition to flow and presence, realism of an experience is associated with immersion in an artificial medium (Bitgood, 2013, 277-279). This realism is divided into two forms: social and perceptual. Social realism is the degree to which social interactions in a game mirror the real world (McMahan, 2007, 75). Perceptual realism measures how realistic an environment looks when compared to the real world (McMahan, 2007, 75).

When playing games that are realistic in appearance and art style, we apply our understanding of real world features to their digital counterparts. When games' scenes or objects are consistent with our expectations for that environment, our potential for spatial presence is increased (Skalski and Tamborini, 2006, 229; McMahan, 2007, 68-69). By using visual wayfinding cues that would naturally appear in a setting, game developers can harness a player's expectations for an environment to help immerse them in a setting; for example, if the developer uses a light source to draw the player's attention in a forested area, a raging campfire would be consistent with our expectations for that scene. Using a disembodied light source, not supported by any physical structures, would be inconsistent with our expectations. Visual features that are not thematically consistent with the game environment can strain our suspension of disbelief, and ruin immersion (Ryan, 1999, 2).

Depictions of realistic game worlds also require the presentation of a seamless game experience. Ryan suggests that graphical issues such as screen tearing, texture pop-in, and dipping frame-rates are all events that could ruin a player's immersion (Ryan, 1999, 2). These are events that do not occur in the real world, so their appearance in a game world can undermine its realism.

Immersion, in part, is established through rich and detailed mental models of game environments. Madigan suggests that prior to experiencing presence, the players must develop a mental model of the environment. Once this representation has been created, the player then subconsciously decides, based on the contents of the model, if the environment is real enough to experience physical presence (Madigan, 2010). Mentally representing oneself within a digital scene is an important factor in experiencing presence (Lee and Jounghyun Kim, 2008, 491).

Consistency

Upholding visual consistency is the primary reason for using naturally-occurring, environmentally-appropriate wayfinding cues. Maintaining a consistent world appearance throughout a game's environments, heads-up displays, and visual design will avoid reminding the player that they are in fact playing a game (Madigan, 2010; Newman, 2013, 119; Ryan, 1999, 2). Ideally, the game should continually reinforce the realism of its world by presenting environmental features that are thematically consistent, while limiting any inconsistent stimuli.

There are several major considerations when attempting to portray a consistent game world:

> Turning to game traits related to consistency, we have:
> - Lack of incongruous visual cues in the game world
> - Consistent behavior from things in the game world
> - An unbroken presentation of the game world
> - Interactivity with items in the game world
>
> Lack of incongruous visual cues in the game world is one of the more interesting precursors to spatial presence… Examples might include heads-up displays, tutorial messages, damage numbers appearing over enemies' heads, achievement notifications, friends list notifications, and the like. (Madigan, 2010)

Madigan suggests that features that do not naturally occur in the game world, but are presented to the player through a user interface, can prevent the experience of presence. User interfaces are often inconsistent with the visual design of the game world, as they prioritize effective communication of vital information over seamless integration into the game's world. This information can be integral to the game experience, so visual incongruity of the UI is often justifiable. However, we can reduce the scope of the UI, and its impact on immersion, by relocating some, or all, of its wayfinding information to the game environment. This relocated wayfinding information should be visually consistent with the game world.

The visual and audio cues that a game features as its primary method for wayfinding should be consistent with the visual style and setting of its levels. It is not uncommon for games to use incongruous visual cues as a method for pulling the player's attention and showing them their destination. Some common examples include: glowing doors, floating arrows, and disembodied blinking lights. These inconsistent visual cues could be substituted or diminished through the use of effective and visually congruous in-level wayfinding cues. For example, a blinking light that signals the entrance to the dungeon does not fit the visual language of a standard medieval setting, but a brightly burning torch might. However, in a science fiction world, a blinking light would be far more visually appropriate than a torch bolted to the wall.

Objects or effects that are visually inconsistent with the game world will grab the player's attention, at the expense of the player's immersion. Game level features need to conform to the logic established by the game:

> An important aspect of suspension of disbelief is indeed believability. Sometimes it is forgotten that suspension of disbelief does not mean that a level can incorporate any idea or arbitrary restriction that the level designer wants to use. This is not because those ideas are too wild or too fantastical, but because they need to conform to the game's internal logic, or game logic. (Kremers, 2009, 151)

If a game features wayfinding cues that would not realistically exist in a setting, these cues should be supported through the game lore; for example, the great witch of the west scattered these glowing lights across this medieval world to attract new travellers to her hut. Any visual stimulus used within the game, no matter how fantastic it is, would be more supportive of immersion if it is grounded within the game's world. Justifying these wayfinding cues will better situate them as realistic game world objects, and not just existing because of the developer's needs. As stated by Madigan, "Abstractions and contrivances… are the enemy of immersion."(Madigan, 2010).

Below, this thesis will discuss various in-level visual cues that have been documented as effective, and outline new, innovative hypotheses on in-game wayfinding cues. These cues may be used in a variety of game settings to guide the player to their destination, maintaining a consistent visual style within the game world, and increasing the game's immersive potential. Immersive levels will continually expose the players to visual stimuli that are consistent with the game's visual style, while attempting to circumvent incongruous cues (Bates, 2004, 22). Once a game has established a theme or visual style within a level, it can immerse the player through consistency of aesthetic features (Fiel and Scattergood, 2005, 66; Bates, 2004, 110-111). Aligning wayfinding cues with an environment's visual style, colour palette, or theme, will ensure a consistent level aesthetic.

The environmentally-appropriate visual cues discussed below, if deployed creatively, will give environment designers additional tools for guiding the player through their levels. These cues can be used in place of thematically inconsistent visual cues, or UI-based wayfinding systems, to guide the player to their destination. This will enable the production of an effective and immersive environment-based wayfinding system.

Shocks

Objects, events, or features that stifle the player's immersion, also known as "shocks", can appear in any game. Shocks are "…poor design elements that jar the user out of the sense of 'reality'…" (McMahan, 2007, 76). These could include: dips in framerate, screen tearing, unfinished game assets, inappropriate wayfinding cues, etc. Shocks align well with Madigan's outline of incongruous cues, which stretch to include common game features like user interfaces and heads-up displays (Madigan, 2010). Any features used to introduce the player to the game's systems may also be seen as a shock:

> …if a player is told by a character to hit control-T on his keyboard to teleport, then it would remind him that he's typing at a computer and not in some fantasy realm. Generally, to maintain the players' sense of escapism all content should be appropriate to what would be seen, said or done in the game setting. (Ryan, 1999, 2)

Though well-meaning, tutorial prompts, user-interfaces and heads-up displays, can intrude on the player's sense of escapism. These overlays and hints would not naturally occur in the game's setting. Scott Rogers and Luca Breda have both suggested that games that feature no heads-up displays created a very cinematic experience, as it removes layers that separate the player from the game world (Rogers, 2010, 8.8; Breda, 2008).

Using the visual cues discussed below, we can reduce the UI wayfinding feature's intrusion on the game experience. However, some game systems may be too difficult to effectively communicate through in-environment cues. Games often feature many complex systems, and vast amounts of information that must be clearly and efficiently communicated to the player. Ammo count, inventory, crew status, health bars, etc. may all be too complicated and too imperative to relay through the game world.

Other systems which may intrude on the realism of the world, such as the loading screens, start/pause menus, etc., are often a necessity. These features cannot be removed without compromising a game's playability; for example, pause menus allow the player to pause and resume a game at will, breaking the consistent presentation of the game world. However, this allows the player to temporarily halt the game without penalty. Non-interactive cut scenes will temporarily inhibit the direct control of characters, creating an inconsistency in the feedback to the player's inputs. But these sequences allow the developers to create scenes that are not possible through basic gameplay. Though each of these features may remind the player that "this is a game", they are integral tools for modern games. As such, it may be undesirable to create a game that is entirely free of shocks.

Absorption Trait

The developer can create the most immersive, engaging game experience possible, avoiding shocks, and visual inconsistencies, but the player is ultimately responsible for experiencing immersion. "Involvement" in a medium is the desire to become absorbed in the illusion of the world, and this desire can vary from player to player (Madigan, 2010). Their involvement will determine how consistent the game world must be for immersion to occur. This involvement may be an inherent "absorption trait", or it could be acquired through repeated exposure to the game world. (Madigan, 2010). Despite the developer's efforts, not all players will become immersed in their environments.

Fun over Immersion

Though the creation of realistic environments can enhance the player's immersion and enjoyment of a game, video games are not always interpretations of reality. Moore suggests that games, as abstract interpretations of reality, should be free to gloss over the minutia and tedium of real life, focussing on fun (Moore, 2011, 31). Immersion, enabled through in-level wayfinding cues, may absolutely be an effective method for creating a great gaming experience. However, if stripping a game of certain visual stimuli or wayfinding systems makes it more visually consistent, but less enjoyable, then the priority of immersion should re-evaluated. As games are a unique entertainment medium, they should be free to reduce their portrayal of realism in favour of a more fun experience (Moore, 2011, 32).

UI Wayfinding

Developers may decide that immersive wayfinding is not a vital game feature. In large open-world games, it may be unreasonable to guide the player through massive environments with total reliance on in-level visual cues. Providing sufficient, clear wayfinding cues within a large map would be a difficult task. In open-worlds, players often approach game tasks from multiple directions, so strategically placed in-level directional cues may never be seen by the player. Additionally, many open-world games may require the player to pass through the same physical spaces at several points in the story. Visual cues used to guide the player to a particular destination will no longer be helpful once the tasks are completed, resulting in an abundance of obsolete cues (unless removed from the game). Though UI-based wayfinding systems may reduce immersion, this may be outweighed by their wayfinding importance.

When open-world games feature smaller regions, tighter areas, or when a game is built in a sequence of smaller environments, in-level visual cues can be used to reduce the reliance on UI elements as the primary wayfinding method. By allocating the wayfinding cues throughout environments, games can provide the player with ample navigational information, reduce the presence of UIs and HUDs, and add an additional layer of player participation to the game.

Newman suggests that UI wayfinding mechanisms, like maps or compasses, can be used to reduce the cognitive load dedicated to wayfinding (Newman, 2013, 115). This allows the player to focus their attention on other gameplay tasks, such as combat or puzzle solving. However, Madigan states that requiring active player navigation may actually increase their immersive experience. When the player's focus is totally dedicated to navigation, they will be less likely to notice shocks to immersion within the level. Creating cognitively demanding environments is one of the keys to creating an immersive experience (Madigan, 2010). Additionally, demanding mental resources within an activity is one of the components to experiencing flow (Csikszentmihalyi, 1997, 31).

By increasing the frequency and density of wayfinding information in the environment, games can redirect the player's attention towards the game world, and away from the UI. This requires the player to engage with the environment, producing a more immersive and enjoyable gaming experience. However, for a player to navigate with minimal UI aid, environments must be well constructed and provide effective wayfinding cues.

Modern UI Wayfinding Strategies

User interface and heads-up display wayfinding systems can vary greatly in their persistence and pervasiveness. Over the last several years, different games have exemplified how user interfaces can be harnessed to guide the player to their destination. Outside of the classic persistent mini-map featured in many games, there are several systems that are frequently seen in modern games. Three of the most prominent methods include: floating points, manually engaged dynamic directions, and persistent dynamic directions.

The floating points wayfinding system uses persistent floating markers to indicate the direction of the player's goal. These points hover on the player's screen, not confined to the HUD area, in the direction of the objective. The markers do not account for obstacles between the player and their goal, but may display the direct distance to the objective. With this information, the player knows the direction of the goal, and how far in that direction it is located. However, the player is still responsible for navigating towards the goal. If there is more than one current goal, multiple points may appear on screen. Recent games that use this method include: Dishonored (see Figure A-1 below), Deus Ex: Human Revolution (see Figure A-2), and Dead Rising 3.

The manually engaged dynamic directions system is a non-persistent cue that must be engaged by the player. Upon the player's request, the game will generate a dynamic in-level or UI cue that will point towards the goal. In *Mass Effect 2/3,* activating the navigation aid will spawn a small minimap and dynamic arrow that will point towards invisible checkpoints in the level (see Figure A-3 below). In the *Dead Space* series (see Figure A-4) and *Bioshock Infinite* (see Figure A-5), navigational aid is spawned in the environment as an arrow or line, travelling from the character's feet towards their current goal. These guides have pathfinding, and will go up stairs, bend around corners, etc. With included pathfinding, these cues can totally remove player's involvement in wayfinding.

The persistent dynamic direction system communicates wayfinding information through an ever-present dynamic visual cue. The cue will constantly update to show the most efficient path to the goal. This visual cue may be placed within the player's HUD, or located in the game world. In the games *Dead Rising 1/2* (see Figure A-6), and *Bioshock 1/2*, the UI contains an arrow that is fixed at the top of the screen. It consistently points towards in-game checkpoints that lead the players to their goal. Another version of this persistent, dynamic system is present in *Fable 2/3* (see Figure A-7). The game dynamically generates a glowing breadcrumb trail, with pathfinding, showing the player exactly which direction to travel.

Each of these systems offer the player a different amount of information, and consume a varying amount of screen space. This is not an extensive account of UI wayfinding cues, but these systems, in addition to persistent mini-maps, are frequently seen in modern games. As discussed above, wayfinding systems which remove the player from active navigation may reduce the player's immersion and enjoyment. By featuring less-intrusive UI wayfinding systems, such as a manually engaged dynamic direction system without pathfinding, we give the player the option to wayfind through environmental cues, with additional help available when necessary.

Wayfinder Attention and Priorities

Prior to examining pre-existing and new in-level wayfinding cues, this thesis will outline concepts from other disciplines that may have a positive impact on game level design. Fields such as environmental and perceptual psychology, fine art, architecture, design, and urban planning, all have theories on wayfinding and attention that will lead to the creation of more effective levels and wayfinding cues. These theories will provide a deeper understanding of wayfinder attention and priorities when traversing environments.

When visually exploring a scene for information, all of the stimuli within the environment are competing for our attention (Bitgood, 2013, 36). Each object has the potential to pull focus away from the scene's intended focal point. To create effective and pulling wayfinding cues, and to ensure that important stimuli are the focus of the scene, several strategies can increase an object's attention-grabbing potential. Objects of importance should trigger the explorer's *orienting response*, have *landmark qualities*, or be of high *perceived value*.

Discussed in greater detail below, humans' "orienting reflex" or "orienting response" is a natural response to unanticipated environmental stimuli. Often manifested as unexpected movements or noises, these powerful stimuli cause the explorer to drop their current search, and immediately turn to face the stimulus's origin (Bitgood, 2013, 67; Bitgood, 2010, 8). Examples of orienting response-inducing stimuli within a museum include: "…a loud noise, a sudden movement, or a flash of light…" (Bitgood, 2010, 5). If harnessed effectively, this reaction could be harnessed within a game scenario to grab and focus the player's attention on important environment features.

When using a sudden, unexpected stimulus to grab the player's attention is not environmentally appropriate, games can use objects that are high in salience to grab the explorer's attention. High salience is associated with an object's contrast to its surroundings. This could be a contrast in size, colour, shape, isolation from other objects, feature movement or some other form of "multi-sensory stimulation". Bitgood has referred to these distinguishing features as "landmark qualities" (Bitgood, 2013, 67; Bitgood, 2010, 6). We can increase the player's willingness to investigate a high value by ensuring that it contrasts with its surroundings in one or more of the above categories. Landmarks, and their integration into game wayfinding, is discussed in greater detail below.

Though games can create highly enticing focal points, to ensure that the player can see and investigate this point, their location in the scene is vital. For items of high salience to be effective, they must be visible to the explorer as they move through the environment. Unsurprisingly, objects within an explorer's line of sight have a higher probability of grabbing their attention (Bitgood, 2013, 67). If the developer is to rely on landmarks as the primary wayfinding information, pulling the player through the level, they must ensure that the player has consistent visibility of interesting landmarks. As the player investigates one landmark, the next desired landmark will immediately or soon thereafter come into view. Levels can string the player along a path of interesting landmarks, introducing newly visible stimuli as players advance from cue to cue.

Though distant high contrast stimuli may be visually enticing, players may not give these visual stimuli a high priority on their exploration checklist. The player's relative distance to an interesting stimulus is a highly important factor in determining its relevance to the player's exploration and attention. The closer the stimuli are to the viewer, the more likely they are to capture attention (Bitgood, 2013, 67). If distant landmarks are competing with stimuli in closer proximity to the explorer, they will likely not have immediate pull. However, the player will ultimately reach this distant stimulus after attending to all nearby stimuli. Explorers tend to follow the most efficient pathway for seeing all of the environment's interesting stimuli (Bitgood, 2010, 6). The closest interesting stimulus is visited first, with the explorer progressing along the string of stimuli until reaching the final destination.

By controlling the structure of the environment and the location of its assets, the developer can influence the players' investigating priorities. To be effective at physically pulling in the viewer, the stimulus must hold the viewer's attention while the viewer inhibits their attention for other environment features (Bitgood, 2013, 77). We can increase a focal point's potential success, and support the viewer's sustained attention, by minimizing its competition (Bitgood, 2013, 67; Bitgood, 2010, 6). Minimization of visual competition can occur through increasing a stimulus's relative value, or through physical isolation.

A stimulus's value is derived from its pertinence to the current goal, and the potential benefits/costs of attending to the stimulus. Costs could take the form of currency, effort, or time required to engage with a stimulus. The longer it takes for the participant to gain the rewards from the feature, or the greater the effort required, the lower the value the stimulus will have. This is well represented by explorers' tendency to focus on nearer focal points over distant focal points. By weighing the cost/benefits of attending each stimulus, we are assigning it a "perceived value" (Bitgood, 2013, 77-78). Stimuli within the environment that are perceived as objects of a low-cost, high-benefit ratio, will be more likely to capture attention than items of low-benefit, high-cost. The item that offers the greatest benefit, for the least amount of time or work invested, is highly valued (Bitgood, 2010, 6-7). A small treasure chest located behind difficult enemies is likely to have a low perceived value by the player. However, a great reward, such as advancement in story, or strong items, located at the end of an unguarded hallway, will have a very high perceived value. This perceived value theory may be referred to as the "optimal foraging theory", which also suggests that the amount of value given to an object is based on the benefits versus cost. This theory has been applied to museum visitors' attention to help direct attendees (Bitgood, 2013, 49).

Though an object's perceived value is vital for exploratory priorities, its value relative to other immediate objects will determine its navigational success. Explorers will be more willing to attend to a focal point if its surroundings are perceived as having a lower value. This is known as the "available-alternatives" theorem (Bitgood, 2013, 77-78). The number of "available alternatives" can be decreased by reducing the number of distracting stimuli, and increasing the focal point's isolation. This isolation of all visually interesting stimuli will increase the likelihood that each focal point receives attention (Bitgood, 2010, 8). Reducing a focal point's competition will require dispersing visually interesting stimuli throughout the game environment. Distributing stimuli to avoid direct competition, will increase the likelihood that each focal point will entice the viewer at the correct time (Bitgood, 2010, 7). Bitgood suggests that if the intended focal point has a low perceived value, explorers will likely pass over this object and continue their search for a new, more valuable object. Once an object of high value is detected by the viewer, they will become engaged with this object and investigate it (Bitgood, 2010, 4).

Top-Down Vs Bottom-Up Attention

Top-Down

Modern game quests often revolve around seeking out and retrieving important plot devices. Established in the game's story, players are frequently tasked with locating important artifacts or devices that will progress the narrative. When exploring an environment, attempting locate a stimulus, the player will engage in one of several patterns of searching: naïve, primed, or exploration (Darken and Sibert, 1996, 54). These concepts could be incredibly beneficial for game wayfinding, as the information provided to the explorer before a search can have a large impact on the searcher's sensitivity to the primed environmental features.

Primed searches involve providing the explorer with information on what they are looking for, and where to look (Darken and Sibert, 1996, 54). Searchers are aware of their goal, and search the environment for features associated with that goal. This is known as a “top-down” process (Ware, 2008, 12). These concepts are important to wayfinding because they enable the manipulation of an explorer’s attention. Both Johnson and Wright et al. suggest that priming the perceptual system with information on the current goal can increase our awareness of, and sensitivity to features associated with that goal. Our goals create bias in our perception, making searching for items that we are familiar with much more efficient (Johnson, 2014, 11-12; Wright, Blakely and Boot, 2012, 67). If sent on a primed search, the player’s attention will be hypersensitive to features associated with their goal; for example, if the players know that the goal object is green and rounded, their perceptual system will be much more sensitive to seeing these properties within the environment. This would make wayfinding, and locating their goal much more efficient.

When the amount of information used to prime the searcher is reduced, a naïve search is created. This search occurs when the explorer knows what the goal object is, but not its location (Darken and Sibert, 1996, 54). This is commonly seen in games, as players are often aware of the goal object, but are given vague directional information for finding it. However, an exhaustive search of the environment may not be required. As the players are aware of the objective’s appearance, they will still be hypersensitive to its features within the environment. This will make spotting features associated with the goal object within a busy scene much easier. If the searcher is unaware of the objective, or its whereabouts, they are simply performing “exploration” (Darken and Sibert, 1996, 54).

Bottom-Up

Though searchers can become hyper-aware of primed search features, alarming events in the immediate environment can effectively divert primed searches. This would be an example of “bottom-up” attention. When our brain interprets an event as important, our attention is captured and directed towards the source of the stimulus (perhaps through the orienting response). Our brains decide that these stimuli need immediate attention, taking priority over any pre-existing searches (Wright, Blakely and Boot, 2012, 67).

Bitgood suggests that features of the environment which override the searcher’s attention, pushing them to investigate, are creating “stimulus-driven attention”. These stimuli prevent the viewer from conducting an extensive, calculated search of their environment, because they are associated with the “inhibition of return”. Bitgood states that once a museum visitor has been distracted from their currently attended stimulus, perhaps through an orienting response to another exhibit, they are unlikely to immediately return to the stimuli that they were distracted from (Bitgood, 2010, 5). If game developers create powerful stimuli that are triggered with precise timing, they may be able to prevent players from exploring certain areas of their game. Or, these types of stimuli could be used to draw attention towards an important feature.

Searching, Attention Fatigue and Attention Restoration

Bitgood suggests that there are two primary patterns for searching an environment: sequential and simultaneous. Both of these search types will occur if the searcher is performing exploration, and not a naïve or primed search. Sequential searches move from one stimulus to the next, until the explorer locates something worthy of their attention (Bitgood, 2010, 5). Simultaneous searches involve scanning the whole environment for an object that contrasts with the surroundings. When the viewer finds an interesting stimulus in either search type, they will stop to investigate the point of interest (Bitgood, 2010, 5). Bitgood suggests that arranging the environment to support a sequential search type is likely the most effective for ensuring that each important feature grabs the attention of the viewer (Bitgood, 2010, 6). Games can harness sequential search patterns by stringing together focal points or landmarks in a sequential line, slowly but effectively guiding the player through the level.

Though naïve searches may be common in games, increasing sensitivity to a goal's presence, extensive top-down searching may actually have a negative impact on the player's attention, leading to attentional fatigue. David Kopec's "attention restoration theory" suggests that instances of extensive top-down, goal-driven attention, require high amounts of mental concentration. Our directed attention can fatigue over time, reducing our capacity for concentration. Concentration and attention can be reestablished through periods of "effortless attention" or "involuntary interest-based attention". Effortless attention can be created in areas where there are no hazards, and little effort is required for navigation, such as an enclosed corridor (Kopec, 2006, 24).

As video games frequently feature content that requires top-down, attention-heavy searching, attentional fatigue is likely a common occurrence. If the players experience attentional fatigue while playing, they may lose interest in the game, or have diminished concentration. Attentional fatigue could be combatted by punctuating intense visual searches with sections of effortless attention. Developers can encourage effortless attention in the player through both the level structure, and the quest information provided. By physically structuring an environment to be linear, with the level topography guiding the player directly to their destination, the wayfinding attention required from the player is drastically reduced. A primed search, where the player knows exactly where and what to look for, could also restore attention. Or, developers could create a section that encourages exploration-type searches (unprimed, non-goal driven searching), allowing the player to move through a calm environment at their own pace. As will be discussed below, natural environmental features are also highly effective at restoring directed attention. Each of these strategies may be implemented to restore the player's attention after extensive periods of intensive attentional focus.

Much like excessive directional attention, humans can also experience an overload from environmental stimuli. Navigating an environment that contains too much information can lead to sensory overload (Kopec, 2006, 24). Wirth et al. suggest that a medium can maintain the concentration of the explorer by offering a constant stream of information to absorb. However, if the viewer becomes overloaded with too much, or too complex information, they may experience fatigue (Wirth et al., 11). This could have a negative impact on player enjoyment and game immersion.

The amount of environmental stimuli present must be carefully balanced, as a lack of visual stimuli can also lead to issues. Environments that do not provide sufficient visual stimuli, failing to maintain explorer attention, can cause disinterest and problems like anxiety (Kopec, 2006, 24). Balancing player attention, and potential overload, may be a challenge. As such, developers may choose to use in-level visual cues to supplement the wayfinding information presented in the UI. This gives the players the option to use the environment or the UI to navigate. If the environment is providing excessive visual stimuli to the player, they are able to redirect their wayfinding attention to the UI.

Wayfinding Techniques in Games

As discussed above, maintaining a cohesive game world through visually consistent environments is highly important for game immersion and player enjoyment. Below, pre-existing in-level wayfinding cues, seen in various games, will be documented and discussed. Intelligent use of these cues could lead to immersive and navigable game environments. They can reduce developer reliance on incongruous visual cues and UI wayfinding systems, while maintaining a level's visual style.

It should be noted that game wayfinding documentation is infrequently in a published state. Those texts which have been published are almost entirely reliant on anecdotal experience with creating video game worlds, and not backed by research trials or extensive evidence. 3D world design for games is a young field, and is very thin in scholarly studies. As such, some of the pre-existing wayfinding cues listed below will be supported with evidence from fields outside of game design.

Byrne suggests that, ideally, players should be guided through game environments with a variety of in-level cues (Byrne, 2005, 65). Each category of wayfinding cue discussed below will have scenarios where they are most applicable, and others where their presence may not be appropriate for the surrounding scene. These cues should be used when both effective and thematically appropriate to the game. As players are sensitive to reoccurring events and stimuli within games (Byrne, 2005, 62), continuously relying on the same wayfinding cue throughout the experience, despite a change in visual style, may compromise the environment's realism. As such, these cues should be used in combination to create the most immersive and effective environments possible.

Kremers states that environment wayfinding features can be classified under two main categories: push and pull.

> Push and pull mechanics are born from elements in the environment that seek to influence the player's progression, either forcibly or by necessity. Take for example the scenario where in order for players to progress, they need to go down a lift, but after they have reached the desired location, the lift breaks down and makes backtracking impossible. This is a clear example of a push. Now imagine an alternative scenario where the player is nearly out of

> health and being chased by a strong enemy creature. Somewhere in front of the player, a health-pack. This is a clear example of pull. (Kremers, 2009, 265)

For the purpose of this thesis, pull mechanics will be defined as any gameplay feature or visual/auditory stimuli used to draw in the player through willing participation. Pull mechanics will primarily take the form of visually intriguing stimuli. Push mechanics will be defined as any device used to hinder the player's progress in a certain direction, in an attempt to force the player down a set path. Pushes could include the physical barriers discussed above: streams, mountains, sandstorms, locking doors, etc. Nearly all of the pre-existing, and all of the new visual stimuli that will be discussed below will fall under the pull category.

Push and pull strategies can be used to influence the player's "movement impetus", which is defined as: "… the will or desire of a player to move forwards through a level." (Davies, 2009) As outlined by Davies, levels can influence a player's movement impetus through several methods: presenting an object of importance in front of the player, drawing the eye to an item of interest, and narrowing physical spaces/architectural pressure to channel the player (Davies, 2009). The wayfinding cues discussed below will mainly focus on drawing the player's eye, and presenting the player with objects of interest and importance, both of which would be pulls. Other movement impetus-inducing strategies that will not be the focus of this thesis include: creation of time limits, announcing a threat behind the player, or leading the player with an in-game character (Davies, 2009).

Light

Strategic lighting is one of the more expansively covered in-level wayfinding cues, used to both guide the player, and communicate the contents of the environment. When deployed effectively, lighting is a highly effective wayfinding cue, and it is the "preferred navigational tool" for many players. (Shbeeb and Skinner, 2012, 3). In addition to sound, it is the most dominant form of wayfinding cue in video games, with the Bartle types "Achievers" and "Explorers" both heavily preferring lighting navigation cues (Shbeeb and Skinner, 2012, 4).

Lighting permits developers to pique the interest of the player, create refuge from the dark, highlight specific landscapes and items, and provide greater visibility of the surrounding areas. Psychologist Yannick Joye suggests that illuminated regions of an area will "draw attention and trigger explorative behaviour" in the explorer (Joye, 2007, 312). Humans also have a natural tendency to wayfind towards the well-lit areas of an environment (Ginthner, 2002, 2-3), making lighting an effective tool for pulling a player's attention

Key Lighting and Fill Lighting

Byrne makes the distinction between two different lighting types: "key lighting" and "fill lighting." Key lighting is the most important implementation of lighting for wayfinding. They are lights used to highlight and illuminate areas of the environment and items that are critical to the player's progression (Byrne, 2005, 262-263). More specifically, Kremers suggests that key lighting can be effectively used to highlighting environment exits or points of physical progression. The level can communicate the exit/final destination of a region by ensuring that it is well lit with key lighting. This both highlights the exit location of the area, insuring visibility, and will influence the player to associate well-lit sections with progression (Kremers, 2009, 214-215).

Key lighting has great potential as an immersive wayfinding cue. Byrne suggests that key lighting can be implemented subtly, with the light emitting from features that would naturally occur within the environment; for example, street lights can illuminate important features of a level, or lit windows can indicate a secondary entrance to a building (Byrne, 2005, 262-263). These uses of key lighting follow the visual style of the environment, while still highlighting important points for the player to view. By giving key lighting a sensible point of origin (light post, illuminated exit sign, lantern, etc.), we can create effective tools for navigation that maintain an immersive and visually consistent game level.

Not all lighting within games serves as key lighting. The lighting used to illuminate the environment as a whole is referred to by Byrne as "fill lighting". This lighting allows the player to see their surroundings, while not necessarily highlighting important features (Byrne, 2005, 262-263). Jenssen states that fill lighting plays an important part in "player guidance", helping the player read their surroundings, and enabling exploration decision-making (Jenssen, 2012). Unless design decisions restrict lighting, environments should have sufficient fill lighting for the player to properly perceive their surroundings. Lighting can be adjusted to portray certain moods, or produce tension, but in general, it is desirable for environments to clearly communicate their contents to the player.

It is important that an environment's fill lighting does not interfere with its key lighting. For the key lighting to be effective as a directional cue, the player should be able to discern between lights that serve a fill purpose, and lights that highlight vital game features. Key lighting could be differentiated from fill lighting by light properties such as hue, brightness, light concentration, physical isolation, or light source; for example, if the player is exposed to a hallway of fluorescent fill lights, and the final fluorescent light in the hallway is the key light, the player may not identify this key light as important. However, if the developer uses a red emergency light as the key light, illuminating the exit or an important object, the player may be more willing to investigate, as it varies in brightness, colour, and origin.

Contrast in an environment's lighting may also pique the player's curiosity. Covered at greater lengths below, contrast can be an effective and enticing visual feature. When contrasting lighting, designers can use darker areas, or lack of lighting, as a viable wayfinding cue. Byrne suggests that dark sections of environments, if properly contrast with the area's illumination, may stir the player's interest. "A brightly lit area at the end of a dark room will guide the player to that spot. Likewise, a shadowy corner of a well-lit room will almost always invite curiosity…" (Byrne, 2005, 101). It is not the physical appearance of the dark sections that are visually appealing, but how they contrast with the surrounding environment. This contrast of illumination can also be used to greatly emphasize the well-lit sections of the room. Ginthner suggests that the greater the contrast in illumination between a focal point and its surroundings, the larger the focal point's impact on the viewer (Ginthner, 2002, 3).

Path Highlighting

Depending on the visual style of a game, it can be an effective wayfinding strategy to ensure that the primary path is the most well-lit, or only well-lit section of the environment. This is known as "path highlighting". Magnar Jenssen suggests that this is an effective method for aiding wayfinding through complex environments. Path highlighting can be used if exit key lighting is not sufficient communication of the path forwards (Jenssen, 2012). Even when a scene becomes complex and highly populated with assets, path lighting will override the visual noise from the environment, ensuring a clear path forward. This strategy is particularly effective due to humans' tendency to follow the brightest path available.

> In a study by Taylor and Sucov (1974)... the downlights illuminating the path to the right and those illuminating the path to the left had an equal level of illumination, 69% of the people went to the right. Whereas when the path to the left had a higher level of illumination, 75% of the people went to the left. The study found that basically people are like moths—attracted to brightness. (Ginthner, 2002, 2-3).

Humans are naturally drawn to lit areas. By priming the player to seek out lights (providing rewards for following key lighting), and harnessing their natural attraction to illumination, we can create effective cues for light-based navigation. Rogers states that *Naughty Dog*, developers of the *Uncharted* series and *The Last of Us,* use a "squint test" to ensure that the primary path is the brightest area on screen. If the player squints their eyes, the brightest areas on screen should be the main path.

If using path highlighting, the environment should be supplemented with enough bright and dark areas to help players visually discern between the main path and secondary areas. Even if the players do not associate the well-lit sections with the main path, the main path's content will be well illuminated, allowing players to plan their movement (Rogers, 2010, 226). As humans are naturally drawn towards light, following the brightest path within a game should be a natural reaction.

For further examination of lighting's impact on videogame navigation, see *In-Game Lighting and Its Effect on Player Behaviour and Decision-Making* by Joy Brownmiller.

Breadcrumbs and Landmarks

Humans can have weak skillsets for wayfinding. We tend to gloss over details, forget information provided to us, misinterpret wayfinding cues and maps, and misunderstand architectural layouts (Arthur and Passini, 1992, 5). As such, it is important for games to provide wayfinding cues of ample volume and quality. In addition to the other wayfinding cues discussed in this thesis, we can use various visually interesting stimuli to act as points of orientation, and guide the player through game levels.

Levels can lead players to their destination by supplying a series of enticing visual or auditory "breadcrumbs". Breadcrumbs can take the form of interesting objects, lighting, sounds, or other attention-pulling features. They will catch an explorer's attention, and entice them to move in and investigate. As the player approaches a breadcrumb, a new breadcrumb will come into view, signaling the next destination and stringing the player along, sequentially, towards a predetermined end (Bates, 2004, 116; Moore, 2011, 302; Byrne, 2005, 62). As stated above, moving the explorer through the environment with sequential visual cues is the most effective method for ensuring that each cue receives attention (Bitgood, 2010, 6), and breadcrumbs are great enablers of this. This navigation strategy can be seen numerous video games, and theme parks like Disneyland (Rogers, 2010, 221).

The difficulty of a game's navigation can be tuned by tweaking the number, frequency, distribution, and strength of the breadcrumbs. "The bigger and more numerous the bread crumbs, the easier it is for the player to find his way through the woods" (Bates, 2004, 131). The more directed the player, the lower the navigational difficulty.

Landmarks are a variety of breadcrumb that are commonly used in games. They are objects, or bundles of objects, which act as compelling destination points, beautification features, and objects of orientation (Carpman and Grant, 2002, 431-432). They often take the form of "fountains, statues, distinct buildings, and large machines…" (Co, 2006, 101), and are frequently the focal point of their environment (Co, 2006, 101).

A landmark can appear in any state, but it has to be unique. The uniqueness of its appearance and its size relative to its surroundings are what lend the landmark memorability and recognition. This ease of recognition makes landmarks effective points of reference and orientation for players (Rouse, 2004, Chapter 23; Bates, 2004, 111), which aids the process of cognitive mapping (Newman, 2013, 115). Cognitive maps, or mental maps, are mental representations of an environment's spatial layout (Carpman and Grant, 2002, 431). They aid in spatial orientation (Arthur and Passini, 1992, 23), increase wayfinding efficiency (Carpman and Grant, 2002, 431) and increase immersion in a medium (Madigan, 2010; Lee and Jounghyun Kim, 2008, 491). As the area's focal point, landmarks help visually complete the scene, reduce the wayfinder's anxiety, and provide a final destination to focus on (Pagan, 2001).

Landmarks presented at a distance, but still in the player's line of sight, will coax the player to explore the environment and find a path to this object (Moore, 2011, 302). As distant landmarks are often seen as an ultimate destination and the focal point of a region, it should be "distinct from its surroundings", contrasting its immediate environment (Darken and Sibert, 1996, 52) and feature "landmark qualities" (Bitgood, 2010, 6). Landmark qualities are object features that increase its salience to an explorer, such as: contrasting colour, shape, or movement (Bitgood, 2013, 67). This contrast in appearance with its surroundings will make the landmark more visually interesting, and more likely to pull the player in.

Though landmarks may visually contrast with their surroundings, Rouse suggests that they can be "worked into the story and setting of the level itself." (Rouse, 2004, Chapter 23). They do not have to be incongruous cues, and their existence and appearance can still be grounded in the game's world. To make landmarks a more effective and pulling wayfinding cue, Bates suggests that it is proper practice to supply players with a reward for reaching the landmark destination (Bates, 2004, 116). By rewarding the player, the game is creating a positive association between the landmark, and treasure/rewards. This is an effective tool for priming the players to seek out certain features of the environment.

Physical Barriers and Choke Points

Prior to the development of any game environments, the design team will decide on an overall environmental structure that will best support their gameplay. The majority of games which use a first or third-person viewpoint, will employ a linear environment, an open environment, or a combination of the two (see Bethesda's *Elder Scrolls* series). Scott Rogers refers to linear and open environments as alleys and islands, respectively.

> Alleys create a directed gameplay experience; the player has a goal to reach and the level is built to help them reach it. Your alley can be narrow like those found in Portal or it can be wider to give the illusion of freedom and space, as seen in Call of Duty: Modern Warfare 2.
>
> …The Island level, in my opinion, is a bit more challenging to design and build. The game camera has to be flexible enough to accommodate a wide variety of widths and elevations. Scripted events are tough to execute as there's no guarantee that the player will be looking in the right direction. Combat encounters can be completely circumnavigated by players… Despite these limitations, island level design offers expansive space that allows the player the freedom to choose the order in which they want to experience the gameplay. (Rogers, 2010, 219)

Linear and open environments can have radically different approaches to level and wayfinding design. As open environments often have a much freer approach to quests and wayfinding, they will not be discussed in this section.

Linear games often feature a single path, larger areas, or branching paths that terminate at a single area of advancement. This ensures that all players will advance through the environments in a certain order, and guarantees that players must pass through progression points to advance the game. This is an important feature that is unique to linear games, as it allows the development of game sections that all players will see. Designers can inject important plot points, items, visuals, or other content, into these chokepoints, ensuring that all players who advance past this point will be exposed to the same important information.

By providing additional spaces outside of the main path, linear games can create a more believable environment. "Fingers", as described by Rogers, are dead ends that extend off from the main game path, terminating before feeding back into the path forward. This provides players with additional areas of exploration, while still ensuring that players must advance down the primary path (Rogers, 2010, 228). And again, pathways that do not follow the primary path should reward the players for their exploration (Fiel and Scattergood, 2005, 46). However, adding too many fingers or secondary areas to the main path may be confusing. Despite how linear the level may be, every stream that breaks off from the main path will increase the chances that the player will get lost.

One of the most effective methods for pushing the player to a single destination is through the use of chokepoints. By implementing physical barriers, such as walls, cliff faces, rivers, etc., which physically funnel the player's movements, levels can force the player to move towards a location (Aarseth, 2000, 114). These chokepoints also help regulate the player's progress through the game, guaranteeing that the player experiences game content in the intended sequence. "The point is to ensure the player does not get too far too fast" (Bates, 2004, 113). However, if chokepoints are not properly used, or if the player is able to maneuver around their physical restrictions, gamers may bypass important pieces of content (Newman, 2013, 119). If used too extensively, physically funnelling the player takes away the player's participation in wayfinding. As defined above, wayfinding should include some decision making or problem solving by the player.

Barriers can also be used to block the player from revisiting content that they have already experienced. Once the player has passed a choke point/trigger, the game can spawn a physical barrier, preventing backtracking to the previous area (Bates, 2004, 113). This would be an example of Kremer's push mechanic. By blocking off sections of the environment, the game can help refocus the player on the path forward and reduce wayfinding confusion from the available backtracking options. These physical barriers often take the form of crumbling walls, locking doors, imposing enemies, etc. However, blocking off previous sections will restrict the player's ability to return and search the previous environment. So, if the player misses exploring an area and their access is blocked, the player is permanently barred from any treasure, experience, or exploration that they may have overlooked. To ensure that players who value exploration take their time with exploring an area, the developer may want to communicate to the player that once they pass this part of the map, they will be unable to return.

Colour

Colour, while used extensively in all parts of game design, can also be a key to wayfinding. Colour is an important tool for drawing the attention of the player to a certain area or object within an environment. Kopacz suggests that we can create "focus" within scenes by applying colour to emphasize important features. Objects that are composed of the brightest colours within a scene, or are of high contrast, will often draw the viewer's attention. However, the more frequently a colour is used, the lesser its ability to pull attention (Kopacz, 2004, 109-111). So, for a colour to pull the focus of a player, it must have high brightness, be in contrast with the colours in the current setting, or it must be used strategically and sparingly. Developers can strategically restrict the use of certain colours specifically for wayfinding. By limiting a games' use of a certain colour, we can harness this colour across environments to mark the path forward. Three recent games that use this strategy are *Mirror's*

Edge, using obvious red cues, *The Last of Us*, using subtle yellow cues (Madigan, 2013), and *Tomb Raider* (2013), using white cues.

Mirror's Edge uses bright, obvious red colour cues within the environment to indicate the most efficient, or only route forward. As the players are traversing environments with haste, the red colour used is high in saturation, and is restricted to wayfinding objects. But this colour serves two purposes: it highlights which direction the player must go, and the object required to go that direction; for example, if the player must jump across a large gap between rooftops, a small ramp at the edge of the roof will be highlighted red. This will show the player that they must use this ramp to get across the gap. Thus the player knows which direction to go, and how to get there.

In this game world, the items for navigation have been coloured red purely for the sake of wayfinding. In a room filled with white pipes, a singular red pipe will indicate the path forwards. It is clear to the players that these object exist in a coloured state, not due to natural appearance, but because the developer needs to help the player with wayfinding. While this may result in some inconsistencies in the game's aesthetics, the player needs to move through the environment quickly, and the level needs to relay obvious cues to the player.

The Last of Us relies on in-game colour cues that are not only more subtle, but also make sense in the world. Using the colour yellow to indicate the path forward, the game does not colour objects along the primary path simply for the sake of wayfinding. The developers ensure that any object that is used for wayfinding would be naturally coloured yellow. Caution tape, ladders, bridges, paint streaks, and signs, all could reasonably be coloured yellow, while still appearing to naturally fit their surroundings. The developer does not colour non-yellow objects simply for the sake of game wayfinding; for example, the player will not see a stop sign or tree trunk that have been coloured yellow to mark the path forwards. They will, however, see ledges of loading bays painted yellow, yellow cabs, caution tape, etc. that mark the path forward through natural cues. This is a direct contrast to *Mirror's Edge*, where objects will be inconsistently coloured within the same level to communicate the wayfinding information. Again the pacing of these games is a large determinant of the blatancy of the visual cues used for wayfinding.

Tomb Raider (2013), used a similar strategy of restricting colours to deliver effective wayfinding cues. A high brightness white is used to highlight interactive features of the environment's wayfinding puzzles. Ledges, poles, planks of wood covered in white residue, beams wrapped in white rope, white drapery, boxes hanging in white meshes, etc. all represent objects that the player may use for wayfinding. Areas of navigational puzzles are riddled with white objects, each of which may or may not be essential for the player to reach their destination. By surveying an environment, players can see a series of white features, producing a path for advancing through an area.

Tomb Raider (2013) also allows the player to engage their “survival instincts”, which will temporally highlight quest objectives, pick-ups, and traversable/interactive surfaces to the player. This provides gamers with obviously coloured wayfinding cues when activated, and more subtly coloured items during regular play. However, it remains the player’s responsibility to determine how each white object can be utilized to reach the ultimate destination.

Through continual exposure to these colour cues within levels, the players will begin to recognize their purpose as the wayfinding infrastructure. When players have noticed that a colour cue indicates the path forward, they will become sensitive to this colour, making it easier to spot within scenes, and easier to filter out non-essential information when conducting a search (Madigan, 2013). Madigan suggests that if the developer is to use colour as the primary method for wayfinding, objects of importance within the game, such as ammo, or pick-ups, should be coloured the same as the primed wayfinding colour. This will help the player notice both the path forward, and important items (Madigan, 2013). It should be noted that up to 8% of males, and 0.4% of females are affected by colour-blindness (Spalding, 1999, 469). This must be considered when designing a colour-based wayfinding strategy.

Use of colour in-games can also be inspired by real-life visual cues. By harnessing our pre-existing knowledge of colours and wayfinding in the real world, games can implement visual cues that will immediately communicate the state of an area. Dak Kopec suggests that our understanding of modern “symbolic representations” of colour, namely red and green, and their associated meanings, stop and go, can aid in navigation (Kopec, 2006, 90). Green and red colour cues are often used in games to communicate the accessibility of an area or doorway. Doors that are totally inaccessible, or must be unlocked through player effort, will often feature some form of red accenting. Doors that have green accenting are often immediately and easily accessed by the player. This can be seen in games like *Mass Effect*, where doors with a green control panel indicate free access, and red door panels indicate that the door must be unlocked. This trend is continued in later games in the series, featuring a similar colour scheme: green: freely accessible, amber: door can be opened through hacking or “bypassing”, red: currently inaccessible and likely will be unlocked by completing mission requirements. The game also features uncoloured doors. Though some uncoloured doors are opened as the player advances, most are permanently inaccessible, only present to exaggerate the level’s sense of scale.

The *Mass Effect series* features these colour cues on or near the door in the form of access panels, or holographic overlays. As this is a futuristic game world, there is no reason to doubt that this representative technology is incongruous to the time period. Additionally, doors’ holographic overlay, used in the series’ later games, resembles the player’s “omni-tool”. This visually suggests that the omni-tool is the player’s method for interfacing with locked doors. The coloured visual cues on the doors are grounded within the game’s technology, and thus are believable forms of communicating a door’s status. These highly visible colour cues aid with wayfinding by providing immediate visual feedback on the current state of the doorway. Players are able to quickly see which pathways are accessible, without having to approach the doors, and make wayfinding decisions with this information.

However, other games, such as *Fable II*, represent some doors' accessibility by presenting the doors with an ambient glow of colour. Closed doors will take on a green glow if legally operable, or a red glow if inoperable. This colour glow, while effective at communicating the status of the door, is clearly direct communication from the developer to the player. The doors are glowing because the developer needs to communicate the door's accessibility, not because the doors would naturally glow within this world. Thus, the door colour cues are visually inconsistent with the game world.

These colour features absolutely can be included in a game, but if not consistent with the "game logic", they can stifle the player's suspension of disbelief. If game immersion is an important consideration for a title, the designers need to ensure that visual features within the environments conform to the internal logic of the game (Kremers, 2009, 151). While glowing doors could certainly exist in the world of *Fable*, as magic exists, the game does not establish that doors are magically enchanted in any way. These colour cues become features of the game world that are incongruous to the fantasy setting that has been established.

Though colour cues can be successful as a wayfinding tactic, restricting the use of a particular colour for the purpose of wayfinding can have a major impact on the aesthetic style of a game. If a developer desires to use colours as the primary wayfinding mechanic, they must ensure that this does not have a negative impact on the game's art direction. For further information on the creation of colours, colour properties, use of colour contrast, and how to use colours effectively in a scene, see Appendix B: Colour Creation and Effective Use.

High Ground

High ground is another level design strategy that is supported by documentation outside of game design. Alex Galuzin suggests that using both high ground and lighting in tandem can pull a player in a certain direction (Galuzin, 2011, 84). As the effectiveness of light was discussed previously, we cannot assume that high ground is effective in itself. However, evidence from the field of psychology suggests that humans do tend to prefer higher ground, and ascend to elevated points when available.

One of the main supporting theories for this idea is Appleton's prospect-refuge theory. Humans are inclined to seek out locations that offer a good overview of the landscape, as well as potential places of refuge. We tend to seek out environmental features and elevation points that enable us to survey the surrounding areas (Joye, 2007, 306-307). This inherent trait may influence the pleasure that humans experience with landscape art, which often emulates a high position overlooking the surrounding area (Mather, 2014, 141). Creating a physical space that offers the player a view of the surrounding landscape could potentially influence the direction that they travel.

If players tend to seek out high ground in a game, developers can take advantage of this by including elevated points that give views of important content, or by terminating a level atop a peak. By providing points of ascent in consistently flat or declining areas, players may be enticed to climb these points. Interesting objects could be located atop these elevated points. Or, the elevated points may simply provide a valuable view of the surrounding landscape and nearby landmarks. If a level terminates atop a peak, cliff, or tower, the player will know to move upwards whenever possible, seeking out stairways or other methods of ascent. Higher ground both influences the player to climb it, and also sets up additional visual cues and landmarks, influencing where the player will travel next.

Humans' tendency to seek out higher ground grants a greater understanding of the immediate, and distant surroundings. This aids in establishing a mental model of the world. As stated above, the production of a mental model is an important aspect of experiencing spatial presence within a digital environment. By providing an elevated point within a game level, games are providing level progression that is innately preferred, enabling the creation of mental models, and providing an overview of the immediate area.

Motion and Sound

The final pre-existing wayfinding strategy that will be discussed is the use of motion and sound. Shbeeb and Skinner suggest that the use of moving objects and motion within levels can be an effective strategy for catching the eye of the gamer and guiding them in a certain direction. This strategy is most effective for those who fall under the Achievers, Killers, and Explorers categories of Bartle's gamer psychology classifications (Shbeeb and Skinner, 2012, 3). Both Killers and Explorers are also heavily guided through sound (Shbeeb and Skinner, 2012, 4).

Both sound and motion, when used effectively, can result in the player dropping their current goals, and engaging with the source of the stimulus. By presenting an explorer with an unexpected visual or audio cue, we can trigger their orienting reflex, grabbing their attention, and influencing where they look and travel (Bitgood, 2010, 6). This orienting response to strong stimuli is automatic, and is associated with our evolutionary survival traits (Bitgood, 2010, 5). If a level designer wants the user to explore an area on their own time, then it would be wise to avoid the use of strong, orienting response-inducing stimuli.

If an orienting response is induced within a player, the player may never return to the stimuli that they were originally investigating. This is an example of "inhibition of return", causing the player to drop their previous activity, and pursue this new, powerful stimulus. Bitgood suggests that once this strong stimulus is noticed by the explorer, they may discontinue their search of the environment, and never return to the original focal point (Bitgood, 2010, 5). These unexpected, novel, and potentially dangerous cues, will take a high priority, and will be processed and pursued first (Bitgood, 2010, 5). Examples of stimuli that would cause the orienting response, and an inhibition of return, include: fire alarms, flashing lights, and sudden movements. With these cues, we can alter the player's attention, and physically draw them toward the stimuli's source.

New, Tested Strategies

Though the wayfinding ideas outlined above are discussed in game design documentation, they are further supported through other disciplines. Perceptual and environmental psychology, fine art, architecture, urban planning, and design all contribute valuable information to creating immersive game wayfinding cues. They also offer theories on wayfinding, attention capture, and focal point production that are not discussed by game design literature. These theories will be discussed below, and interpreted into in-game, environmentally appropriate wayfinding cues. The general categories of wayfinding cues that will be examined are: Material Lines, Implied Lines, Shorelines, Complexity, Symmetry, Density, Mystery, Nature, Change Blindness, Region Contrast, and Figure-Ground Contrast. If these cues are effective, this could increase the number of immersive wayfinding cues available to designers for game environments. These cues are situational, and are best used in environments where they are appropriate, providing additional wayfinding support while helping to maintain immersion.

As many of the cues rely on creating visually intriguing, or visually appealing stimuli to draw the viewer in, it is important to note that beauty may truly be "in the eye of the beholder" (Reber, Schwarz, and Winkielman, 2004, 364). Though visual preference may be an effective indicator of wayfinding potential, with players moving toward stimuli that they find visually attractive, there may not be any visual stimuli that are consistently preferred by all viewers.

Below is a discussion of the research and supporting evidence for each new cue. In the second chapter, these wayfinding ideas are interpreted and implemented into testable game scenarios. In the final chapter, these cues are tested in a laboratory setting, then statistically and qualitatively analyzed for significance and applicability.

Lines

When initially examining this topic, the primary focus was on how game level design, and game wayfinding cues, could be improved with fine art strategies. Much of 2D art employs various techniques to emphasize regions or objects in the scene. This is in an attempt to pull the viewer's gaze towards this area, which is often the focal point of the painting (Dewitte, Larmann, and Shields, 2012, 136; Zakia and Page, 2011, 93; Costache, 2012, 98, 213). Some of these strategies may be effective in video games, pulling the player's eye towards important scene content, and influencing their travel.

Lines, also referred to as lead lines, are one of the more common tactics for leading the eye towards a destination. Within a scene, lines, implied or actual, can lead the eye across a visual pathway, guiding it to the focal point of the painting (Dewitte, Larmann, and Shields, 2012, 47-49, 53, 136, 137, 140; Mulligan, 2004, 54; Zakia and Page, 2011, 21). Lead lines can be produced by anything that provides the eye a path or line to travel down, with minimal interruption from its surroundings. Examples include: streams, trees, architecture, arms, etc. Urban scenes offer a high potential for lines, with modern architecture naturally featuring smooth, carpentered edges and corners (Butler, 2003). If using multiple lines within a scene, observers may be drawn towards the lines' point of convergence (Butler, 2003). The point where the lines converge is known as the *vanishing point*.

Different forms of lines can have different properties, guiding the viewer's eye at a varying pace. Straight, long lines, will push the gaze very quickly through an image, potentially causing the viewer to overlook image features along the path of the line (Excell, 2014). Curved lines can be used to slowly guide a viewer through a scene, providing the viewer with the opportunity to look at the features along its path (Excell, 2014).

Lines can be created in two main forms: implied lines or actual lines (Dewitte, Larmann, and Shields, 2012, 54). Generally, actual lines are continuous, unbroken lines that move directly from one destination to another. Implied lines are a series of objects that, based on their physical features (colour, shape, etc.) and proximity, are perceived by the viewer as a line.

Though games can use arrows and signs to draw the player's eye (Galuzin, 2011, 89), lines may be a more subtle tool for directing the player's gaze. Both implied and actual lines that are nested in an environment may guide the viewer's eye and avatar towards the termination point of the line. These lines would be hidden in naturally occurring object materials, or they could be formed by organizing pre-existing level assets to create implied lines. Though lines in fine art can draw the eye towards the focal point, uncertainty of this technique's effectiveness rests in the player's willingness to actually follow any guiding lines with their character.

Unfortunately, there are factors that may restrict 3D environments from effectively implementing lines as a guiding technique. As fine art presents a fixed perspective of a 2D scene, the image features will be seen consistently across viewers. Though game environments can force players to view a scene from an intended angle, most environment features will be viewed from various angles and distances. If the lines or implied lines are not seen from a specific angle, their effectiveness may diminish.

Below, the thesis will discuss how thematically consistent lines, created through environmental objects and materials, can be applied to games to create effective wayfinding cues. The general support for the effectiveness of lines, presented above, is applicable to all line theories discussed below. Actual lines, embedded within game materials, will be the first lines strategy discussed.

Material Lines and Shorelines

Game floors and walls are large canvases that host various materials, maintaining and reinforcing the game's aesthetics. Lines often exist in abundance in game floor and wall materials, including wood floors, various types of tiles, outdoor siding, etc. Aligning floor materials, and when appropriate, wall patterns, to ensure that their long uninterrupted lines point towards the player's objective, reappropriates the material’s purpose. The floor material can depict a certain aesthetic, while producing subtle lines that point towards an exit or object.

Arthur and Passini have stated that textures and guiding lines can be used to distinguish different paths through an environment. “…directional guidance can be given by distinguishing the access path from the surrounding area. This may be achieved through texture or by a guiding shore line. It must be noted that a well-articulated path usually has these distinguishing characteristics in any case.” (Arthur and Passini, 1992, 126). If the developer choses to visually differentiate the primary path from the secondary paths, this can be done through the presence of visually distinct floor lines. These are often seen in hospitals, and may be effective in less complex environments. However, if the building is highly complex, the lines can have inconsistent results (Carpman and Grant, 2002, 431).

This suggests that humans are, to some extent, able to navigate spaces based on visual cues that rest on the ground. This provides developers with a massive, ever-present canvas to apply actual lines. By orienting the floor textures so that its lines are perpendicular to the desired location, the player’s eyes may travel along the floor lines, towards the intended destination. This technique will be most effective with floor materials that have discernible, naturally occurring lines, such as hardwood floors, or elongated tiles. This creates a subtle, but still visible line effect in the floor.

Shorelines are another cue that may communicate the main path to the player. Shorelines are physical features that highlight the edges or boundaries of an area or pathway. These could be road curbs, floorboards, flowing water features, extensive riverbed, etc. These features flank and help emphasize paths, and can be used to mark paths and introduce an entrance (Arthur and Passini, 1992, 122). Or, if properly communicated, shorelines can be used to differentiate an access path from its surroundings (Arthur and Passini, 1992, 126). This could be used to visually communicate the primary path of the game versus the secondary paths.

When navigators are able to associate a particular shoreline feature with progress, these may act as “continuous cuing devices” (Carpman and Grant, 2002, 431), consistently highlighting the proper path forward. Water features, planters, wall benches, duct systems, heating systems, pipes, all could travel along the walls/floors of the desired path, providing the player a definitive feature to follow throughout the environment. Or, for outdoor environments, river shorelines, road barriers, curbs, etc. may also be used.

Implied Lines

The next concept, implied lines, has great theoretical potential within videogames. Implied lines are lines perceived in space, where no actual line exists, as the viewer’s brain links together multiple separated objects (Berdan, 2004; Dewitte, Larmann, and Shields, 2012, 53). Creation of implied lines in a video game will involve aligning several objects, within an area, that approximate a smooth line. The lines can be produced by a sequence of identical repeated objects, or a series of different objects

(Arthur and Passini, 1992, 128). This offers a huge number of possibilities and applicability for implied lines in many different scenes.

If placed in the appropriate location and orientation, a series of separated objects, such as chairs, desks, bricks, rocks, barrels, tires, shelves, etc., may invite the player to follow the line with their eyes, then with their avatar. Implied lines can be used to point towards the exit of an area, or towards other important objects. For the sake of immersion and efficiency, the implied lines should be created by reorganizing a series of objects that already exist within that setting; for example, the chairs and desks within a classroom could be re-arranged to lead the player to the exit.

For the objects to be grouped together and seen as a line, they must meet a combination of the following criteria: they must exist in close proximity, have a similar orientation, create a smooth line, or have similar appearance. While any combination of these factors may result in an implied line, the more requirements covered, the more likely they will be grouped together. Each of these requirements fall under a set of psychology principles known as the Gestalt Laws or Gestalt Principles of grouping. The Gestalt principles outline how our visual systems tend to group or separate objects depending on their features and organization within a scene (Johnson, 2014, 18). Harnessing these principles, we can create spaces of guided wayfinding that use pre-existing in-game assets to guide the player's eye. The Gestalt principles that are most relevant to creating implied lines within a game environment are: proximity, (good) continuation, and similarity.

The Gestalt principle of proximity is a highly important rule for seeing objects as grouped (Bruce, Green, and Georgeson 1996, 107; Hackett, 2014, 15) and may be the most vital for seeing implied lines. This principle states that objects' relative proximity to each other has an impact on our ability to see the objects as a single group. Simply put: "Things that are close together are grouped together" (Bruce, Green, and Georgeson 1996, 107). Objects which are separated by too great a distance will not appear to be grouped (Johnson, 2014, 13-14); for example, placing three barrels within close proximity will influence our visual system to lump these objects into a single unit. While it is certainly possible to group items purely through proximity, following other Gestalt principles will increase the likelihood of grouping.

To create a group that will be perceived as an implied line, objects need to be well aligned, with little interruption in their perceived connection. This Gestalt principle is referred to as good continuation. Also known as continuation or continuity, good continuation suggests that if viewers are able to connect several objects in a straight or curved line, then the objects will likely be grouped. When perceiving objects in a line, we will select the objects that form "smooth contours" (Wagemans et al., 2012, 1189), or the smoothest line possible (Hackett, 2014, 15). Our perceptual system is predisposed to viewing shapes as continuous structures, not as broken segments (Johnson, 2014, 18). If objects are positioned and oriented to create a smooth line, while remaining in close proximity, we will interpret all the involved objects as a single line.

Unfortunately, production of lines purely through the principle of continuation may be fragile. If a single object in the line is out of alignment or features a different orientation, this may be seen as an interruption, challenging our perception of the line. “The eye prefers to follow things that have the least amount of change or interruption.” (Zakia and Page, 2011, 162). However, as the visual system tends to connect objects in the smoothest line possible, objects outside of the smoothest line may not actually impact the line. If several objects perpendicularly branch out from a straight or smooth line, the eye may continue along the original line, ignoring the harsh turn of the branch. Some outliers may not stifle our perception of the intended line. “…perceptual organization will tend to preserve smooth continuity rather than yielding abrupt changes…” (Bruce, Green, and Georgeson 1996, 108). However, those objects in the smooth line must follow its direction, curve, or orientation.

Similarity is the final Gestalt principle that will be examined. In its simplest form, it suggests that objects that are similar in appearance are grouped together (Johnson, 2014, 16; Bruce, Green, and Georgeson 1996, 107). Grouping will occur if the objects in the designated area share common features (Brooks, 2015, 60). However, objects do not need to be identical in appearance to be grouped through similarity. There is flexibility in which object features will group items through similarity. Paul Hackett suggests that items of comparable shape, colour, or orientation can be perceived as similar, and thus are grouped (Hackett, 2014, 15). This is not a list of features that need to align for object similarity, but an outline of features that can create grouping through similarity.

The number of features that can match objects as similar is very extensive. “… there may be as many variations of the similarity principle as there are features to be varied (e.g., texture, specularity, blur). However, many of these variations of similarity grouping have not been studied systematically, if at all.” (Brooks, 2015, 60) While an endless number of features may group objects as similar, there has not been a definitive exploration of what features will and will not qualify groupings through similarity. However, this provides the opportunity for creating immersive implied lines, as it allows for flexibility in the grouped objects’ appearances.

As similarity of orientation is subtle and easily implemented in a game engine, it may be one the most applicable similarity features for games. Combining object proximity, good continuation, and similarity through orientation, we can align several unlike objects and produce an effective, immersive implied line. However, several objects aligned with the exact same orientation may appear odd. For a more natural appearance, the developer can vary in the orientation of the aligned objects. For objects to have noticeable variation in orientation, the difference in orientation must be at least 30 degrees. “…as a rule of thumb a thirty-degree orientation difference is needed for a feature to stand out.” (Ware, 2008, 29). Therefore, objects within an implied line can have a rotation variation of up to 30 degrees while still appearing to have a similarity in orientation. Any objects that exceed this variance in orientation are at risk of no longer appearing similar through orientation, potentially breaking the line of objects.

While there are additional Gestalt principles that will enhance our understanding of grouping tendencies, the principles stated above are most relevant for creating simple implied lines within video games. Using these Gestalt principles, developers can create implied lines within levels that will guide the viewer's eye, and influence the player to move towards the line's destination. Proximity, when used in combination with similarity and continuation, can create effective, environmentally appropriate implied lines out of various objects that would naturally occur in a game level.

All of the line strategies discussed above (material, shorelines, and implied lines), if they prove to be effective, are not necessarily cues that the developer should solely rely on. They should be used where they will not intrude on the visual style of the level, and can enhance its wayfinding properties; for example, implied lines are optimal in environments that are well populated with objects. Developers can reorganize its contents to produce the implied line, without requiring the addition of unnecessary assets. Material lines are best used in environments where lined materials are already present. Reorienting the material will point lines in the direction of an important game object or exit. These are cues that should be used if the appropriate situation arises, implemented in a manner that will not compromise the visual style and immersion of a level. They should be used in tandem with the other in-level cues discussed in this thesis.

Change Blindness

Using theories from perceptual psychology, the persistent colour cues used in games like *The Last of Us* could be enhanced and expanded to fit many different games, despite the game's colour palette. Initially, the game can introduce a high-contrast navigational colour, which the player will associate with progress. Then, over time, the colour's appearance can be altered until it is harmonious with the environment, but still recognizable to the player.

In a world of muted and matte colours, a bright, high saturation blue could be introduced as a marker of the primary path and important game features. This colour could be used to mark door frames, windows, signs, railings, etc. or other important objects, along the primary path of the game, signaling the direction forwards. When used as the player is advancing in the level, the player will begin to associate that colour with progress in the game, as was done with *The Last of Us*. When initially exposed to the player, the colour will be in high contrast with its surroundings, both making it more visually interesting and easier to see. With each exposure to this wayfinding blue, the saturation or brightness of the blue is reduced by a small amount. Over the span of the game, level, or any appropriate length of time, the contrast between the wayfinding colour and the environment will be reduced until it matches the visual style of its surroundings. If this reduction of contrast is done slowly, over multiple exposures to the stimuli, the player will fail to notice the change in the colour's properties. This *change blindness* will cause the players to recognize this new harmonious colour as the high-contrast colour they were originally exposed to. This technique could also be used to alter several different properties of a material, such as: increasing a material's saturation, decreasing its reflectiveness, altering its roughness or emissive colour, etc. Nearly any feature of a colour, or property of a game material, could be altered over time, with the player failing to notice the changes made, and still recognizing it for its original wayfinding purpose. This thesis will focus on the alteration of colours.

Failure to notice changes in an object, after small gradual alterations to its appearance, is known as "change blindness". " '...change blindness' shows that alterations in a visual display can go unnoticed when they are done gradually, one feature at a time or in small increments of single features, such as color or texture." (Shimamura, 2011, 18). By gradually making changes to the colour associated with progression and important objects, a game can alter its appearance to be more fitting to its surroundings. In addition to change blindness, this is also possible due to humans' ability to recognize objects despite a change in their location, perspective, or alterations to the item itself. Waller and Nadel suggest that, despite small changes that may occur to objects, including changes to their lighting or shape, humans are able to persist in recognizing these as the objects originally exposed to (Waller and Nadel, 2013, 89).

Humans can have great difficulty detecting changes in stimuli within a scene. In an experiment outlined by Mather, which examines the basic principles of change blindness, participants were presented two images in succession, separated by an image of a black screen. The second image displayed the same scene as the first, but with a feature removed. The change in the scene is incredibly difficult for participants to detect, and most are blind to it. However, the change is more easily identified if the element that changed is relevant to the participant's objective (Mather, 2014, 56).

As changes are more easily identified in objects pertinent to the observer's goal, care must be taken when altering the designated wayfinding colour. Changes must occur gradually, through multiple exposures. These colour cues will be important to the viewer, and initially high contrast to the environment, so any extreme, or sudden alterations may be noted by the player. Or, if the change is too great, the player will cease to associate the two colours as the same. When attempting to recognize an object, our brain stores a mental representation of the object, and compares it to the stimuli that are currently in view. If the stored representations and the current image do not match, the viewer may fail to recognize the object (Mather, 2014, 62). Therefore, each exposure to the cue must take a small step towards aligning the colour with its desired state.

The process of colour recognition likely mirrors that of object recognition, with the brain making comparisons between the original stimulus, and the present stimulus. If there is too large of a disparity between their appearances, the viewer will fail to recognize it as the wayfinding colour. However, as the wayfinding colour should only be presented when necessary, there may be large gaps between instances of the colour. Combat scenarios, puzzle solving, crafting, dialogue, etc. may all occur between exposures. These will act as mental buffers between exposures, and may reduce the player's ability to notice the change.

However, Kopacz suggests that humans have difficulty retaining information on the colours they have been exposed to, often unable to recall the colours that they have seen. "Humans have a fairly limited capacity to retain color images accurately… we are rarely able to accurately re-create a color seen many times. Even when the color is present in the midst of several similar colors, we may not be able to discern them." (Kopacz, 2004, 15) Based on Kopacz's suggestion, the player may not be able to identify the exact colour that has been positively associated with progress. However, Kopacz's comment is geared toward our ability to accurately re-create colours that we have been exposed to. If players are able to recall the general colour of the wayfinding colour cue, they may be less inclined to notice its gradual change as its contrast with the surrounding environment is reduced.

For this strategy to be effective for an extended duration of time, it is vital that the wayfinding colour is used exclusively when the player can be rewarded for approaching it, or positively associate the colour with progress. If the colour is used freely throughout the environment, the player will be uncertain if the coloured object actually implies that this is the proper path forward. Without consistent positive association between the colour and progress or rewards, the player will stop giving it value.

Once the player is able to recognize the colour as an indicator for navigation, they will continually seek it out, and this may actually aid them in spotting the colour more easily. Johnson suggests that our brain can actually prime our perceptual system to be more sensitive to environmental features that we are currently searching for.

> When you are looking for something, your brain can prime your perception to be especially sensitive to features of what you are looking for (Ware, 2008). For example, when you are looking for a red car in a large parking lot, red cars will seem to pop out as you scan the lot, and cars of other colors will barely register in your consciousness, even though you do in some sense see them. (Johnson, 2014, 11-12)

The ability to spot primed stimuli more easily will be highly beneficial for this wayfinding strategy. It suggests that the players will be able to efficiently locate the wayfinding colour, even if it exists in small quantities, and after its contrast to the surrounding environment has been reduced.

Through continual positive exposure to the colour, players can be primed to recognize it and associate it with the path forwards and rewards. Then, the colour's appearance can be altered, while it remains a perceptually sensitive, recognizable stimulus. This may ultimately create a colour-based navigational system that relies on colours that are consistent with the visual style of the game. To maximize the immersive potential of this technique, the colour should be used appropriately in the environment, on signs, door frames, floorboards, or any feature that could feasibly exist as the primed colour.

This wayfinding cue could be used throughout the entirety of the gaming experience, or in an individual region, if it is large enough to provide a sufficient number of exposures to the colour. However, changing wayfinding colours within each region may be jarring and confusing to the player.

Nature

Nature is the next category of stimuli that may be used to physically draw in the player. Natural objects do not rely on priming, or fine art techniques to influence the viewer, they simply engage an innate human preference for natural stimuli.

Studies conducted by Kaplan and Wendt have demonstrated that humans have a high preference for natural scenes over scenes of man-made environments. In their research, Kaplan and Wendt supplied participants a variety of colour slides, asking them to rate the slides for preference and complexity. They ultimately found that the participants in the study greatly preferred nature scenes to urban scenes (Kaplan and Wendt, 1972, 1). When Kaplan and Wendt analyzed participants' reactions to natural and urban slides, they found that, with a single exception, the least favourable natural slide was preferred over the most favourable urban slide (Kaplan and Wendt, 1972, 2). Humans value common, non-spectacular instances of natural elements, over uncommon man-made objects, such as physical art, statues, etc. (Kaplan, 1988, 54). This is an extreme disparity in attractions to landscapes and features.

These findings were supported by various other environmental psychologists, who have found that natural scenes are consistently preferred over man-made urban settings which do not contain any vegetation. When comparing multiple urban settings, those that contain natural elements, such as trees or water features, are the most highly preferred.

> …vegetative elements and settings containing vegetation still cause aesthetic or liking reactions. Different empirical studies show that individuals consistently prefer natural, vegetated landscapes over urban settings without vegetation. When urban environments are mutually compared, highest preference is associated with urban settings containing some vegetation, especially trees, or a water feature (Smardon, 1988; Thayer & Atwood, 1978; Ulrich, 1986). (Joye, 2007, 307)

Joye suggests that natural features, both water and vegetation, are enjoyed because of their contribution to the survival of the human species. Various forms of vegetation were indications of food, shelter from the elements, and elevation for surveying the surrounding area (Joye, 2007, 307). By placing natural features within an urban game environment, the player's potential enjoyment of the level may be increased, and the natural element may act as a focal point. Players may gravitate towards natural features, especially if they are situated within the endless human constructs of an urban environment.

There are studies that suggest that humans enjoy the presence of water even more so than vegetation. In a questionnaire developed by Komar and Melmid, which was distributed to various participants in the USA, Germany, Kenya, and China, the vast majority of respondents preferred scenes that depicted outdoor settings over indoor settings. This preference was mainly due to the inclusion of outdoor water elements. The majority of the viewers preferred scenes that are relaxing to look at, due to the water, and not confusing or busy. The forested outdoor scenes were less appealing than those which included water. The preferences of the participants were consistent across international borders, suggesting that a universal aesthetic preference for water may exist (Mather, 2014, 128-129).

Kaplan and Wendt have suggested that both water and foliage are "primary landscape qualities", and these qualities can influence people to react positively to landscapes. Though Kaplan and Wendt support that these natural features have evolutionary significance, they suggest that the human preference for natural elements may be due to texture or colour (Kaplan and Wendt, 1972, 4). Kopacz asserts that over the past two decades, the majority USA citizens preferred blue, red, and green, respectively, as their favorite primary or secondary colours (Kopacz, 2004, 98). However, restricting choices to primary and secondary colours severely limits the number of colours available.

In a study of college student colour preference conducted by Naz Kaya, green had the highest number of positive responses, followed by yellow and then blue. Kaya suggests that the associations between green and nature were responsible for creating soothing emotions and comfort (Kaya, 2004, 399). However, Plass et al. suggest that research demonstrates that humans experience the greatest in pleasure from warm hues, which do not include green or blue (Plass et al., 2014, 130). The studies on overall colour preference are somewhat inconsistent. Perhaps preference for natural elements in scenes is due to their representations of nature, and not their base hue.

In addition to being highly preferred visual stimuli, natural elements and settings have additional properties that may make them a valuable resource for video game environments. Yannicke Joye asserts that natural elements induce positive responses, but also can also help restore concentration. Attention restoration theory, created by Kaplan and Kaplan, states that natural settings and features, such as vegetation and water, can restore directed attention.

> Besides causing liking responses, natural elements (e.g., vegetation and water features) are also found to contribute to the restoration of human individuals. Two major interpretations of restorative responses have been proposed. The first, attention restoration theory (ART), was developed by the Kaplans (e.g., R. Kaplan & Kaplan, 1989). Essentially, ART interprets restoration as the recovery of directed attention or the ability to focus. This capacity is deployed during tasks that require profound concentration, such as proofreading or studying. Natural settings have been found to be ideally suited to restore or rest directed attention

> (e.g., Hartig, Evans, Jamner, Davis & Garling, 2003; Hartig Mang, & Evans, 1991). (Joye, 2007, 308)

As discussed above, when traversing environments that are highly complex with visual stimuli, the explorers may experience attentional fatigue. Natural areas may be used as restorers of attention, punctuating sections with high attentional demands, and reinstating the player's ability to focus.

Natural items, as wayfinding cues, act as visually appealing stimuli that may draw the attention and presence of the explorer. By creating important objects in the form of nature, or placing important objects near or within the view of the natural stimuli, nature can be used to draw and direct attention towards important game points. Or, planters full of bushes, or simple water features could be combined with shorelines, travelling along an edge or wall, leading the player to the next point of interest.

However, natural elements as wayfinding cues should only be used when an appropriate situation arises. While the developer could certainly prime the user to associate natural features with the primary game path, they may be best used to contrast against an urban setting, or a man-made interior. As humans see geometric and organic objects as contrasting states (Dewitte et al., 2012, 58), using natural items within a man-made setting will create a strong contrast in state, drawing the player's attention. This preference for natural items may be heightened by continued exposure to man-made scenes. If players are injected into areas of endless geometric structures, supplying elements of nature will provide visual variety, and relief from the man-made environments.

Mystery

Implementation of mystery in an environment is one of the more promising strategies for encouraging player movement. In addition to the primary landscape qualities discussed earlier (water and foliage), Kaplan and Wendt suggest that humans prefer scenes that promise further information, or present mystery to the viewer. This theory has been echoed by multiple other theorists, who state that mystery within a landscape increases scene preference (Kaplan and Wendt, 1972, 4; Joye, 2007, 312; Kaplan, 1988, 49; Mather, 2014 141).

Mystery can be created when visible trails curve, and vanish behind an obstruction, take sharp turns, or are structured to obscure its contents. The viewer is unaware of what the later sections of the trail hold. However, the viewer knows that if they pursue this unknown, traveling deeper into the scene, they could be rewarded with additional information (Kaplan and Wendt, 1972, 4). It is this potential of acquiring new and interesting information on the scene that that makes areas of mystery so appealing (Kaplan, 1988, 49).

> A landscape with mystery is one where the path turns and disappears around a bend, leaving the observer unclear as to its destination. A brightly lit field incompletely glimpsed through foliage provides another example of mystery. In both instances there is promise that further

> information could be obtained if the observer could walk deeper into the scene. (Kaplan and Wendt, 1972, 4)

This additional information does not necessarily have to exist for mystery to be effective, but the potential of its existence is enough to stir the curiosity of the viewers. Humans are seduced to follow the path into the unknown by the temptation of additional knowledge about the scene (Kaplan, 1988, 50).

Though mystery can be created through several means, Joye suggests that the simplest method, within any architectural setting, is the creation of a “deflected vista” (see Figure 1-1). These can be created when the barriers of the architecture, be it the interior walls of a hallway, or a building’s exterior wall, bend as they extend out from an initial point. This bend prevents the viewer from seeing what lies farther down the pathway. The severity of the bend will determine the immediacy of the mystery within the scene, with strong bends in the “architectural trail” limiting viewing distance much more than weak bends. The curiosity created by these curves may encourage the viewer to follow the lines of the architecture, explore its hidden elements, and push deeper into the scene for more information (Joye, 2007, 312, 307). Mystery can also be created by simply obscuring the observer’s view of the scene’s contents (Kaplan and Wendt, 1972, 4).

Figure 1-1 - A depiction a deflected vista versus a straight hallway. - Unreal Engine 4

Mystery creates pleasure in the viewer/explorer because it both excites them, and coaxes them to explore the environment. Mather suggests that the exploration of new areas may be a reward in itself, the pleasure from exploring a mystery landscape may be rooted in evolution. Humans have an evolutionary tendency to search our immediate environment for resources, competition, or predators. This exploration of the environment has been associated with increased dopamine levels in animals (Mather, 2014, 141).

Kaplan states that the appeal of searching new, unseen territory, may rest in our anticipation of what will be present within the mysterious environment. Based on the environment surrounding the mysterious feature, we can decipher the possibilities of what may lie beyond our sight, confirming those estimations through further exploration (Kaplan, 1988, 50). Optional mystery features in the environment offer a unique relationship to the explorers, as they give explorers the control over how much they want to learn of this environment. The explorers are responsible for expanding their knowledge of their surroundings (Kaplan, 1988, 50).

A simple implementation of mystery within a game could include branching paths, where the termination points of the paths are not visible until the player explores them. For maximum navigability, it is advisable that these branching paths extend out at right angles. Extensive use of pathways that branch off in odd directions may lead the explorer to become disoriented (Carpman and Grant, 2002, 435). This may be a concern if using deflected vistas. Despite how the mysterious corridors are oriented, offering too many branching areas of mystery, may ultimately confuse the player, making navigation more difficult.

> Although mysterious settings can be aesthetically appealing, too much irregularity or surprise can have the result that the layout of the building becomes confusing and non-transparent, ultimately leading to orientation and way-finding problems. Legibility can be enhanced by integrating signalizations and distinctive markings, by offering views on the outside, and by making the building shape more regular (Evans & McCory, 1998). (Joye, 2007, 313)

Mystery can also be produced without breaking the player's line of sight. By reducing the amount of light in a particular region, the player's visibility of an area's contents can be restricted. Totten suggests that this may invite players to explore the shadows (Totten, 2011, 4). However, as discussed above, humans' preference for light and lit areas may be a deterrent from entering these shadowy sections.

While mystery may prove to be a very enticing feature of game levels, even when players know the proper path forward, they will often explore the level in its entirety to avoid missing any items or rewards (Newman, 2013, 116). Thus, areas of mystery may both pique the player's curiosity of the mysterious area, and provide additional areas of content for pillaging. By offering rewards or items for those who venture into the areas of mystery, developers are ensuring that the player will be willing to do so in future scenarios.

Density

The complexity of the information presented within a scene can have a sizeable impact on scene preference. Scene complexity is a representation of how much visual stimuli is present, how dense the stimuli are, and how much there is to look at. Some theorists suggest that the more complex the scene, the more likely the viewer is to enjoy it (Reber, Schwarz, and Winkielman, 2004, 364; Kaplan, 1988, 48; Doherty, 2005, 24-26).

Kaplan and Wendt have suggested that the increased enjoyment of high complexity scenes is due to their unpredictability. If there are not redundant items present, then viewers are uncertain of what else the scene might hold. The more varied a scene is, the less likely that the participant will be able to predict what they will see next. This is similar to the rationale for viewers' enjoying scenes of mystery (Kaplan and Wendt, 1972, 4).

When complex scenes are viewed, the sections of the image that do not contain an abundance of information are rarely focussed on. Our eye will move away from these "uninformative parts" and towards sections that contain the "highest density" of information (Mather, 2014, 84). However, areas of high density can also be relatively unimportant if not properly contrasted with their surroundings. In an image or environment that is highly complex and densely populated with objects, but offers no contrast in density, it will appear as a visually homogenous scene. If these scenes introduced a single area of low object density, the viewers may attend to this section more readily, as contrast in a scene of homogeneity is very appealing .The more homogenous a scene, the smaller the visual contrast required to create a "pop-out" effect (Ware, 2008, 29).

While areas of lower object density may contain less visual information than dense areas, the novelty of experiencing a space with a different level of complexity may be a pulling force for the viewer. Through extensive exposure to the same level of scene complexity, this complexity may be subordinating itself, making an area of lesser, contrasting complexity much more appealing. When we subordinate an area of a scene, we are discouraging the viewer from visually attending to this section (Dewitte, Larmann, and Shields, 2012, 136).

The developer may be able to create contrast between areas of high density/complexity and low density/complexity to pique the player's attention and pull them in a certain direction. If the player has been continually exposed to visually complex, busy environments, an area free of clutter may be very appealing. Contrasting a messy construction site, or streets that are filled with rubble, against an entrance that is free of debris, may pull the player towards the calmer, low-complexity space. Or, in a thickly wooded area, a cleared walking trail may be an enticing path forward. Alternatively, if the player has been exposed to simple regions with a small number of visual stimuli, they may be very willing to enter into a visually complex area for the additional visual stimulation. In a massive, open grass field, the player may be pulled towards any available alternative stimuli, such as a large barn, or cluster of cows. Sections of an image that contrast with the surrounding areas will often pull the attention of the viewer (Ramachandran and Hirstein, 1999, 33).

Areas of contrasting density can be used to highlight important areas or objects in the environment. In a sparsely populated environment, a small cluster of objects could surround a point of interest, drawing the player in. Or in a densely populated area, a section of sparse population, featuring a key object, will also pull the player's attention and provide greater emphasis on the key object.

Similar to some of the previous tactics, the complexity contrast will likely best be used in scenarios where the developer already has environments that are either object dense, or are sparsely populated. In visually sterile environment, games can introduce a cluster of objects around, or leading to an object or area of great importance. Or, in a densely populated area, games can introduce patches or paths of minimal density space, providing refuge for the player from the dense area. Additionally, contrasting the complexity of areas within a game level, may be sufficient for establishing different recognizable regions. When an environment is easily divided into regions, the landscape becomes more legible, more enjoyable to navigate, and increases the ease of cognitive map formation (Kaplan, 1988, 51).

Complexity

If developers create a level that is highly populated with objects, and thus is highly complex, they will likely use a large number of repeated game assets. Reusing game assets wherever possible is a symptom of modular game development. Because of the high time cost of developing art assets, those who assemble game levels have to creatively use, and re-use a small asset bank to produce various believable environments. It may be implausible to create environments with high object density, and high complexity, featuring countless unique visual stimuli.

Game Designer Joel Burgess suggests that repeated exposure to the same environmental stimuli can lead to “art fatigue”. Over a series of multiple exposures to the same stimuli, the player will begin to recognize their repeated presence. This can make the world feel inauthentic (Burgess, 2013). Another side effect of reusing game objects is “object satiation”. This phenomenon occurs when repeated exposure to homogenous visual stimuli leads to decreased attention from the viewer, potential boredom, and “fatigue like” symptoms (Bitgood, 2013, 37; Bitgood, 2010, 16). If the player is moving through an area of objects that are clearly repetitive, they may become bored or disengaged.

To counter object satiation, levels can attempt to maintain the attention of the explorer by providing a persistent flow of highly detailed stimuli. Highly detailed, complex, dense environments may have a greater chance of maintaining attention than a low detailed, sparsely populated space. However, much like the fatigue from repeated stimuli, explorers of a highly detailed environment can face sensory overload, producing fatigue, and pulling the explorer out of an immersive state (Wirth et al., 11). If the wayfinders face overstimulation, they may begin to reduce how much information they take in, and gloss over area features (Arthur and Passini, 1992, 34).

While the complexity of the scene can be a determinant of the viewer’s enjoyment, there is also evidence that suggests that scenes of relative simplicity can be visually appealing. Enjoyment of simple scenes is based on the viewer’s ability to comprehend what is appearing within the scene. This is referred to as “coherence”. Coherence, as outlined by Kaplan, is the ability to make sense of a scene through a surface level analysis. Coherence is increased when the image provides stimuli that make it easy to organize into areas. The presence of repeated elements can increase the identifiability of a region, and thus make it more coherent.

> Coherence is the "making sense" component at this surface level of analysis. It includes those factors which make the picture plane easier to organize, to comprehend, to structure. Coherence is strengthened by anything which makes it easier to organize the patterns of light and dark into a manageable number of major objects and/or areas. These include repeated elements and smooth textures that identify a "region" or area of the picture plane. (Kaplan, 1988, 242)

Joye supports Kaplan's description of a coherent scene, suggesting that "symmetries, repeating elements, and unifying textures" all make a scene easier to understand (Joye, 2007, 307). This supports the application of modular art in game levels.

The use of repeated items within an environment not only makes the scene easier to make sense of, but this can also lead to an increased enjoyment of a scene. The more we are repeatedly exposed to the same stimuli, the more we have a preference for it (Reber, 2011, 229). Reber et al. state that this is referred to as the "mere exposure effect" (Reber, Schwarz, and Winkielman, 2004, 370). Scenes that have high numbers of repeated and redundant elements have less information and lower complexity than scenes that feature a high number of unique objects. Reber et al. state that the easier a scene is to process, as a result of less information, repeated stimuli or symmetry, the more pleasing the scene is to the viewer (Reber, Schwarz, and Winkielman, 2004, 368-369).

The ease with which we understand a scene's contents is indicative of our fluency in processing that scene, known as "processing fluency". The more fluently a scene can be perceived, the more it will be enjoyed. Again, fluency can be increased by the repetition of stimuli and environmental symmetry (Reber, Schwarz, and Winkielman, 2004, 364).

> We propose that aesthetic pleasure is a function of the perceiver's processing dynamics: The more fluently perceivers can process an object, the more positive their aesthetic response. We review variables known to influence aesthetic judgments, such as figural goodness, figure-ground contrast, stimulus repetition, symmetry, and prototypicality, and trace their effects to changes in processing fluency. Other variables that influence processing fluency, like visual or semantic priming, similarly increase judgments of aesthetic pleasure. (Reber, Schwarz, and Winkielman, 2004, 364).

Similar to fluency and coherence, Kaplan and Wendt suggest that a scene's legibility is a determinant of preference. Legibility is the ability to understand a scene and its contents quickly and without excessive attention. The more quickly and easily we can interpret a scene, the more legible it is. Again, a scene's legibility can be increased through repeated elements. Viewers prefer scenes of high legibility because they can quickly make sense of its contents, and make "micro predictions" about what other areas of the environment may hold (Kaplan and Wendt, 1972, 4).

Environments high in legibility, coherence and fluency, as created through repeated game objects, could take countless forms. As the use of modular game art is a common practice within level design, it is very simple to create environments that feature repeated elements: forests often feature the same tree model, canyons can be created from the repeated use of the same rocks, or ornamental hallways could be lined with repeated pillars or sculptures. The possibilities are truly endless and simple to implement. Additionally, repeated exposure to the same stimuli also increases preference for it.

Any representation of repeated stimuli may be appealing to the player, pulling them towards the areas of repetition out of visual interest. Or, in a game that features multiple unique regions, the presence of repeated game assets within a particular environment may aid the player in identifying and differentiating the game regions.

Settings that consist of repeated homogenous objects, though visually appealing, are not ideal for creating distinct destination points. “Uniformity does not favor decision making.” (Arthur and Passini, 1992, 87) Distinguishable focal points may be essential for game wayfinding. Fortunately, areas with homogenous appearances enable the creation of high-contrast objects. The more consistent the environment’s appearance, the smaller the level of contrast needed to produce a focal point (Ware, 2008, 29). Environments of repeated objects give the developers an opportunity to create a strong focal point, without the need for a heavily incongruous cue.

Because of the extensive support for humans’ preference of both visually complex (presented above) and visually simple areas, these two types of environments will be compared in a test environment. This test will demonstrate the effectiveness of either visually complex scenes, or visually simple scenes, as a method for pulling the attention and physical presence of players within a game setting.

Symmetry

Much like repeated stimuli, symmetry is another environmental feature that is visually appealing due to its perceptual fluency and high level of coherence (Joye, 2007, 307). As such, much of the evidence of visual pleasure from ease of processing, presented in the above sections, also applies to the concept of symmetry.

Reber et al. suggest that both balance of an overall scene, and general symmetry, contribute to our interpretation of beauty. This is due in part to our ability to easily process scenes of symmetry (Reber, Schwarz, and Winkielman, 2004, 364, 365). Symmetrical objects and patterns are perceived much more efficiently than those which are asymmetrical, as they contain less information (Reber, Schwarz, and Winkielman, 2004, 368- 369). Visual preference for symmetrical objects or scenes may have a positive influence on the player’s gaze (Costache, 2012, 97), and possibly their physical movement. This is assuming that visual pleasure actually impacts navigational tendencies.

In addition to its ease of processing, our interest in symmetrical forms is evolutionarily rooted in identifying both predators and prey, each of which are often symmetrical figures. Symmetrical objects will quickly pull our attention, allowing us to identify potential dangers, or important food resources with great haste. Additionally, animals, including humans, tend to show preference for same-species animals that are symmetrical in features. Symmetry in organisms can be an indicator of overall health or fertility (Ramachandran and Hirstein, 1999, 27). These factors are a large determinant for both our preference for symmetry, and our ability to quickly process symmetrical objects and areas within an environment.

Though players may be pulled towards areas or objects of symmetry, the overuse of symmetry in games may reduce its positive perception. Symmetrical environments, or symmetrically organized spaces, may appear very strange to the player. Though sculptures, works of fine art, or newly created buildings may be symmetrical, many of the stimuli that we encounter in our life is not. Don Carson suggests that symmetrical environments may not only be unnatural, but potentially boring to the player.

> And above all give them asymmetry whenever possible. The world we live in is far from geometrically perfect, and spaces where every chair, desk, and potted plant is lined up in a grid only helps emphasize how fake your world really is! This is the same with your architectural interiors. Many architectural monuments can be perfectly symmetrical, but in our lives little else is. If you must create a long expanse of repeating pillars, or some such element, make one unique among the rest. Nudge it out slightly, or knock the thing right over, it will only add life to an otherwise mathematically perfect, but boring, environment. (Carson, 2000, 3)

This suggests that it may be best to create all game environments as appropriately asymmetrical. When the developer does decide to feature an object or area of desirability, they can then harness the appeal of symmetry. This would create interest from the inherent appeal of symmetry, and the area/object would also contrast with its surroundings, producing an environmental focal point. Bruce et al. suggest that it is beneficial for scene focal points to be symmetrical, as symmetry is more likely to stand out from a background than asymmetry (Bruce, Green, and Georgeson 1996, 116).

Contrast

The final environmental feature that will be examined as a testable wayfinding cue is contrast. Contrast is likely the single most powerful method for producing a scene focal point. If players tend to investigate visually interesting stimuli, contrasting objects and areas could be harnessed as wayfinding cues, reeling in players voluntarily.

Contrast can be produced through many object or area properties, including: shape, size, texture, orientation, luminance, depth, motion etc. (Dewitte, Larmann, and Shields, 2012, 58; Ware, 2008, 29). Contrast, as the word implies, requires the object of contrast to have a noticeably different physical appearance from its surroundings (Ware, 2008, 33).

As stated above, the effects of contrast can be intensified through the homogeneity of backgrounds. The more consistent in appearance an environment is, the greater the “pop-out” effect when an object is in contrast with the surroundings (Ware, 2008, 20). Or, the more consistent the appearance of an area, the smaller the visual disparity required to produce a contrasting item (Kopacz, 2004, 39); for example, in a room full of grey cubes, a small red cube, or a large grey sphere will have a large visual impact. Though the contrasting stimulus is only altering one object trait, the homogeneity of the surroundings increases the effects of the contrast. However, if the contrasting object is situated within an environment of great visual variety, then the features of the contrasting object may have to be exaggerated to stand out. “The more the background varies in a particular feature channel – such as color, texture or orientation – then the larger the difference required to make a feature distinct.” (Ware, 2008, 29). Though contrast as a concept is easy to understand, there are no definitive rules about how much a certain feature needs to vary to properly contrast its surroundings.

Region Contrast

It is important to note that we can produce contrast between an object and its environment, or between regions and the whole environment. Carson suggests that contrast is an important tool for creating dramatic effect, and we should provide the player with contrasting environments whenever possible (Carson, 2000, 3). By contrasting regions within an environment, we can produce areas that pull the player’s attention and presence. Visually contrasting regions can also aid in the differentiation of areas, and the development of environment mental maps (Carpman and Grant, 2002, 431, 434). Detailed mental maps of game environments aid in player wayfinding, and can be a requirement for establishing immersion within the game.

Games can communicate a changing of environment regions by altering object appearances or surface textures; for example, changing flooring and wall materials as a player steps through a door would be an effective method to portray a new region. By creating contrasting areas within an environment, we are suggesting to the player that they are entering into a new space and progressing. This may cause the player to view contrasting regions as areas of importance. Stephen Kaplan suggests that areas within an environment which appear to be important, such as unique regions, should actually be important (Kaplan, 1988, 48-49). So when a game does present a region that contrasts with the environment, this region should be important to the player’s progression.

Bates suggests that, for the sake of immersion, the appearance of a level should support a consistent graphical style (Bates, 2004, 110-111). However, Arthur and Passini suggest that in a real world environment, destination zones need to be properly articulated through differentiation. Regions within an environment must differentiate themselves, for wayfinding purposes, through distinct visual features. The more visually homogenous the environment, the less likely the explorer will be able to differentiate its regions (Arthur and Passini, 1992, 87). Fortunately, it is possible to create identifiable regions of contrast, while still maintaining a consistent graphical style. As contrast can be established through multiple different channels, game artists have a variety of options for making a region stand out, while maintaining stylistic consistency.

Our ability to group and differentiate regions within an environment is reliant on two main factors: identity and equivalence.

> *Identity*… is the characteristic that allows us to differentiate one space from another. Equivalence is the characteristic that allows us to group them into zones along some common traits. In order to distinguish one destination zone from another, the zones must have distinct features, but the spatial units within a zone have to have some common characteristics. (Arthur and Passini, 1992, 87)

To maintain the illusion that the player is in a consistent, real environment, all regions within an environment should demonstrate some equivalence. This ensures that the clash of region appearances is not too intense, and that regions which do contrast could feasibly exist within the same environment; for example, if the player is moving between a rocky chasm and a dense forest, the natural objects should remain consistent in graphical styles. The forest could be scattered with small rocks which resemble stone walls of the chasm, and the chasm could sporadically feature trees.

Ultimately, by presenting players with regions of contrasting appearances, games are aiding in player wayfinding, providing visually interesting stimuli that grabs their attention, and enabling the creation of mental maps. All of these are positive features that will aid the player in navigating and understanding the game's environments.

Figure-Ground Contrast

In addition to regions of contrast, individual objects of contrast also have a high potential for wayfinding/attention-grabbing. Environment focal points can be produced through contrast, by creating a disparity in appearance between an object and its background. When an object clearly stands out against its background, due to its uniqueness or physical location, this is often referred to as the "figure-ground effect". This effect allows us to see objects in the environment as separate entities from their setting/background of the scene. This aids in the visual isolation and attention dedicated to objects (Hackett, 2014, 15).

The background of a scene is often less visually interesting, and more uniform than the figure (Hackett, 2014, 18). Ware suggests that an object can "pop-out" when it is differentiated from a background of homogeneity. Contrast in colour, size, motion, and orientation can all create a pop-out effect, establishing a figure-ground contrast (Ware, 2008, 29). The more variety in the background's visual stimuli, the stronger the contrast required between the figure and ground. The more homogenous the background, the lower the intensity of contrast required. If contrasted effectively, small objects can create effective focal points within large homogenous environments (Kopacz, 2004, 39). Objects will contrast with the background when any of its features vary greatly with that same feature of the background (Ware, 2008, 29, 33).

When contrast of an object and its environment is not sufficient for pulling attention, developers can physically separate objects of focus from their surroundings. This isolation will enhance the object's ability to stand out (Bitgood, 2010, 8; Bitgood, 2013, 35). However, physical separation of an object will reduce the potency of the contrast between the object and its background. The closer together the contrasting features, the greater the pop-out effect from contrast (Kopacz, 2004, 49). If emphasis of an object is the key goal for an area, then physically isolating the focal point from other objects is a sensible path forward. However, if the developer wants to create an object that is in high contrast, the object of contrast must have objects to contrast with.

High-contrast objects, as scene focal points, will be visually inconsistent with the surrounding area. While this inconsistency is required to create contrast, features that are too incongruous may pull the player out of immersion. If engaging their creativity, the developer can create contrasting focal points that align with the established visual style of the area; for example, a large angelic statue amongst a cemetery of small headstones will be high in contrast due to its size and form. However, it is still thematically and environmentally appropriate for the scene. Using objects of high contrast within an environment may be an effective method for grabbing the player's attention, and redirecting their navigation.

Other Ideas

All of the ideas discussed above were well supported by sources from multiple disciplines. They are also wayfinding concepts that can be interpreted into testable lab scenarios. However, research into various topics of study have provided additional wayfinding strategies that will not be tested through trials. These ideas, discussed below, may provide value as techniques for improving wayfinding efficiency.

Door Protrusion

Arthur and Passini suggest that entrances are more prominent when they either project or recess from the surface on which they are located. This strategy may be effective for highlighting important doors or entrances within a game environment. Additionally, this technique may be most useful when the navigator is approaching the entrance from an oblique angle (Arthur and Passini, 1992, 118, 139).

Artificial Depth

Colour can be used to create artificial depth within scenes. It is a technique that is heavily used within fine art, but its application in digital environments is undocumented. Various comparisons between colour hue, intensity, and lightness can communicate the relative distance of a stimulus. "Advancing" or "retreating" colours may appear closer or farther from the viewer, purely based on their hue.

When equal in saturation and intensity, red objects will often appear closer to the viewer than blue objects (Ross, 1974, 51). However, in lower-light conditions, when the eye is more sensitive to blue, blue will likely appear closer than red (Ross, 1974, 52). Colour depth can also be produced through the general categories of warm and cool colours. Assuming consistent saturation, warmer colours (red, orange, etc.), will typically appear closer to the viewer than cool colours (blue, green, etc.) (Kopacz, 2004, 128).

In a landscape that is homogenous in appearance, depth can be produced by contrasting the value and saturation of colours of the same hue. When comparing colours of the same hue and saturation, those which that have a higher value (lightness) will most often appear to be closer to the viewer (Dewitte, Larmann, and Shields, 2012, 82; Kopacz, 2004, 126). When similar in hue and value, colours that have higher saturation tend to be perceived as advancing colours, and those with lower saturation tend to be seen as retreating colours (Kopacz, 2004, 130).

In general, objects that are coloured to contrast their background will appear closer than objects that are coloured similarly to the background. This is because atmospheric particles between the viewer and the object will scatter light. The larger the distance between the object and the viewer, the larger the variation between the object's "inherent contrast" (the contrast of the object with zero colour distortion), and the "effective contrast" (the contrast of an object viewed at a distance) (Ross, 1974, 49). The greater the distance between the viewer and the object, the lower contrast between the object and its background.

If the player is provided an overview of a game environment, colour depth could be used at great distances to make a landmark appear farther or closer. If a landmark is coloured to artificially appear closer, this may influence the player to visit this landmark over other distant landmarks. Or it could be used to exaggerate a variance in depth that may already exist between landmarks in large open-world games.

Chapter 2 - Methodology

This chapter outlines the methodology of creating testable game scenarios to observe the effects of the new in-level cues outlined above. Environments were created in Unreal Engine 4 to measure each cue's navigational impacts on research participants. Each environment, or "hallway", represents one of the general wayfinding categories stated above, with most categories represented by several hallways. These hallways were structured to enable an accurate depiction of a wayfinding cue, record participant choices, and feature easily traversable terrain. In Chapter 3, the data from the trials is statistically and qualitatively analyzed to observe if the wayfinding cues had a significant impact on navigational choices.

Participants

Testing the new in-game wayfinding cues involves creating research environments which could be traversed by research participants. A total of 37 research participants have been gathered from the research participation pool at the University of Alberta to test these environments. The students are enrolled in either Psychology 104 or 105 during the summer of 2015. As a requirement of the study, research trials are to take no longer than 50 minutes to complete. This study received approval from both University of Alberta's Research Ethics Board, and the Department of Psychology's Research Participation Program.

Of the 37 total participants, 22 self-identify as female, and 15 as male. The following metrics are also recorded: participants' ages, number of hours per week spent playing video games, and dominant hand. Participant ages range from 18-41, with the mean, median, and mode ages of 22.4, 21, and 20, respectively. Hours of videogames played per week have a range of 0-30, with a mean, median and mode of 6.77, 3, and 0, respectively. Of the 37 participants, 34 are right hand dominant, and 3 are left hand dominant.

Materials

To test the effectiveness and game applicability of the new cues, digital scenarios were created to interpret and implement each of the cues described above. Participants' decisions in these digital hallways, as represented by their physical movements, indicates which cues the participants are physically pulled towards. A greater description of the game environments, their mechanics, and accompanying images is shared below. For additional detail on the computers used, and the testing setup, please see Appendix C: Computer Specifications, Testing Setup, Camera, and Lighting.

To ensure proper ethical practices and procedures, the trial's questionnaire, protocol, consent, alternate task, debriefing forms, and digital scenarios, all received approval from the University of Alberta Research Ethics board, and the Department of Psychology's Research Participation Program. To view the consent, debriefing, and protocol forms associated with this study, see Appendix D: Research Trials Documents.

Design

The digital hallways were constructed in Unreal Engine 4, and represent game-like scenarios of the wayfinding cues discussed above. These hallways are linear environments that offer an entry section, where the camera will arrive in each hallway, and two distinguishable exit areas divided by a centre wall. One of the exit areas will contain stimuli structured to represent a visual wayfinding cue that was supported in one of the above categories. The other exit will not contain this stimuli, or will structure this same visual stimuli so that it does not represent the wayfinding cue. The environments are crafted as physically linear hallways to provide optimal control over the participants' movements, and to ensure that they see all the necessary visual stimuli.

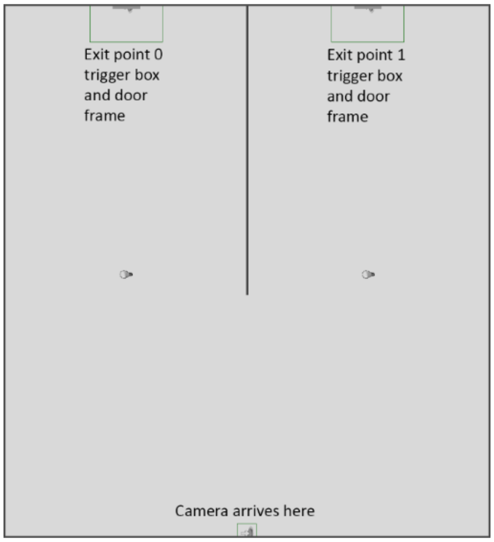

Figure 2-1 - Overhead view of a standard room. - Unreal Engine 4

Nearly all of the hallways follow the general shape depicted in Figure 2.1. However, to better communicate the visual stimuli and the represented cue, some are elongated or shortened, feature only a single exit point, or may contain turns.

All major surfaces in the environments, the floors, walls, roof, and centre walls, were all mapped to allow for several textures to be applied to a single surface. The floors and roofs were divided into four identifiable sections: Entry 0, Entry 1, Choice 0, and Choice 1. The walls help support these regions. This enables the creation of multiple distinguishable regions within the same hallway. These areas can further be differentiated by the inclusion of other visual features.

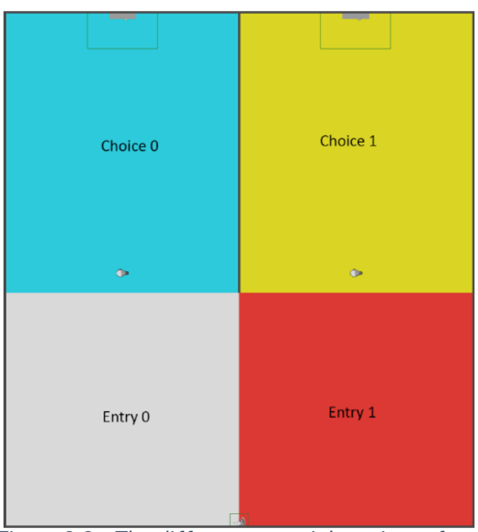

Figure 2-2 - The different material sections of a standard room. - Unreal Engine 4

The choice sections are the areas of space, divided by a centre wall, that are immediately in front of the hallway's exit points. They stretch towards the entry area from the back wall, terminating at the end of the dividing wall.

The entry sections are necessary areas of space that enable priming and visual differentiation. They provide a buffer of space between the camera spawning point (where the participants start in the hallway) and the beginning of the choices sections. This ensures that as the camera spawns, it is able to provide a view of the entirety of the choice sections. For some areas, the entry section is lengthened to allow the hallway to establish a visual style before the participant encounters the choice areas. This permits the creation of visually contrasting sections in the environment, by priming the players in the entry, then continuing this primed visual style in only one of the choice sections.

The centre wall is a 10 cm thick wall that is placed in the centre of the hallway, connecting with the back wall, extending the length of the choice sections. Unless otherwise specified, the distance between the participant starting point and each exit is equal for all scenarios.

The basic processes for testing is as follows: the participants' camera is spawned in the first hallway where, based on the visual stimuli present, participants decide which choice area they find more physically pulling. With their decision made, the participants then travel towards the exit of the chosen area. As the participants are forced to choose one of two exits to advance in the trial, this is a two-alternative forced-choice procedure. Once the participants have reached the exit point of their choice, their camera is transported to a refresher room, where it will remain for several seconds. The refresher rooms act as a buffer of time between the hallways, reducing associations or priming that may occur. Next, the participant is automatically transported to the next hallway, and the cycle starts again until all hallways have been experienced.

Once the digital hallways are completed, the participants are then provided with a questionnaire. For each hallway, the questionnaire presents an image of the hallway, in the order that they were experienced, and a small text box for participants to type in. It asks participants which choice they selected, and to discuss their rationale for why they made their decision. This will reveal the basis for their preference. For additional information on the questionnaire, please see Appendix E: Questionnaire Information.

As the participants for this study are students of various ages, backgrounds, and gaming experiences, all aspects of the test are created to assume the lowest level of gaming experience. The environments, control scheme, avatar, etc. are all tuned to be highly approachable. Though originally set in the third-person, certain aspects of the avatar animations and model may have an influence on participants' choices; for example, the avatar's stance animation had it leaning to one side and the colour of the avatar may have a priming effect on participant choice. To combat this, the avatar has been removed from the scenario and the camera has been moved to a first-person perspective. The angle of the camera and the layout of the environments have been adjusted to provide maximum visibility of each testing hallway. If the tested visual cues prove effective, these strategies could be applied to game levels of both a first-person and third-person perspective. For additional information on camera positioning and environment lighting, see Appendix: C below.

A single method of camera control is available to the participants. The control scheme is simplified to ensure that gaming experience would not be a requirement for trial completion. All of the navigation within the trials is executed through either the directional arrow keys, or the WASD keys. The directional arrows move the onscreen camera in the corresponding direction, and the WASD keys move the camera forward, left, backwards, and right, respectively. The option of two different input methods allows for increased compatibility with participants with either dominant hand.

Though a simplified control scheme enables all to participate, it also poses challenges to development. The most glaring handicap of this control scheme is the lack of camera rotation. The camera is fixed to always face towards the environment exits. This reduces the chances that the participants can become disoriented when navigating the environments, but it also restricts participants' ability to look around the environment. However, the environments are specially crafted to enable the participants to explore and see the entirety of the hallway's features, without the need to rotate the camera. The placement of the camera, the arrival point, and the layout of the environments ensure that the participants have a full view of the environment and its content as their camera is transported to the hallways.

Attached to the camera is a capsule-shaped collision mesh, approximately 0.8 m in diameter, and 1.8 m in height. This capsule is a representation of where the body of the avatar would be in the scenario. This body is vital for the recording of participant choices. In video games, objects in the environment feature invisible meshes that surround them. These meshes aid in *collision detection*, indicating if multiple objects, or if the player and an object, are in physical contact. When the player collides with a large object, their progress in that direction is halted by the contact of the two meshes.

When initially designed, the test environments were created to replicate the experience of a game environment, featuring full collision of the player and their environment. However, as the trials need to accommodate for those with a low familiarity with games and their systems, the environments needed to be easily navigable. If collision meshes were enabled on all environmental features, participants with a low level of gaming experience would frequently become stuck in environments. As the control scheme is highly simplified, removing actions like jumping and rotating, it may be very difficult for participants to navigate around environments that are highly populated with collision-enabled objects. Because of this, collision detection was removed from all visible objects, apart from the actual hallway structure. This permits the creation of environments that are densely populated with assets, without the risk of frustrating the participants. Thus, all placeable objects in the environment, despite their size, will not affect the participants' forward progression.

Within the hallways, participant choices are recorded by the game engine for later analysis. *Trigger boxes* surround all of the exit doors, extending as a 1.5 m box from the exit point. As the avatar capsule overlaps with the exit trigger box, the game engine detects which exit the participants have chosen, the camera is transported to the refresher room, and the participants' choices are stored by the game engine.

A large number of the wayfinding categories have both a *baseline test* and a *scenario test*. Baseline tests are designed to test the basic principles that the wayfinding hypothesis proposes. The environments and stimuli they contain are minimalist, featuring only the visual stimuli necessary for communicating the principles of the hypothesis; for example, in a hallway that demonstrates the basic principles of implied lines, only the objects required for creating the implied lines will be placed in this hallway. These baseline tests aim to reduce the amount of confounding stimuli that may be present during any of the tests. This creates observable results for the most basic implementation of the hypotheses.

Scenario tests are alternate test hallways that will also measure the effectiveness of the cues, but in a much more game-like setting. They will feature more detailed environments that will emulate how these cues may be applied in a game setting, while still providing valuable testing results. These hallways will also test the effectiveness of these visual cues for pulling the attention of the wayfinder when the cues are competing for attention with other stimuli in the environment; for example, in a scenario version of an implied line test, the objects required for the implied lines will also be accompanied by other objects that may naturally occur in a game-type setting. It should be noted that in some scenario tests, because they are comparing multiple stimuli, more than a single feature will differ between the two choices. As such, it is possible that visual factors outside the tested cues may have an impact on participant decisions.

The wayfinding categories tested below include: Material Lines, Implied Lines, Shorelines, Complexity, Symmetry, Density, Nature, Change Blindness, Region Contrast, Figure-Ground Contrast, and Depth. The categories contain a varying number of test hallways, each with a corresponding number (Nature 1, Nature 2, Complexity 1, Complexity 2, etc.). Additionally, each of the hallways below will have an order number (22nd Hallway, 8th Hallway). This number represents the order in which the hallways were experienced by the participants during the research trials. The order in which the hallways are presented below is not representative of their testing order. The hallway order was randomized to avoid any priming from the sequential experience of hallways in the same category.

To simplify the statistical analysis in the third chapter, all of the stimuli that are in support of a category's wayfinding hypothesis will appear in choice 1. Unless otherwise stated, the contents of choice 1 will embody a wayfinding cue discussed in the first chapter. Though choice 0 may have be similar in appearance to choice 1, it will not contain the visual cue that is in support of one of the wayfinding categories. As such, if a significant number of participants select choice 1 in any given hallway, this will be in support of the corresponding wayfinding hypothesis. In other experiments, these choices may be described as the control and experiment group. However, these titles are not necessarily applicable to the choices available here. Simply put: the stimuli in choice 1 support the wayfinding hypothesis, the stimuli in choice 0 do not support the wayfinding hypothesis.

Much like the hallway order, the side on which choice 1 and choice 0 are located for each hallway is also randomized. For additional information and rationale on the hallway randomization, the choice side randomization, and the test versions, please see Appendix F: Test Randomization, Inversion, and Versions.

The physical measurements for the most common hallway layouts are as follows:

	Standard Hallway	Elongated Hallway
Choice Sections	12 m length, 10 m width	11.5 m length, 8 m width
Entry	10 m length, 20 m width	21 m length, 16 m width
Total	22 m length, 20 m width	33 m length, 16 m width

Table 2-1 - Dimensions of the most common rooms

For all the descriptions below, the X-axis represents scene depth, the Y-axis represents scene width, and the Z-axis represents scene height.

For visual representations of all test hallways, and for additional supporting text on select hallways, see Appendix G: Hallway Images and Supporting Text. For all of the visual representations of the hallways located below and in the appendix, choice 1 will always be located on the right side of the image, and choice 0 on the left. Again, this is not a representation of how the hallways were experienced by the participants.

No Differentiating Stimuli - 21st Hallway - Standard Hallway

This hallway is free of differentiating visual stimuli (see Figure G-1 below). It has no materials, lighting, or objects that differentiate the left or right sides. It is designed to test for right or left side bias in the participants. Humans have demonstrated a fairly large right side bias when moving through spaces with no differentiating features.

Arthur Melton has found that in symmetrical museum exhibits, visitors have a “strong tendency” to turn right when entering a space, and move in a counter clockwise pattern (Bitgood, 2013, 36). Paco Underhill has echoed this, suggesting that in both retail spaces and art galleries, visitors tend to turn right, starting a counter-clockwise search of the environment. However, this may be due to driving laws, as those from Japan, Britain, and Australia, who drive on the left side of the road, tend to explore galleries in a clockwise movement pattern (moving left first) (Underhill, 2009, 78).

Unfortunately, neither Melton nor Underhill quantify humans' left or right navigational tendencies. However, Taylor and Sucov have demonstrated that in a corridor with left and right exits, when illumination is equal, wayfinders tend to travel right 69% of the time (Ginthner, 2002, 2-3). As such, it is important to observe if these tendencies will exist within a game-like environment.

Material Lines

In two-dimensional art, using implied or real lines in a scene can create an effective visual pathway for a viewer's eyes to travel towards a destination (Dewitte, Larmann, and Shields, 2012, 47-49, 53, 136, 137, 140; Mulligan, 2004, 54; Zakia and Page, 2011, 21). In a game environment, developers may be able to use lines to guide the player's eye towards important stimuli within the environment. As wayfinders can navigate through ground-based visual stimuli (Carpman and Grant, 2002, 431), this provides a massive canvas for in-game wayfinding cues. Lines embedded within game materials may provide an organic platform for introducing eye leading lines within a game scene. Materials with visible lines could be oriented to point towards important level features, or to guide the player down the primary path. While the effects of lines within a 2D scene have been demonstrated, their effectiveness in a dynamic 3D scene has not been tested.

Material Lines 1 - 1st Hallway -Baseline Test - Standard Hallway

This hallway examines the effects of basic lined materials within a game environment (see Figure G-2 below). In Choice 1, which supports the wayfinding hypothesis, black lines extend from the camera spawn point, straight to the opposing wall's exit. If the participant follows these lines with their eyes, it may draw their gaze to choice 1's exit. In choice 0, which does not support the wayfinding hypothesis, the material lines have been oriented to be parallel to the exit, making it less likely that the participants' eyes will travel along the lines towards the exit point.

Both ground materials, in choice 0 and choice 1, are identical in all features except orientation. Symmetrical cube objects were placed at an equal depth within each choice section to help the participants distinguish the relative depth of the exits.

Material Lines 2 - 12th Hallway - Scenario test - Standard Hallway

This hallway also tests the effects of material lines on wayfinding preferences. However, as a scenario test, it uses materials that emulate textures that may be used in a real game setting (see Figure G-3 below). White lines have been embedded within a wooden material, which may be perceived as the caulking or glue that holds the flooring together. These lines also emphasize the orientation of the material. Normal maps and reflective information were applied to both the lines and the base wood material to emphasize the existence of the lines. Both the width of the boards, and the width of the lines on the boards are identical on both sides. Wall materials further communicate the lines within the environment.

Again, based on the hypothesis presented in the previous chapter, choice 1's lines are oriented towards the exit, and may pull the viewer's eye along the lines, towards the exit point. This may influence the participants to travel to the exit of choice 1. The lines in choice 0 are parallel to the exit wall, and thus may be less likely to draw the participant's eye towards the exit point.

Implied Lines

Implied lines are a more covert method for manufacturing eye guiding lines. According to the Gestalt principles, our brain tends to group objects based on multiple different factors. Through the Gestalt principles of continuation, similarity, and proximity, several like objects that are in close proximity, or a smooth line, will be interpreted as a single unit by the viewer (Berdan, 2004). These principles are highly versatile, as objects can be grouped by similarity of countless different physical features (Brooks, 2015, 60). This is highly applicable in a game setting, as implied lines can be created by reorganizing pre-existing game objects to guide the player's eye and character towards a destination.

Implied Lines 1 - 15th Hallway - Baseline Test - Standard Hallway

Implied lines 1 tests the wayfinding potential of objects that have been organized into an implied line (see Figure G-4). In both choices, five cubes are repeated on the X axis, each separated by 1.7 m. In choice 1, the objects' orientations, and positioning on the Y-axis are aligned to produce a smooth line that points towards the exit. Choice 1 supports the Gestalt principles of continuity, similarity, and proximity, while producing this implied line.

Choice 0 contains a series of the same objects, with greater variance in their orientation, and staggered placement on the Y-axis. The objects in choice 0 will likely be grouped based on similarity and proximity. However, these objects do not point towards the door, and their positioning decreases the likelihood that they will be seen as a smooth line. Based on the Gestalt principle of continuity, the objects in choice 1 will be more likely to guide the eye towards the exit, which may physically influence the participants' choices.

Implied Lines 2 - 24th Hallway - Baseline Test - Standard Hallway

This hallway's choice sections feature four objects that each vary in shape, separated by 2.5 m on the X-axis (see Figure G-5). It was created to observe if implied lines could still be effective if the objects within the implied line varied in shape. Choice 0 and choice 1 feature the same objects, in the same order, with the same placement on the X-axis. The objects are still in close proximity, practice good continuation and similarity of size, colour, etc. However, the Gestalt principle of similarity between the objects has been greatly reduced, with all objects varying in shape.

Again, the objects in choice 1 create a smooth implied line towards the exit point of the hallway. The positioning of the objects in choice 0, which are more scattered across the Y-axis, suggests that participants will likely not perceive this as a line of good continuation.

Implied Lines 3 - 10th Hallway - Scenario Test - Standard Hallway

As a scenario test, this hallway features additional stimuli that create a more believable game scenario, but also offers potential confounding information that competes for the viewer's attention. In this scene, grass material flooring and brick walls house a series of rocks (see Figure G-6). These rocks, although varying in size, all have a similar appearance and share the same material. They are each separated by 1.7 m on the X-axis, and their orientation and order have been mirrored in each choice.

In choice 1, the rocks are organized to form a smooth, continuous line that leads towards the exit door. Choice 0 aligns the rocks more chaotically, terminating farther from the door. The objects in both choices follow the Gestalt principles of similarity of appearance (shape, material, and orientation), and proximity. However, only choice 1 will likely be seen as following good continuation, drawing the participant's eye towards the exit point.

Implied Lines 4 – 2nd Hallway - Scenario Test - Standard Hallway

This hallway takes a unique approach to producing implied lines. It creates implied lines on both the hallway roof and floor, through lighting fixtures and lighting reflection (see Figure G-7 for additional design details). Each side of the hallway features four fluorescent light fixtures, equally spaced, stretching from the entry point towards each exit. The props in choice 0 are oriented parallel to the rear wall, pointing away from the exit. In choice 1 they are perpendicular to the exit wall, pointing towards the exit. The orientation of the lights in choice 1 reduces the distance between the boundaries of each mesh, and creates a smooth line that leads to the exit.

These light fixtures also cast rays of light which reflect off the ground material. Again, the reflections of the choice 1 lights create a continuous, fluid line towards the door. The light's orientation in choice 0 will likely have a negative impact on the perception of a line, for both the fixtures and the light reflection. As such, choice 1 is likely to have a greater navigational impact.

Implied Lines 5 - 9th Hallway - Scenario Test - Standard Hallway

This hallway creates implied lines through several different features, while competing against distracting materials and objects (see Figure G-8). This is to observe if, in a more natural and chaotic environment, the viewer will still follow the implied line. The materials within the hallway portray an interior space, and increase the environment's realism. Benches line the outside walls of both choices to reinforce realism, and act as distractors. Implied lines in this hallway are created through a combination of bricks and planks of wood that populate the environment's floor.

In other trials, the implied lines were created through very smooth or straight lines. Choice 1 in this hallway, while still practicing Gestalt similarity of appearance, good continuation and proximity, creates a less smooth line than previous hallways. Starting nearer to the interior wall and camera, the bricks and wood planks extend towards the door, creating a semi-smooth implied line. If choice 1 in this scenario demonstrates to be effective, this may suggest that implied lines may exist amongst other game objects and still be compelling.

In choice 0, though the objects may be grouped purely based on proximity, they don't necessarily create an implied towards the door. The wood planks were purposefully oriented to pull eyes away from the exit point. The bricks also all had random orientations, and were placed to avoid drawing eyes to the exit.

Shorelines

Shorelines are features of the environment that travel along the floor-wall intersection, framing the pathway forward and differentiating paths within an environment (Arthur and Passini, 1992, 126). They can be used to emphasize a path, draw the eye towards a destination as a line, or can be positively associated with the primary path of a game as a "continuous cuing device" (Carpman and Grant, 2002, 431). The benefits of shorelines without positive association with the primary path exist in their ability to both emphasize an area by outlining it, and guide the eye towards its termination point.

Shorelines 1 - 22nd Hallway - Baseline Test - Standard Hallway

To test the innate effectiveness of a shoreline, a 1 m width, 0.5 m height shoreline outlines the bounds of choice 1, terminating at the hallway's exit point (see Figure G-9). The shoreline was darkened to ensure visibility against the lightly coloured background. Choice 0 contains no notable visual stimuli. As choice 1 contains visual stimuli, and the shorelines may draw the viewer's eye to the exit, it is likely to be the more successful choice.

Shorelines 2 - 20th Hallway - Scenario Test - Standard Hallway

This hallway tests the effectiveness of shorelines when competing with multiple distracting visual stimuli (see Figure G-10). Choice 0 and choice 1 are identical in appearance and features. However, choice 1 features a shoreline that travels along the walls and floors, framing the door and pathway of choice 1. Choice 0 does not contain this shoreline. Objects, such as benches, chairs, lights, and tables, were placed to fill the environment, portray an interior space, and act as distractions.

Complexity

The section below tests two combative hypotheses: preference for complex environments, and preference for simple environments. As outlined in chapter one, some sources suggest that humans prefer scenes of high complexity, featuring multiple unique environmental features. The more diverse a scene's visual stimuli, the more complex the scene is (Kaplan, 1988, 48). A higher complexity scene reduces the likelihood that the viewer can predict what will occur next in the scene, and we find this appealing (Kaplan and Wendt, 1972, 4).

However, other support suggests that a viewer's preference for a scene can be heavily based in their understanding of its contents. Repeated objects within an environment can make a scene easier to understand and process (Joye, 2007, 307), which can increase the enjoyment of the environment. Also, repeated exposure to a stimulus can increase our preference for that stimulus (Reber, Schwarz, and Winkielman, 2004, 370; Reber, 2011, 229). This may be highly beneficial for games, as it is common for games to frequently reuse assets.

As there is conflicting support for human preference of complex and simple scenes, these hypotheses will be tested against each other in the hallways below. In previous hallways, choice 1 has represented the exit section that best supports the tested hypothesis. However, in this scenario its assignment is arbitrary. The conflicting hypothesis creates uncertainty of which visual stimuli will be more effective at physically pulling participants. The hallways below are aimed at lending greater support, for video game wayfinding purposes, to one of the two hypotheses.

Complexity 1 - 8th Hallway - Baseline Test - Standard Hallway

To test the effects of scene complexity versus simplicity, this hallway features choice sections of varying visual complexity (see Figure G-11). Choice 0 contains identical 1m cubes, repeated seven times within the choice section. Three cubes are placed along the outside wall, and four cubes are placed along the inside wall. The placement of the cubes are uniformly staggered to ensure that, at no point, the cubes are symmetrical. Symmetry will be tested as an individual wayfinding concept below. The use of repeated visual stimuli will make this choice easy to understand, and highly legible for the viewer. If successful, this will suggest that scenes with repeated stimuli may be more visually appealing than scenes with diverse stimuli.

Choice 1 features an identical layout to choice 0, but the positioning of the items has been flipped on the Y-axis. It features 7 heterogeneous stimuli, similar in size to the cubes. These stimuli all feature the same material, which is also present on the objects in choice 0. If these shapes demonstrate to be effective at physically pulling participants, despite their homogenous colouring, this will suggest that scenes of structurally heterogeneous stimuli may be an effective visual cue for pulling in wayfinders.

Complexity 2 - 28th Hallway - Baseline Test - Hallway

Same as the hallway above, this compares the wayfinding effectiveness of a visually complex region against a simple, legible region (see Figure G-12). All objects are in the same positioning as the previous hallway.

The complexity of choice 1 is created by seven unique visual stimuli, each varying in appearance. The stimuli are differentiated through unique shapes (different from previous hallway), and unique materials, exclusive to this hallway's choice 1. While the unique stimulus seen in choice 0 is also exclusively featured in this hallway, it is repeated seven times. To produce a fair distribution of stimuli, eight unique objects were created for this hallway. One was randomly selected for choice 0, and the remaining were placed in choice 1.

If choice 0 demonstrates to be more effective at pulling the attention and presence of participants, this will suggest that visually simple environments, constructed of repeated objects, may be a more desirable wayfinding feature than diverse, complex environments. If choice 1 is effective, this would suggest that complex environments, made up of unique objects and stimuli, are preferable to simple environments.

Symmetry

Scene symmetry aids observers to more easily understand an image's contents, which can increase their enjoyment of a scene (Reber, Schwarz, and Winkielman, 2004, 364; Joye, 2007, 307). Symmetrical objects and scenes contain less information than their asymmetrical alternatives. This makes the scenes much easier to process, and thus more enjoyable (Reber, Schwarz, and Winkielman, 2004, 368-369). Humans are also attracted to symmetry due to its association with both predator and prey (most of which are symmetrical in form), and mate health (Ramachandran and Hirstein, 1999, 27).

If viewers find symmetrical game areas visually pleasing, symmetry may be strategically used to pull player's attention and presence in a desired direction. This may be particularly effective if the symmetrical area is contrasted with an asymmetrical environment. Players may find that they generally gravitate towards areas of symmetry, purely due to aesthetic pleasure.

Symmetry 1 - 14th Hallway - Baseline Test - Standard Hallway

This hallway directly compares choices that are equal in features, but with varied layouts. Both choices feature twelve repeated 1 m cubes (six per side) that flank the outside and inside wall (see Figure G-13). Choice 1 arranges these cubes in a symmetrical layout: the cubes are evenly spaced, equally distanced from the nearest wall, identical orientations, and aligned on the Y-axis. This creates an area of completely symmetrical repeated objects.

Choice 0, created to represent an area of asymmetry, features the same number of the same objects, in the same relative locations as choice 1. However, each cube is given a random rotation on the Z-axis. The cubes are also randomly moved between 0 m-0.4 m on the X-axis and Y-axis from their origin point. This creates a definitive asymmetry, while preventing the cubes from travelling too far into the player's walking path, or intersecting with a wall.

Symmetry 2 - 26th Hallway - Scenario Test - Standard Hallway

This hallway examines the effects of symmetry in a very similar format to the previous hallway (see Figure G-14). Choice 1 features twelve symmetrically placed pillars, each spaced out by 2m on the Y-axis, with consistent orientation and distancing from the nearest walls. Choice 0 features the same objects, placed in the same relative location, given a random orientation, and randomly moved on the X-axis and Y-axis between 0 m-0.4 m. Again, this creates an area of asymmetry while using the same assets as the area of symmetry.

Pillars were chosen as the symmetrically placed objects for this test as they are physical features of interior or exterior spaces that would commonly be symmetrically arranged. Materials were applied to the hallway's floor and walls to portray both a more realistic environment, and to act as distractors.

Symmetry 3 - 3rd Hallway - Scenario Test - Standard Hallway

This final test of symmetry attempts to measure the effectiveness of a symmetrical environment when paired against an asymmetrical environment that is still orderly in appearance (see Figure G-15). In the previous symmetry test hallways, the asymmetrical areas, though fully populated with items, relied on disorganization to communicate asymmetry. This hallway creates asymmetry by populating an area with an asymmetrical layout of objects.

The symmetrical section, choice 1, depicts an outdoor environment that is symmetrically populated with benches, planters, and garbage bins. Choice 0 presents the same environment as choice 1, however, some objects have been removed to create an area of complete asymmetry.

This method for creating asymmetry may present an issue, as choice 1 may generate greater appeal due to a higher object density. This may be remedied by populating the asymmetrical area with objects that are unique to choice 0, without mirroring their placement. However, this may also produce interest in the choice due to its unique, and potentially interesting objects.

Density

As suggested in the first chapter, a scene's visual complexity is often indicative of viewing pleasure (Reber, Schwarz, and Winkielman, 2004, 364; Kaplan, 1988, 48; Doherty, 2005, 24-26). In addition to the inclusion of unique stimuli, scene complexity is impacted by the density and amount of the stimuli present. Humans' eyes tend to fixate on areas of scenes that contain the highest amount of visual information, which can be produced through high object density (Mather, 2014, 84). However, other hypotheses suggest that scenes of relative simplicity can also be visually appealing, due to ease of processing (Reber, Schwarz, and Winkielman, 2004, 368-369).

As scenes of both high and low complexity/density may be visually appealing, it may be possible to create navigational cues by contrasting object densities. Continual exposure to an extreme level of object density (high or low), may make areas of contrasting density a highly appealing sight. In a large barren environment, pockets of dense stimuli will likely pique explorers' attention, providing desirable, contrasting visual stimulation. In environments of endless high density, the contrast of a sparsely populated pathway or patch may provide refuge from the bombardment of visual stimulation. Using patches, or streams of contrasting object density may be an effective method for highlighting environmental features.

To test this hypothesis, several hallways will expose participants to a visual density (in entry 0 and 1), then present a choice of opposing density (choice 1), and a choice that continues the established density (choice 0). These hallways are elongated, with an entry of 21 m, and a choice section of 11.5 m. This allows for a longer exposure to an environment density prior to the participants' arrival at the choice sections. These hallways have also been narrowed to a total width of 16 m. This allows for a higher density space, with fewer individual objects.

For each density hallway below, the entry sections leading up the choice sections are entirely symmetrical. This is in an attempt to avoid any priming, or side preference generated through the entry area. If the entry is not symmetrical, the participants' decision may be influenced by the variance in the entry content. As the only variance in these hallways exists in the choice sections, they should be the only features that influence decision making.

Density 1 - 16th Hallway - Baseline Test - Elongated Hallway

This first density hallway presents an entry area that is highly populated with visual stimuli (see Figure G-16 for additional design details). In the entry area, participants pass through a high number of cube objects of various sizes and orientations. By briefly walking through the area of high density, participants are exposed to the visual style of the environment, establishing a high object density as the norm for this area. Choice 0 continues the visual style and density established by the entry. Choice 1 is free of visual stimuli, and offers a contrast in object density to both choice 0 and the entry sections. Due to its high contrast in density with the entry and other choice section, choice 1 will likely pull the attention of the participants.

Density 2 - 6th Hallway - Baseline Test - Elongated Hallway

Testing the same hypothesis as above, in a similar format, this hallway features entry areas which are free of visual stimuli (see Figure G-17). Choice 0 continues the aesthetic style established by the entry, featuring no visual stimuli. Choice 1 contrasts the aesthetics of the entry, featuring a high density of objects. Large cubes line the outside wall of choice section 1, and smaller cubes have been painted in with the same density, size variance, rotation, etc. as the previous hallway.

In this hallway, the exposure to an unpopulated section of space will likely influence participants to move towards the area of contrasting density. Choice 1 provides visual stimulation in an area free of visual stimuli.

Density 3 - 17th Hallway #18 - Scenario Test - Elongated Hallway

Both Density 3 & 4, observe the effects of density contrast within a game type scenario. This hallway's entry is dense in objects, including benches, street lights, chairs, tables, planks of wood, pebbles, rocks, bricks, and planters (see Figure G-18). Both of the entry sections have been populated to appear similar to a city street that is covered in debris. All of the visual stimuli within the entry sections are mirrored, creating a symmetrical space.

Choice 0 continues the aesthetic style established by the entry, surrounding the exit with debris. Choice 1 does not continue the disarray established by the entry. However, it does continue the basic visual style of the hallway, containing benches, street lights, and planters. It depicts the same scene, but free of the debris, chaos, and object density of the other areas.

Density 4 - 5th Hallway - Scenario Test - Elongated Hallway

Continuing the examination of density contrast, this hallway depicts a cobbled street of relative simplicity and tidiness (see Figure G-19). To prevent any priming or association between Density 3 & 4, this hallway was given a slightly different visual style than the previous density hallway. The entry is populated with consistent placement of benches, lights, and planters, depicting a clean, low density street scene.

Choice 0 continues the pattern established in the entry, with orderly maintenance of the hallway's visual style. Choice 1 continues of the entry's basic pattern of objects (planters, lights, and benches), but introduces objects that create a scene of much higher density and complexity. Wood planks, stones, pebbles, bricks, stone chairs and tables, all stylistically appropriate for the surrounding area, give choice 1 a high object density.

Mystery

The next wayfinding category examines the navigational influence of mystery, or promise of additional information. Due to humans' preference for scenes with mystery (Joye, 2007, 312; Kaplan, 1988, 49; Kaplan and Wendt, 1972, 4; Mather, 2014 141), players may find features of mystery appealing, giving them navigational priority. When directly compared, a pathway that is entirely visible will be less favorable than a pathway which promises additional information. Sparring implementation of mystery within a game may influence players to travel to and beyond the point of mystery as their first movement through the environment. Or, players who notice the areas of mystery will likely create a mental note to return later, as players often search environments extensively to avoid missing any content (Shbeeb and Skinner, 2012, 3).

Humans find areas of mystery interesting for a variety of reasons: the potential for uncovering further information on the environment (Kaplan, 1988, 50), our evolutionary tendencies to search our immediate environment for threats, competition, and resources (Mather, 2014, 141), and confirmation of our assumptions on what lies farther in the environment (Kaplan, 1988, 50). Based on these inherent traits, creation of regions or paths that promise further information may be used to influence the order in which the players visit regions of the game level.

The mystery test environments are the only hallways that stray from the basic straight walled shape of other test scenarios. The hallway shape, dimensions, and justification for each hallway will be discussed below.

Mystery 1 - 11th Hallway - Baseline Test - Custom Hallway

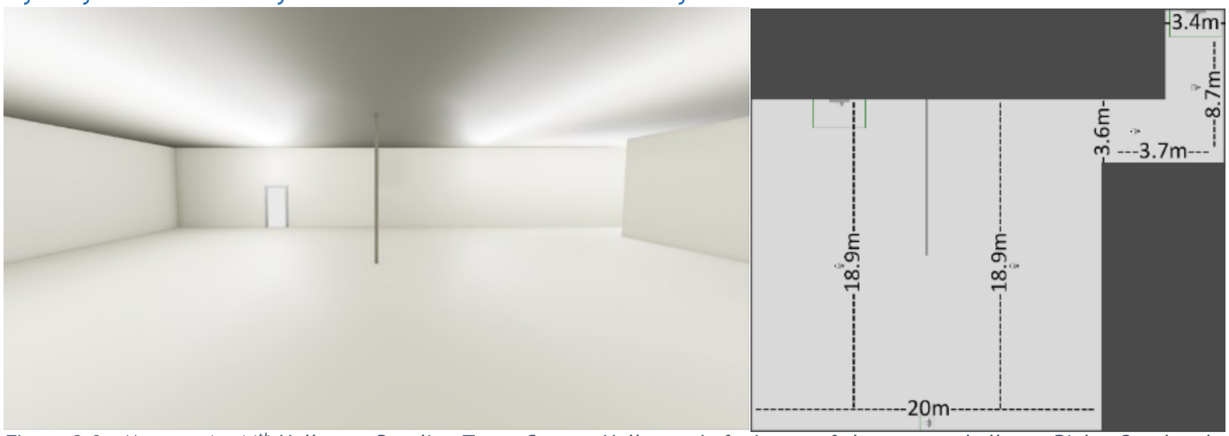

Figure 2-3 - Mystery 1 - 11th Hallway - Baseline Test - Custom Hallway - Left: Image of the mystery hallway. Right: Overhead view and dimensions of the hallway. - Unreal Engine 4

The hallway depicted above was determined as the best implementation of mystery, while maintaining structural simplicity, and ease of navigation with the basic control scheme. The hallway restricts the camera's view of choice 1's exit point, until the participant commits to moving down the mystery hallway. Choice 0 contains no mystery, presenting all of the environments' contents and exit within sight of the camera.

The goal of this hallway is to give the participants a choice between a highly visible hallway and exit, and a branching hallway with no visible exit. Choice 1 features a path that branches out at a right angle from the back of the main hallway. The opening of this branching path is a similar distance from the start point as the exit in choice 0. So, if the participants want to pursue choice 1, they are visually assured that the exit point for choice 1, if it exists, must be physically farther than the exit point for choice 0. If participants move towards choice 1, they are indicating that, although they do not know where, when, or if the choice 1 hallway will end, this element of mystery is more appealing than the assured choice 0 exit. The participants must commit to selecting choice 1 before seeing its exit, as the exit point does not come into view until they have turned the second corner of the branching pathway. For additional information on the creation and structure of Mystery 1 & 2, see Figure G-20 below.

Mystery 2 - 19th Hallway - Baseline Test - Custom Hallway

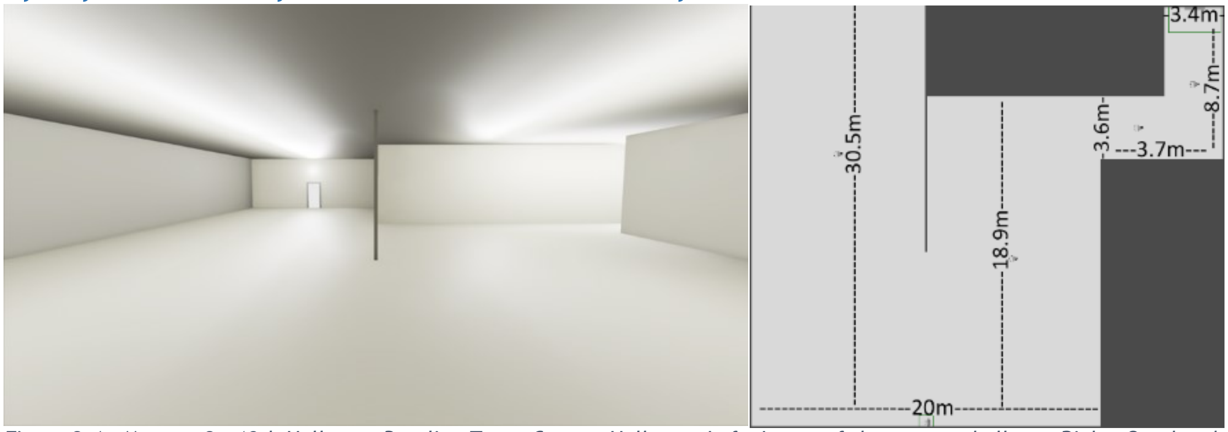

Figure 2-4 - Mystery 2 - 19th Hallway - Baseline Test - Custom Hallway - Left: Image of the mystery hallway. Right: Overhead view and dimensions of the hallway. - Unreal Engine 4

This mystery hallway has nearly the same layout, structure and lighting as the previous mystery hallway. The exit for choice 0 has been pushed back several meters, making the total length of the hall 30.5 m. However, the branching hallway within choice 1 is only 18.9 m from the start point. So, unlike the last mystery test where the participant knows that the exit in choice 0 is closer than the exit in choice 1, the more efficient option is less clear in this scenario. As the mystery path for choice 1 initializes several meters before the exit of choice 0, the participants cannot be assured that choice 0's exit is closer than choice 1's exit. This may make the prospect of exiting through choice 0 less appealing than the previous scenario. As such, this hallway may be the more effective mystery hallway.

Nature

The next wayfinding hypothesis to be examined is the appeal and influence of natural elements. As presented in the first chapter, extensive support suggests that humans almost universally prefer scenes of natural elements and outdoor scenes to man-made or indoor scenes (Kaplan and Wendt, 1972, 1-2; Joye, 2007, 307, 308; Mather, 2014, 128-129; Dewitte, Larmann, and Shields, 2012, 58). Even the most common instances of nature are preferred over rare and unique representations of human constructs (Kaplan, 1988, 54). While human preference for natural scenes over man-made scenes is certainly clear, this preference does not necessarily suggest that nature will alter navigational tendencies in games. If humans favor natural elements visually, but these natural elements are unable to alter our wayfinding tendencies, then their application as a wayfinding cue may be less effective.

To test the effects of natural elements on navigation, several test hallways feature various combinations of natural and man-made structures. These tests will primarily concentrate on the pulling effects of water and foliage, as these are two of the "primary landscape" qualities that Kaplan and Wendt suggest are associated with positive reactions to a nature (Kaplan and Wendt, 1972, 4).

Nature 1 - 27th Hallway - Baseline Test - Standard Hallway

Nature 1 directly compares the pulling potential of natural elements against man-made features of similar colour and size (see Figure G-22). To test this, a hallway features planters, containing statuettes in choice 0, and bushes in choice 1. This comparison examines relatively common instances of nature against unique man-made items. Due to basic human preference for natural items, choice 1 will likely have greater success pulling the participants.

Nature 2 - 18th Hallway - Baseline Test - Standard Hallway

Water is the next wayfinding device that is examined. Similar to the previous environment, this hallway measures the navigational pull of environments which contain natural features, versus those which contain man-made features (see Figure G-23). Channels were installed along the walls of the hallway, with each choice containing a different material.

The material in choice 1's channels depict animated, moving water. Choice 0's channels contain a polished stone that has been customized to appear similar to the water in choice 1. It has been altered to have a similar colour, and reflectivity to the water material, but it should be clear to the viewer that this is an artificial interpretation of water. This colour and reflectivity matching will reduce any bias that may occur due to colour and texture preference. As water is both a highly preferred natural stimuli, and a primary landscape feature, choice 1 will likely be more effective at physically pulling participants than the static, man-made marble channel.

Nature 3 - 13th Hallway - Scenario Test - Standard Hallway

Nature 3 depicts a very obvious, stark contrast between two populated environments. Choice 0 is clearly comprised of man-made structures, and choice 1 is clearly more natural (see Figure G-24). They are heavily differentiated through their comprising colours, materials, and props, each reinforcing the differing visual states.

In Choice 0, carved stone and metal create the majority of the environment's objects, including: street lamps, garbage receptacles, stone benches, brick walls, stone tiled flooring, etc. Choice 1 is comprised almost entirely of naturally-occurring objects: small to large pebbles, larger rocks, bushes of varying size, mossy brick walls, and grass. Again, the natural elements in choice 1 will likely be favored over the objects and materials in choice 0, positively influencing navigation.

Nature 4 - 31st Hallway - Baseline Test - Standard Hallway

Nature 4 is a baseline test created to observe the effects of natural and man-made materials within an environment (see Figure G-25). Choice 0 depicts an alley or walking area that has clearly been constructed by man, with the flooring and walling assembled from cut stone. Choice 1 features the same base materials on the floor and walls, however, they have been overlaid with natural materials. Grass and moss have been applied to the floor and walls, respectively, to communicate that natural features have overgrown the original man-made structures. Based on the support from chapter one, the natural elements of choice 1 should be an effective visual draw for the participants.

Nature 5 - 30th Hallway - Baseline Test - Standard Hallway

This hallway is a very basic test of the pulling potential of natural features in an environment (see Figure G-26). The choice sections are identical in size, material, lighting etc. However, choice 1 has a row of 11 evenly spaced bushes, lining the outside wall. Choice 0 does not contain any visual stimuli. This is an absolute baseline test to observe the effects of natural features when not directly competing against other stimuli, and not contrasting against man-made stimuli. It is highly likely that choice 1 will have a high success rate with the navigators.

Change Blindness

Due of the effectiveness, subtlety, and immersive potential of colour cues in games, they are an important wayfinding strategy that should be explored. Titles like *The Last of Us* have demonstrated that games can effectively guide players with in-level, environmentally appropriate colour cues. *The Last of Us* is set in a world where objects containing the wayfinding colour, yellow, could still exist in abundance, along with countless other vibrant or muted colours. However, other game environments have a much more restrictive colour palette. By harnessing change blindness, games with a niche colour palette can also use effective in-level colour wayfinding cues.

The theory of change blindness suggests that humans are often unable to detect small, gradual alterations to a scene. Colour is one of the features that can be changed in a scene without the viewer noticing (Shimamura, 2011, 18). With change blindness, players can be primed, through rewards or positive reinforcement, to follow a high contrast, obvious wayfinding colour. Then, over time, the wayfinding colour's contrast to the environment can be slowly altered until it is consistent with the saturation or brightness of the surrounding world. However, it will still be recognized by the player as the original wayfinding colour.

Additionally, by priming the players to seek out this wayfinding colour, the level is making the player more sensitive to its presence. Our brain is much more effective at locating stimuli when we have been primed to look for it (Johnson, 2014, 11-12). Even when the wayfinding colour is used in small amounts, and has been adjusted to blend in with its surroundings, our brains may still be effective at picking it out.

Though we may be change blind to any of a material's properties (roughness, specular, metallic, hue, etc.), this test will only focus on the saturation of colours. As high saturation colours are often easily spotted, altering a colour's saturation may be the most effective and subtle form of change blindness for wayfinding.

Change Blindness 1 - 25th Hallway - Baseline Test - Custom Hallway

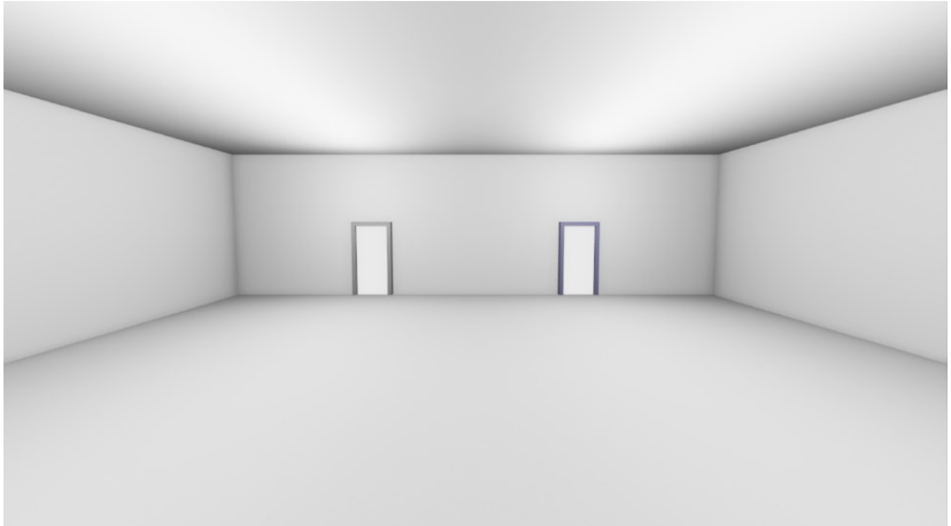

Figure 2-5 - Change Blindness 1 - 25th Hallway - Baseline Test - Custom Hallway - Final "choice" hallway. Participants arrive at this point after the 4 prime hallways. - Unreal Engine 4

To test the concept of change blindness and how it interacts with in-game colour cues, a series of four priming hallways were made to accompany a final decision hallway. Each priming hallway contains only a single exit (see Figure G-28). The only discernable stimulus within the hallway is the door frame that surrounds the exit. In the first priming hallway, the door frame's material is a blue hue with full saturation. As there are no other visual stimuli, and no choices to be made in this hallway, the participants are forced to move through the exit. They are then automatically transported to the next prime hallway, which is a duplicate of the first. However, the saturation of the door frame is reduced by 0.15 (saturation is on a scale from 0-1). This trend continues for two more hallways, until the participants have experienced four priming hallways, each reducing the colour's saturation by 0.15. For a numeric representation of each frame's colour values, see Table G-1.

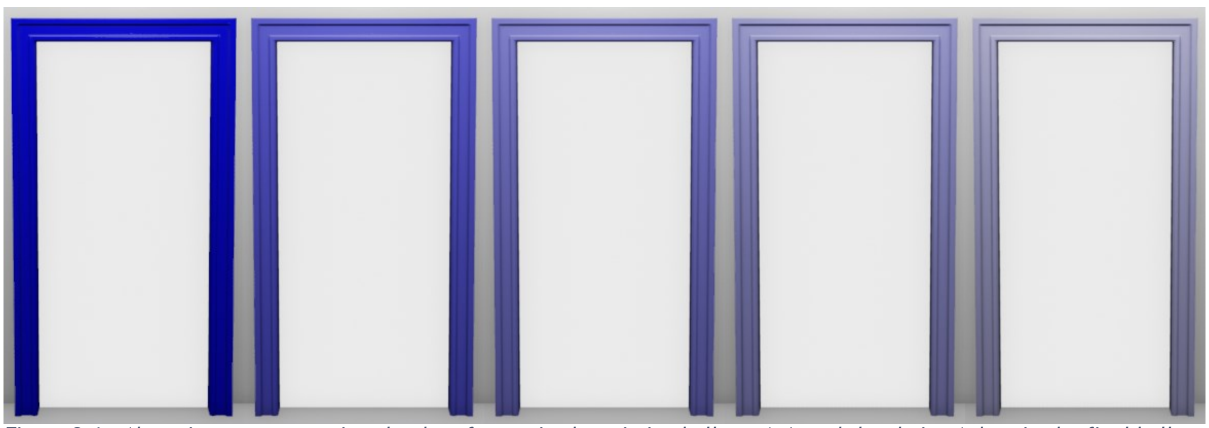

Figure 2-6 - Above is a representation the door frames in the priming hallway 1-4, and the choice 1 door in the final hallway. From left to right, the doors have a consistent blue hue and brightness, but with an altered saturation. The saturation values are as follows: 1, 0.85, 0.7, 0.55, and 0.4. - Unreal Engine 4

After the final priming hallway, the participants are transported to a choice room, standard in size and layout, which contains two exits, but no dividing wall (see Figure 2-5). Again, the only visual stimuli present are the frames around the exit points.

The choice 1 frame continues the trend of the primed rooms, with a material saturation 0.15 lower than the previous prime frame. This frame is the same base hue and brightness as the original primed frame, with only 40% of its saturation (saturation value reduced from 1.0 to 0.4). It retains a slightly discernible blue hue. Choice 0 presents a door frame with equal brightness to the frame in choice 1, however it has a saturation value of 0. This gives it no discernable hue, appearing grey in colour. If participants associate the blue colour on the choice 1 door with progress, as established in the priming areas, then it will likely have a high wayfinding success. For additional design details on the hallway, see Figure G-27.

Region Contrast and Figure-Ground Contrast

As examined in the first chapter, contrast is an effective tool for pulling attention. It is heavily used in fine art and visual design as a method for drawing the eye, and creating dynamic and enticing scenes. It can be produced through countless environmental features, including: texture, colour, size, shape, and depth (Dewitte, Larmann, and Shields, 2012, 58; Ware, 2008, 29). When an object visually clashes with its surroundings in any of the above features, it will be in contrast with the environment. Or, numerous features can contrast with the environment as a whole, creating regions of visual contrast. In a game setting, visual contrast may invite the viewer to travel and investigate the contrasting stimuli.

Contrast between regions can be established through multiple region features, including: overall colour palette, asset shape and form, topography, etc. In addition to pulling attention, contrasting regions can aid explorers in navigation by enabling the creation of mental maps of the environment (Arthur and Passini, 1992, 87; Carpman and Grant, 2002, 431). Environments that do not contain any visually distinguishable sections can be very difficult to navigate (Carpman and Grant, 2002, 431, 434). The more homogenous an environment, and the less visually distinguishable its regions, the more difficult it will be to map and navigate (Arthur and Passini, 1992, 87).

Kaplan suggests that environments that are designed to draw attention, perhaps through contrast, should have some importance to the explorer (Kaplan, 1988, 48-49). Developers can follow this suggestion by pairing a change in visual style with advancements in the game's story. If this association is made, players may actively seek out and move toward areas that visually contrast with the surrounding environment. However, the tests below will observe participants' tendencies to naturally move towards contrasting regions purely due to their aesthetic appeal.

By introducing a single item that contrasts with the surrounding scene, these objects are pushed to stand out from their background, producing an environment focal point and "figure-ground" contrast

(Hackett, 2014, 15, 18). These features can effectively draw a viewer's attention to a location in the scene. This contrast can be exaggerated in scenes that are highly homogenous in appearance. The more visually varied a background is, the stronger the contrast required between the object and its background (Ware, 2008, 29).

Figure-Ground Contrast 1 & 2, below, examine the wayfinding influence of objects of high figure-ground contrast, within visually complex and simple environments. The high contrast object developed for the tests below was created to contrast with multiple scenes of different styles. As such, it is visually incongruous with the scene. This is not suggested for actual game wayfinding cues. Additionally, though attractiveness is subjective, the contrasting stimulus was not made to be visually appealing. The goal was to make a stimulus that would pull the viewer's attention and movement due to its contrast with the surrounding environment, not because of its beauty. If effective, then contrasting objects which are visually appealing will likely be more effective at influencing movement.

Region Contrast 1 - 23rd Hallway - Scenario Test - Elongated Hallway

To create an environment that features contrasting regions, it is vital to establish a visual style that can be contrasted against. For this reason, an elongated hall was used in this test (see Figure G-29). This hallway requires the participants to walk through a 21m entry area that establishes and maintains a visual style prior to the choice areas. This style includes dark wood flooring, outdoor lighting posts, stone walls, stone benches, stone chairs and tables. This visual styling is continued until the choice areas, at which point choice 0 continues the same visual style established by the entry, and choice 1 creates a visual style that contrasts to the entry. The contrasting region is both visually distinct, and occupies a relatively small portion of the hallway. It contains lighter flooring and walls, wooden benches, chairs, and tables, and different stand lighting. The visual stimuli in both choice sections are the same in form and purpose, but contrast in the materials from which they were constructed. Where choice 0's objects are primarily stone, choice 1's are wooden.

As participants move through the hallway, they are given the option of continuing through the same visual style as the entry, or changing to a visual style that contrasts with the surroundings. Support from the first chapter suggests that participants will likely prefer choice 1, as it is in contrast with the surrounding area, indicating a change of space, and producing an environment focal point.

Figure-Ground Contrast 1 - 29th Hallway - Scenario Test - Standard Hallway

This hallway was designed to test the pulling effects of a single object of contrast (see Figure G-30). Both choice sections contain simple planters that run the length of the choice area, and the environment's surfaces have been populated with tiled stone. Choice 1 contains a single object of high contrast. This object was modelled with both spherical and square features, to ensure that it would contrast against nearly any background. It was textured with two contrasting, high saturation colours (blue and yellow), accompanied by emissive green lines. Though not modelled to be visually appealing, the object will likely be perceived as highly contrasting to the surrounding environment, acting as the scene's focal point. This hallway will demonstrate the effectiveness of contrasting objects for influencing movement, and not just grabbing attention.

Figure-Ground Contrast 2 - 4th Hallway - Scenario Test - Standard Hallway

Figure-Ground Contrast 2 is testing the same basic hypothesis as the previous hallway, but in an environment that contains a higher complexity and greater variance in visual stimuli (see Figure G-31). Aside from the high contrast object in choice 1, both choices are identical in features. The object of contrast is forced to compete with far more visual stimuli, some of which is more visually complex and intricate than the object of contrast itself. Again, if the object of contrast can pull the participant's attention and presence in this environment, then a contrasting item that is designed to be visually appealing will likely be even more successful for wayfinding.

Depth

The final test scenario is not testing a theory that was not discussed in the first chapter. It is simply to observe participant navigational tendencies when offered exit points of varying depth.

Depth 1 - 7st Hallway - Baseline Test - Custom Hallway

This hallway presents participants with a scenario where the only differentiating choice features are the physical distances to the exits (see Figure G-32). The exit for choice 1 is approximately 5 m closer to the start point than the exit for choice 0. It is designed to examine if participants will tend to favour travelling shorter physical distances, when the option is available. If either choice is highly successful, this will suggest that perceived distance may have a tangible effect on navigation choices.

Test Procedure

Four computers are available for testing within the lab, with two computers running each version of the program and questionnaire. In an attempt to produce an equal number of results from each test version, minimizing the effects of right side bias, the participants are assigned to alternating test versions.

Prior to going hands on with the digital trials, participants are introduced to the researcher, and walked through the introduction script. The intro script outlines the goals and processes of the study. Participants are then provided the required information and documents on consent and withdrawal. After participants sign the consent documents, the testing process will be initialized, and participants can begin the digital trials. After completion of the trials, the participants are provided with the digital questionnaire. Once the questionnaire is completed, participants are then debriefed on the contents of the research trial, and dismissed. For additional information on the testing procedure, see Appendix H: Testing Procedure. To view the consent documents, debriefing form, and introduction script, see Appendix D: Research Trials Documents.

In the third chapter, the results of the research trials are qualitatively and statistically analyzed to explore their success and applicability in a game setting.

Chapter 3 – Results and Discussion

This chapter will examine the results of all the participants' trial data. Data from the research trials was produced in two distinct forms: choice results, and questionnaire data. Choice results consist of the automatically generated data that was recorded as participants moved through the exits in the digital hallways. When the participants intersected with the trigger box of choice 1 or choice 0, their decision was recorded by the game engine. The questionnaire data is taken directly from the participants' open-ended questionnaire answers for each hallway. This information will help form an understanding of why each participant moved towards a particular choice. The cumulative results of these two streams of data will be presented for each hallway in the order in which they were discussed in chapter two.

Data from only 36 of the 37 research participants will be presented and analyzed. One of the students' data was omitted due to improper test procedure. Please see Appendix H: Testing Procedure for further information on this omission.

For each room, the choice results for all participants will be statistically analyzed and interpreted. This statistical analysis will be conducted through a two-tailed binomial test. The statistical information, though informative on its own, will be supplemented with participants' open-ended responses to the questionnaire. Each of the questionnaire responses have been coded to a single word of significance that best describes the participants' written answer. These coded answers will be presented and discussed in tandem with the statistical analysis. If any of the hallways produced a highly consistent choice selection or selection rationale, this may be indicative of the cue' wayfinding potential in video games.

Binomial Analysis

The statistical analysis of the choice results will be conducted to determine if, on a per-hallway basis, the number of participants who moved towards one exit over the other is statistically significant. This statistical significance will suggest that it is highly unlikely that the positive results of the hallway are due to chance or sampling error. It indicates that the majority of participants selected a choice due to features of that environment. Or, perhaps something within the opposing choice section pushed participants towards their selected exit. Once a hallway's statistical significance has been determined, the data from the questionnaire will be used to highlight which environmental features had the greatest impact on the decision-making process.

To conduct a basic statistical analysis of the choice data, a two-tailed binomial test was selected as the most appropriate method for examining the trial's results. Binomial tests are optimal for scenarios where the test has only two possible outcomes (Howell, 2013, 125). The two outcomes may or may not be equally likely to occur. Additionally, each trial within a binomial analysis is theoretically independent. Within this research, several steps were taken to ensure the independence of each trial: use of a refresher room, randomizing the test order and sides, requesting that participants make decisions on a room-by-room basis, and withholding the questionnaire until the digital test was completed.

Binomial analysis of the research trials was conducted through IBM SPSS. To properly execute a binomial test, three main pieces of information are required: the number of “successes” that were observed during the trial (the number of participants who selected choice 1, the “Observed Proportion”), the number of trials that occurred (number of participants tested per hallway), and the probability of success within the trial (the “Test Proportion”). Again, the hallway exit regions, or choice areas, offer participants two different exits to travel towards. Choice 1 contains visual stimuli that are supported by the hallway’s wayfinding hypothesis. Choice 0, unless otherwise specified, does not contain the same hypothesis-based stimuli, or has reorganized the stimuli to not support the wayfinding hypothesis. It should be noted that while selection of choice 1 may be considered a success, a high number of participants selecting choice 0 will also provide valuable information.

The probability of success for each trial, or the test proportion, is determined by the researcher based on pre-existing knowledge of a subject. For all of the trials conducted (all 31 hallways), a test proportion of 0.5 will be used. This suggests that there are only 2 possible outcomes. If the participants were to randomly select an exit without the influence of personal bias or environment features, their probability of selecting choice 0 or 1 is 50%.

Support from the first chapter suggests that participants should prefer one area of stimuli over the other, often in favour of choice 1. However, this support is based in media that differ from navigable digital environments. As such, there is no pre-existing evidence that demonstrates that these cues are effective for pulling attention within a 3D game setting. Therefore, no assumptions can be made about the probability of success for each trial. Based on a test proportion of 0.5, the binomial analysis will demonstrate if any of the hallways’ choices have a success rate that is significantly greater than 50%.

The execution of a two-tailed binomial analysis will provide a P value. The P value represents the likelihood of the observed proportion occurring based on the estimated outcome of the test proportion. With a P value of <0.05, there is <5% chance of this outcome occurring based on a test proportion of 50%, or chance. So, with a P value of <0.05, it is highly unlikely that the observed proportion, or number of successes, is due to chance. With this level of success, it is likely that the features within the environment are influencing the participants to travel in a certain direction.

Once it is determined that the environment is responsible for influencing a large number of participants, the questionnaire responses can be examined for further information. This will provide a greater understanding of which environmental features had the largest influence on participants, and thus may be the most important feature to consider when implementing this wayfinding technique in a game setting.

The null hypothesis for this research states that the visual stimuli within the environment will not have an impact on participant navigational tendencies, and there is no difference between the choice 1 and choice 0 selection success. In this case, the observed proportion is equal to the test proportion. A failure to reject the null hypothesis will occur when the number of participants who selected choice 0 or 1 is not significantly greater than 50%, and thus did not achieve statistical significance. This study will be using a standard significance level of 0.05 as a significance cut-off point. This is a common statistical cut-off point for statistical analysis of smaller samples (de Vaus, 2002, 169). Failure to reject the null hypothesis will be supported with a P value of greater than 0.05.

H_0: Observed proportion = Test proportion
H_0 = Null Hypothesis

If the null hypothesis is rejected, the alternative hypothesis states that the observed proportion of choices is likely not due to chance, and participant decisions were influenced by environmental features. Therefore there is a difference in choice 0 and choice 1 selection success.

Ha: Observed proportion ≠ Test Proportion
Ha = Alternative Hypothesis

A P value of <=0.05 will support the rejection of the null hypothesis, and suggest that the observed proportion is greater than the test proportion. This P value will state that, with at least 95% confidence, the preference that participants showed for a choice is not due to chance.

A failure to reject the null hypothesis, attaining a P value of >0.05, suggests that it cannot be assumed that any apparent preference for a choice is not due to chance. Neither of the choice sections had a strong enough influence to pull a statistically significant amount of participants. Therefore, any navigational success that a choice demonstrates may be due to sampling error or chance.

It should be noted that with a significance level of 5% (significance cut-off point of 0.05), approximately 1/20 binomial tests will be statistically significant due to chance. As 31 hallways will be tested below, 1-2 statistically significant results may be due to chance.

Coded Data

After participants completed the digital scenarios of the research trials, they were asked to complete an accompanying questionnaire. This questionnaire presented the participants with a single image of each hallway that they passed through, in the corresponding order. A text box sat below each hallway image, asking participants for an open response, describing which choice they selected, and why it was selected.

A total of 1,116 questionnaire responses were hand coded, each to a single appropriate word. As the questionnaire responses were open-ended, the rationale for each participant can vary radically within the same hallway. To avoid losing important information on the participants` responses, the overall number of code categories is 28, which is a high number of codes for a study such as this. However, when the rooms are examined individually, each room contains no more than 11 codes. The more homogenous the response to the room's stimuli, the fewer codes required.

Ultimately, a large number of coded categories were used to maintain a higher level of detailed results within each hallway. This increases the representative accuracy of the codes. Most of the codes act as either the primary, or secondary rationale for selecting a choice in a certain room. Each of these codes are vital for relaying detailed and accurate information on the decision making process for each participant, in each room; for example, the code "Prime (Positive)" only has a total of 9 responses across all hallways. However, it is absolutely vital for the analysis of the results of one hallway. By removing this code, or combining it with another code, data that is vital to a specific hallway will be lost. Condensing the number of codes would have greatly restricted the detail of information provided for each hallway.

For each hallway, the corresponding coded data will accompany the statistical analysis of the participants' choices. These codes are a descriptive outline of the visual features that pulled the participants towards their choice exit (0 or 1). The description of each coding category is outlined below in Table 3-1. These descriptions demonstrate what criteria are met by the questionnaire responses for this particular categorical code. Each code represents the rationale for why participants felt physically drawn toward their selected choice section over the alternative.

Though some codes may appear as though they would have a negative impact on navigation, in reality they have a positive impact on their choices; for example, the answers coded as "Challenge" saw a section as containing navigational challenges. This challenge had a positive effect on navigation, and drew the participant towards the challenging exit. Unless otherwise stated, the codes below represent a positive response. "Negative responses" indicate that a visual stimulus within a choice influenced the participant to avoid that exit, pushing them toward the alternative. The negative codes are marked with an asterisk(*).

Code	Rationale for Selection
Brighter	Choice perceived as having higher overall luminance than the alternative.
Challenge	Choice perceived as more difficult to travel through.
Closer	The exit was perceived as physically closer to the start point.
Colour	Explicitly stated that the colour of the choice, or the colour of its contents, pulled the participant towards this choice.
Complexity	Choice had a higher visual complexity, or more features.
Comfort	Choice and its contents perceived as comforting or comfortable.
Consistency	Explicit statement that selection was due to the visual consistency between the entry and the choice section. The choice section continues the entry's visual style.
Curiosity	Curiosity was created by the choice's features, and influenced the participant's decision.
*Dislike	This is a negative response. Participants were pushed away from a choice due to an explicit distaste for some, or all, of its content. Thus, they selected the alternate choice.
Disorder	Participants were drawn towards this choice because it was disorderly.
Ease	Choice appeared to be physically easier to move through.
Farther	The exit was perceived as the farther exit from the starting point.
Interesting	Participants explicitly state that they found an object or region more visually interesting than the alternate choice.
Like	Participants had a general preference for the aesthetics of this choice.
Line (Away)	Participants saw lines within the choice, and preferred the lines that did not lead towards the exit.
Line (Toward)	Participants saw lines within the choice, and preferred the lines that lead towards the exit, or pointed straight.
N/A	Participants did not provide their rationale, or could not remember their rationale for the decision.
Nature	The choice contains elements and objects from nature.
Natural	The layout, objects, and materials of this choice appear to be more naturally assembled, less likely to be constructed by an architect, or appears to be a more natural interpretation of the represented object, area or material.
*Prime (Negative)	This is a negative response. Experiences from the previous hallways are influencing participants to avoid environment features and select the opposing choice.
Prime (Positive)	Experiences from the previous hallways are positively influencing participants to move towards certain environment features.
Repeated	Participants explicitly state that their choice was influenced by the presence of repeated features.
Side	Selection made due to participants' pre-existing preference for side. Their decision was not based on stimuli within the environment.
Size (Larger)	Participants felt pulled towards the choice that was physically larger than the alternative.
Size (Smaller)	Participants felt pulled towards the choice that was physically smaller than the alternative.
Tidy	Choice was more neat, organized, and featured less disorder.
Symmetry	The choice was interpreted as having symmetrical features.
Other	Additional rationale for navigation which did not have sufficient consistency or volume to produce their own codes. Decisions within Other include: selecting a choice because it looks like a gymnasium, seen as more unique, it appeared to have more or fewer humans sitting in the area, environmental simplicity, a fun appearance, desiring to step on the section's content, etc. The various life experiences of the participants manifest themselves in unpredictable choices and preferences when making navigational decisions.

Table 3-1 - Outline of questionnaire codes.

It should be noted that the responses that received the "Other" code cover a wide array of hugely varying responses. Some of the answers demonstrate how much past experiences, or other beliefs and values, can influence how participants perceive scenes. It is impossible to predict how a scene will be interpreted by the participants, and these choices are examples of how varied human responses can be to the same imagery. The various participants' readings of these scenes resulted in some unpredictable assessments of the environments.

All of the coded data that is provided below is divided into two main categories: “correct” and “incorrect”. The correct choices section contains all of the navigation justifications, stated on the questionnaire, which correctly recalled the side that was selected during the research trials. The correctness of the answers was determined by comparing the participants’ written questionnaire response with the automatically recorded research trial data for the corresponding hallway. If participants were able to correctly recall which choice they selected, their rationale for making this selection, stated in the questionnaire, likely reflects their rationale during actual navigation. Incorrect choices are questionnaire answers where the participants incorrectly recall the choices they made within the research trial. As such, the justification presented within the questionnaire cannot represent their thought process within the digital environment. The results of both the “correct” and “incorrect” responses for each room are stated below.

It should be noted that an “incorrect” response is not a suggestion that the selection within the hallway was incorrect, invalid, or the non-hypothesis supporting choice (choice 0). It is simply recording the participants’ ability to recall which choice they selected. If there is a high number of incorrect responses within a single hallway, it suggests that this visual stimulus is not memorable, and thus has a lower rate of recall. Or, perhaps, though participants are misremembering which choices they made, they see the visual stimuli within their non-choice as more persuasive when seen in a static, 2D image, not in a navigable 3D environment. Additionally, these incorrect memories could provide information on which visual stimuli are the most recognizable and memorable.

Below are the results of the participants’ choices for each hallway, the statistical analysis of these results on a per hallway basis, and the compiled coded data for each hallway. Typically, research papers within the social sciences or psychology will separate the results of experiments from the discussion of the results into independent chapters. However, as this study discloses the results of many hallways, if following the traditional format, there would be a large gap between the presentation of a hallway’s results, and the analysis of these results. Because of this separation, the results and discussion will be combined. This will allow the presentation of statistical and coded data for individual hallways within a stimulus category, then immediately provide analysis and observations on this data, and analysis of the wayfinding category as a whole.

The hallways will be presented in the order that they were discussed in the previous chapter. Again, the room categories include: Material Lines, Implied Lines, Shorelines, Complexity, Symmetry, Density, Nature, Change Blindness, Region Contrast, Figure-Ground Contrast, and Depth. To further supplement the analysis of the results, questionnaire metrics such as gender, or number of hours per week spent gaming, may be included if they provide additional valuable commentary or notable results.

Ultimately, each of the hallways experienced varying successes with the test population. The successful trials are primarily located in the latter half of the tested hallways. The amount of discussion dedicated to each hallway, or theory, will be adjusted based on their success, or potential for success, and how informative or interesting the trial results are. Theories that contain multiple hallways, or produced interesting results may be recapped with an "Overview" section which summarizes important lessons from the research. The discussion for each hallway below will feature a brief outline of the hallway's features, a brief statistical analysis of the room's results, then an examination of the questionnaire results.

No Differentiating Stimuli - 21st Hallway - Standard Hallway

No Differentiation	Results	Percentage	P Value
Choice 0	17	47	0.868
Choice 1	19	53	

Table 3-2 - No Differentiating Stimuli Results

This hallway, which featured no differentiation between choices (see Figure G-1), measured the potential right or left side bias of navigators when no other influencing features were present. This hallway was constructed to feature no visual stimuli to differentiate choice 0 from choice 1, and should not influence the participant's' movement decisions. Of the 36 participants, 53% were drawn towards the right side, choice 1, and 47% were physically pulled towards the left side, choice 0. Binomial analysis of these results produces a P value of 0.434. This P value failed to reach statistical significance, and thus was unable to reject the null hypothesis. Based on an estimated test mean of 0.5, it cannot be certain that a P value of 0.868 is not due to sampling error or chance.

<table>
<tr><td rowspan="4">No Differentiation Correct</td><td rowspan="2">Choice 0</td><td>Side</td><td>N/A</td><td>Brighter</td><td></td><td rowspan="4">No Differentiation Incorrect</td><td rowspan="2">Choice 0</td><td>N/A</td><td></td></tr>
<tr><td>8</td><td>6</td><td>1</td><td></td><td>2</td><td></td></tr>
<tr><td rowspan="2">Choice 1</td><td>N/A</td><td>Side</td><td>Closer</td><td>Size (Larger)</td><td rowspan="2">Choice 1</td><td>Side</td><td>Like</td></tr>
<tr><td>8</td><td>6</td><td>1</td><td>1</td><td>2</td><td>1</td></tr>
</table>

Table 3-3 - No Differentiating Stimuli Codes

Participant selection rationale was fairly consistent across choices, with many participants selecting a side based on a pre-existing preference for direction (Side). The other equally prominent code, "N/A", suggests that a large number of participants were unable to recall how they made their decision, or were uncertain of their rationale at the time of selection. Though the choices were visually and structurally identical, some participants did make interpretations of the hallway, seeing one choice as brighter, having an exit that was closer to the start point, or being physically larger in size. These interpretations did have an impact on their navigation rationale. However, these are subjective interpretations of the scene and do not reflect its physical structure and contents.

5 participants incorrectly recalled their decision, with their rationale primarily reflecting those who correctly recalled their decisions. As the hallway had no recognizable or memorable features, it is unsurprising that some participants were unable to remember their choice, or made decisions based on a personal preference for side.

The first chapter presented evidence that humans, particularly in North America, have a "strong tendency" to turn right when entering a space (Bitgood, 2013, 36). This gravitation extends to specific spaces, such as retail stores and art galleries (Underhill, 2009, 78). In an experiment that has a very similar structure to this research, Taylor and Sucov suggested that participants tend to turn right at the end of a real world corridor in 69% of trials, all stimuli being equal (Ginthner, 2002, 2-3). This support all suggests that, in a real-world scenario, humans are likely to travel to the right side of a space first, or select the right side if given the option. Because the Taylor and Sucov experiment had a structure that is similar to this research trial, the expected mean for this hallway could be 0.69 for the right side of the hallway. However, none of these sources refer to trials within a digital scenario, or video games. Navigational tendencies and priorities within a digital medium, where risk of real danger and work required for exploration are relatively low, may have a large impact on participant wayfinding choices. Because of this difference in medium, the test proportion cannot be anything other than chance.

If the binomial analysis of the results of this hallway is conducted with an expected mean of 0.69, estimating that 69% of the participants will select the right exit point (choice 1), a statistically significant P value of 0.03 is produced. This suggests that it is highly unlikely that the results are due to chance, with results significantly lower than expected. The participants within this study were much less likely to demonstrate an inherent preference for side than humans in other real world trials. Ultimately this result suggests that humans within digital trials, and perhaps videogames, may not have a significant bias for side.

Though there was not a heavy side bias from the group as a whole, side bias or a favorite side may still have a significant impact on the wayfinding decisions of individuals. In the sample population, there were four participants who had a heavy bias for one side, not including the participant who was excluded from analysis. These participants made a notable number of their wayfinding decisions based on their preference for a certain side or direction, selecting a choice based on the “Side” code in 9-13 total hallways each. Fortunately, they did answer the remaining questions based on the criteria provided for them, thus their data was not excluded from the study. Three of these participants were heavily biased to the right side, with one heavily biased for the left side. Not surprisingly, the participant who defaulted to the left was one of the three participants within the testing pool who was left handed. The other three participants were right handed. Although these participants were of mixed gender, all four play 8+ hours of video games per week, with an average of 14 hours of games played per week amongst them. Those who play a high number of games per week, when navigating digital scenarios, may be much more likely to navigate based on preference for side than non-gamers.

Again, while side bias may be an important factor in wayfinding, within this sample, the side preference was not consistent enough to produce a significant observable bias. Summing every choice made, from all participants in all hallways, there were a total of 564 right side choices (50.5%), and 552 left side choices (49.5%). A two-tailed binomial test of the overall right/left side choices produces a P value of 0.742. This suggests that any slight preference demonstrated for the right side is purely due to chance. Creating two versions of the test ensured that if one of the hallways had highly consistent choice results, it would not supply any misleading information about right vs left side bias. Both the results of this hallway, and the overall average of right vs left choices suggest that, within this sample, there is no observable preference for the left or right side.

Lines

Fine art frequently harnesses subtle lines to draw the viewer's eye towards a scene's focal point (Dewitte, Larmann, and Shields, 2012, 47-49, 53, 136, 137, 140; Mulligan, 2004, 54; Zakia and Page, 2011, 21). As games feature a large number of structures, surfaces, or objects that could be textured or arranged to create lines, this technique may be highly effective for enticing players to investigate game level features. Three different methods for creating lines were in a 3D scene were tested: material lines, implied lines, and shorelines. Each of these strategies has different properties, and thus may vary in their effectiveness and applicability within games.

Material Lines

Hallways #2 and #3 examined the effectiveness of lines embedded in the environment's floor or wall materials, for pulling a viewer's eye and avatar towards a destination. The material lines were clearly visible within the environment's flooring and/or wall materials, using both a baseline and scenario test to observe its potential effects. If effective, these lines can act as subtle cues to the participant, and can exist within a wide variety of game environments.

Material Lines 1 - 1st Hallway -Baseline Test - Standard Hallway

Material Lines 1	Results	Percentage	P Value
Choice 0	16	44	0.618
Choice 1	20	56	

Table 3-4 - Material Lines 1 Results

Material Lines 1 (first hallway experienced by participants), is the baseline test for material lines. It depicts an environment with a basic black and white floor pattern, which produces distinguishable lines (see Figure G-2). Choice 1 and its corresponding entry, depicts floor lines that have been oriented perpendicular to the back wall, pointing towards the exit. Choice 0 features the same flooring material, but the lines are oriented to be parallel to the exit wall. This hallway saw 56% of participants selecting choice 1, and 44% participants selecting choice 0. A two-tailed binomial analysis of these results produces a P value of 0.618. This fails to reject the null hypothesis.

Material Lines 1 Correct	Choice 0	Line (Away)	Other	Farther	Closer	Dislike	Side	Brighter	Material Lines 1 Incorrect	Choice 0	Line (Toward)	N/A	Like
		3	2	1	1	1	1	1			4	1	1
	Choice 1	Line (Toward)	N/A	Like	Farther	Ease	Dislike			Choice 1	Line (Away)	Ease	Dislike
		9	2	2	1	1	1				2	1	1

Table 3-5 - Material Lines 1 Codes

Questionnaire responses for this hallway were dispersed across multiple coding categories. A large portion of those who selected choice 1 stated that the lines' orientation towards the exit was the main factor for their decision, as demonstrated by the code "Line (Toward)". The rationales for choice 0 were less consistent, with multiple codes with low instances. Of the 36 participants, 10 incorrectly remembered their choices. This suggests that this strategy may not be the most memorable wayfinding stimuli.

Though choice 1 did not reach statistical significance, the coded data suggests that some participants were positively influenced by the material lines. The mode response, “Line (Toward)”, demonstrates that more participants were influenced by the lines pointing towards the exit than the lines pointing away from the exit, as represented by “Line (Away)”.

Though a relatively small portion of codes, the number of participants who selected choice 0, but remembered selecting choice 1 due to the “Line (Toward)”, is higher than the correctly remembered “Line (Away)” codes for choice 0. This suggests that the material lines in this hallway were also effective a 2D cue, influencing participants to misremember their decisions.

Material Lines 2 - 12th Hallway - Scenario test - Standard Hallway

Material Lines 2	Results	Percentage	P Value
Choice 0	13	36	0.132
Choice 1	23	64	

Table 3-6 - Material Lines 2 Results

Material Lines 2 (12th hallway experienced) was the scenario test for the material lines category. The hallway’s lined material depicts hardwood flooring and walls, with white “caulking” lines (see Figure G-3). In choice 1, the lines of both the flooring and the walls are perpendicular to the back wall, pointed towards the exit. In choice 0, the lines of both the floor and walls run parallel to the back wall, pointing away from the exit. During the test, 64% of the participants were drawn towards choice 1, with 36% moving towards choice 0. A binomial analysis of this data produces a P value of 0.132, failing to reject the null hypothesis.

Material Lines 2 Correct	Choice 0	Line (Away)	Dislike	Like	Closer	N/A	Natural			Material Lines 2 Incorrect	Choice 0	Like
		3	3	3	1	1	1					1
	Choice 1	Line (Toward)	Like	Farther	Ease	Dislike	N/A	Comfort	Prime (Negative)		Choice 1	Comfort
		12	3	2	1	1	1	1	1			1

Table 3-7 - Material Lines 2 Codes

Questionnaire responses to this trial show inconsistent rationale for the selection of choice 0, with a relatively low mode. The majority of the choice 0 responses are evenly dispersed across the codes “Line (Away)”, “Dislike”, and “Like”. Choice 1 also features a wide array of interpretations of the scene, but more than 50% cited “Line (Toward)” as their decision rationale. Again, while not statistically significant, a notable number of participants explicitly state that the orientation of the lines toward the exit is their rationale for navigation.

Only 2 participants were unable to correctly remember their decisions, suggesting this was a far more memorable hallway than the previous test hallway. This may be due to environment features, or perhaps due to delivery order of the hallways.

Overview – Material Lines

Based on the rejection threshold of 0.05, neither of the hallways rejected the null hypothesis. By combining the results of both trials, totalling the choice 1 selections (43), and testing it with the total number of trials (72), a P value of 0.125 is produced. This, again, fails to reach statistical significance. However, Lines (Toward), for choice 1, was the largest single rationale for navigation, with 21 total codes. The most common response for choice 0, across both hallways, was "Line (Away)", with a total of 6 codes.

Ultimately, a non-trivial number of participants saw the material lines oriented towards the exit in choice 1, and were positively influenced. Due to the statistical outcome of the research trials, it is difficult to recommend using material lines as the sole, unprimed method for guiding players through game levels. However, orienting materials that contain lines towards important features in the environment will likely have minimal adverse effects on the players' wayfinding, and may positively impact the wayfinding of some players.

Alterations to the material's orientation should only occur when it will not have a negative impact on the aesthetic experience of the environment. If orienting the materials of the environment will compromise the visual style of the level, create an unappealing arrangement, or an inconsistent environment appearance, the wayfinding benefits of this strategy may not outweigh its aesthetic impact.

To expand on the testing of material lines, an environment which features material lines could be heavily populated with room-appropriate objects. This would allow us to observe the potential of material lines when visually competing for attention with other environment stimuli. It may also be worth investigating the potential of environments that solely feature wall-based material lines. These were not exclusively tested within the research trials.

Implied Lines

Implied lines present the same potential affordances as material lines: drawing the viewer's attention towards an important feature within the environment. However, implied lines are created by groups of objects, arranged to be seen as a grouped line when no actual line exists (Berdan, 2004; Dewitte, Larmann, and Shields, 2012, 53). By arranging several like objects (similar in colour, shape, direction, orientation, etc.) in a smooth line and in close proximity, a series of items can be perceived by the viewer as continuous group. These implied lines can be used to both draw the viewer's eye toward the line's termination point, and physically guide the player to a destination.

Implied Lines 1 - 15th Hallway - Baseline Test - Standard Hallway

Implied Lines 1	Results	Percentage	P Value
Choice 0	13	36	0.132
Choice 1	23	64	

Table 3-8 - Implied Lines 1 Results

Implied Lines 1 hallway examines the potential of objects repeated in a smooth line as a method for drawing the participant's eye and movement (Figure G-4). Choice 1 features a smooth line of identical cubes that point, in an implied line, towards the exit. Choice 0 features the same number of the same object, but they are not organized to be perceived as a line towards the exit. 64% of participants opted to move towards the exit in choice 1. The remaining 36% of participants, selected choice 0. A binomial test of these results produces a P value of 0.132, which fails to reject the null hypothesis.

Implied Lines 1 Correct	Choice 0	Natural	Ease	Like	Interesting	Other	Disorder	Challenge	Implied Lines 1 Incorrect	Choice 0	Line (Toward)	N/A
		3	1	1	1	1	1	1			2	2
	Choice 1	Line (Toward)	Tidy	N/A	Side	Like				Choice 1	Dislike	N/A
		9	7	3	1	1					1	1

Table 3-9 - Implied Lines 1 Codes

Questionnaire responses to this hallway demonstrate a mode response of "Line (Toward)", coded for choice 1, and a notable number of respondents influenced by the tidiness of choice 1, as represented by "Tidy". Choice 0 saw very little consistency in its codes, with questionnaire responses reporting greatly varied selection rationale. Overall, the participants who selected the choice 1 exit were influenced by its implied line, and relative tidiness. While this is may provide some positive support for the potential of implied lines, this trial exposes some critical flaws with implied lines, and their application in games.

For this test, and nearly all other implied lines tests, the code "Natural" can be seen as a persistent rationale for selecting choice 0. This code suggests that choice 0 is more organically organized, and appears to be a more naturally-occurring and believable scene. Implied lines, as tested within these trials, are a direct contrast with this thesis's goals to create more believable, immersive environments through environmentally appropriate visual cues. The arrangement of objects into an implied line, seen in choice 1, creates a scene that is unnatural in appearance, causing some participants to avoid this group of items.

Implied Lines 2 - 24th Hallway - Baseline Test - Standard Hallway

Implied Lines 2	Results	Percentage	P Value
Choice 0	18	50	1.00
Choice 1	18	50	

Table 3-10 - Implied Lines 2 Results

This hallway examines the production of implied lines through several structurally different objects (see Figure G-5). Choice 1 features four physically different objects which create an implied line toward the exit. Choice 0 features the same objects, in the same order, but are physically arranged to prevent the interpretation of an implied line. The choices saw an even split of participants, each drawing in 50% traffic. These results produce a P value of 1.00, which fails to reject the null hypothesis.

Implied Lines 2 Correct	Choice 0	Like	Natural	Side	Dislike	N/A	Interesting	Challenge	Implied Lines 2 Incorrect	Choice 0	Line (Toward)	Tidy	Ease
		3	3	2	1	1	1	1			3	2	1
	Choice 1	Tidy	Line (Toward)	N/A	Ease					Choice 1	N/A	Disorder	
		6	5	4	1						1	1	

Table 3-11 - Implied Lines 2 Codes

Similar to the responses for Implied Lines 1, there is a great variance in rationale for selecting choice 0, with “Like” and “Natural” as the most common codes. Again, “Tidy” and “Line (Toward) are the top rationale for selecting choice 1, but with a relatively low concentration due to the split in selection. There are a total of 8 incorrect answer recalls. 6 of these misremembered answers were from choice 0, primarily recalling Line (Toward) and Tidy as the reason why they chose choice 1.

Observations from these results echo those presented in the previous hallway. Again, participants do in fact see the implied lines, and it does have an influence on their navigation. However, the most common rationale for choice 1, and the hallway as a whole, is tidiness. Tidiness may be a feature inherent to implied lines, as the objects must be arranged in a smooth line to be perceived as a line. However, this also suggests that the organization of the objects into a tidy arrangement is just as important, if not more important, than the line itself.

For choice 0, “Natural” persists as a primary rationale, suggesting that the features of choice 1 appear to be unnaturally organized and assembled. This, again, is a direct contrast to this thesis’ goal of creating immersive, environmentally appropriate visual cues.

Implied Lines 3 - 10th Hallway - Scenario Test - Standard Hallway

Implied Lines 3	Results	Percentage	P Value
Choice 0	22	61	0.243
Choice 1	14	39	

Table 3-12 - Implied Lines 3 Codes

Implied Lines 3 is a scenario test which demonstrates how implied lines may be used in a game-type scenario. The floors and walls are textured with high fidelity brick and grass, and the implied lines are created from arrangements of similar, but structurally unique rocks (see Figure G-6). Choice 1 features a series of rocks, arranged to produce an implied line that leads towards the exit. Choice 0 uses the same objects and order, without intentionally directing the viewer’s attention towards the exit. Choice 0 physically pulled in 61% of the participants, while choice 1 brought in the remaining 39%. A two-tailed binomial analysis of these results produced a P value of 0.243, which fails to reject the null hypothesis.

Implied Lines 3 Correct	Choice 0	Natural	N/A	Ease	Like	Side	Implied Lines 3 Incorrect	Choice 0	Line (Toward)	Closer	Tidy	Like	Natural
		7	4	3	2	1			1	1	1	1	1
	Choice 1	Line (Toward)	Tidy	Side	Closer			Choice 1	Ease	N/A			
		7	2	2	1				1	1			

Table 3-13 - Implied Lines 3 Codes

The codes “Natural” and “Line (Toward)” were the most common questionnaire responses for choice 0 and 1, respectively. Similar to the previous implied lines hallways, participants valued choice 0 because it appeared to have a more natural and organic appearance. This may be a particularly relevant aspect of this hallway, because it depicts a natural environment. As the rocks in choice 1 were intentionally organized in a smooth line, participants found this arrangement of natural objects off-putting. This is an example response to choice 1: “I chose the left. The right seemed too unnatural and coercive.” If participants feel that they are being coerced by the environment’s features, it is clearly an unnatural, jarring arrangement of items.

Within choice 1, participants react positively to the scene’s implied lines. However, the potential benefits of the implied line arrangement does not outweigh its impediment to immersion and believability. There was a total of 7 incorrect responses, with a highly inconsistent spread of rationale. This provides little additional information.

Implied Lines 4 - 2nd Hallway - Scenario Test - Standard Hallway

Implied Lines 4	Results	Percentage	P Value
Choice 0	23	64	0.132
Choice 1	13	36	

Table 3-14 - Implied Lines 4 Results

This hallway took a unique approach to presenting implied lines (see Figure G-7). Both choice 0 and choice 1 feature the same number of the same objects, the same relative spacing, and the same light output. However, to create a more continuous and connected implied line, the lights within choice 1 were rotated to be perpendicular to the back wall. This reduces the total distance between the edges of the lights, and increases the implied line effect from the roof fixtures, and the reflection of the light on the ground. The lights and fixtures in choice 0 are oriented to be parallel to the back wall, creating a greater distance between the individual light units, and a less compelling implied line. Choice 0 and choice 1 pulled in 64% and 36% of the participants, respectively. A two-tailed binomial analysis of these results produces a P value of 0.132, failing to reject the null hypothesis.

Implied Lines 4 Correct	Choice 0	Brighter	Like	N/A	Side	Line (Away)	Closer	Dislike	Natural	Comfort	Other
		5	4	3	3	1	1	1	1	1	1
	Choice 1	Line (Toward)	N/A	Closer	Ease	Dislike	Side	Size (Smaller)	Natural		
		4	2	1	1	1	1	1	1		
Implied Lines 4 Incorrect	Choice 0	Line (Toward)	Like								
		1	1								
	Choice 1	Line (Away)									
		1									

Table 3-15 - Implied Lines 4 Codes

Questionnaire responses to this hallway produced a great variance in codes. Again, “Line (Toward)” was the most common code for choice 1, but with a mode of only 4. “Brighter”, the overall mode, received only 5 responses. Though care was taken to ensure consistent lighting across choices, some interpreted choice 0 as the brighter alternative. This unexpected interpretation of the hallway’s features suggests that the lights’ orientation had little impact on navigation. There were a total of 3 incorrect questionnaire responses.

Though not necessarily effective within a game setting, this scenario did produce some interesting results. It is the only scene within the implied lines category where neither choice is seen to be more natural in appearance, nor significantly easier to navigate. Additionally, the sub-group which plays 8+ hours a week of games had highly consistent choices within this environment. Of the gamers who play 8+ hours per week, 10/11 (90.9%) selected choice 0, creating a significant two-tailed binomial test P value of 0.012. The coded rationale for these gamers was as follows:

[redacted]

Table 3-16 - Implied Lines 4 8+ Hours Per Week Gamer Codes

However, heavy gamers were too inconsistent in their questionnaire responses to make any suggestions about the population.

Implied Lines 5 - 9th Hallway - Scenario Test - Standard Hallway

Implied Lines 5	Results	Percentage	P Value
Choice 0	21	58	0.405
Choice 1	15	42	

Table 3-17 - Implied Lines 5 Results

The final implied line scenario looks at the navigational influences of implied lines within a scene of higher object density (see Figure G-8). The implied lines were competing for participant attention with the environment's materials and other objects. Choice 1 produces an implied line through bricks and wood scattered on the floor, arranged to point towards the exit. Choice 0 features the same objects, placed and rotated to decrease the likelihood of drawing the participants' eyes towards the exit. In this hallway, choice 0 was able to positively influence 58% of the participants. Choice 1 was only able to pull in 42% of participants. Statistical analysis of this data produces a P value of 0.405, which fails to reject the null hypothesis.

Implied Lines 5 Correct								
Choice 0	N/A	Natural	Ease	Disorder	Tidy	Side	Other
	4	4	3	2	1	1	1
Choice 1	Line (Toward)	Tidy	N/A				
	7	4	3				

Implied Lines 5 Incorrect				
Choice 0	N/A	Line (Toward)	Closer	Side
	2	1	1	1
Choice 1	Ease			
	1			

Table 3-18 - Implied Lines 5 Codes

Much like the previous implied line hallways, those who moved towards choice 1 did so because of the line that it produces, and the relative tidiness inherent to the implied lines. However, this implied line still only influenced a relatively small number of the participants. Choice 0 saw a wider spread of rationale, with its natural layout again playing a role in participant selection, in addition to other various rationales. There were a total of 6 incorrect recalls.

This hallway provides some important information on the potential application of implied lines within video games. It produces implied lines through a series of small, ground-based objects, each no more than 6 centimeters tall. However, some participants, coded by "Ease", still found them a challenge to navigate around. Whenever a series of objects create a line, they will invariably create some sort of barrier, preventing participants from travelling in a certain direction. All implied lines tests were created to ensure that the objects in the line were not blocking the straight path to the exit. However, many participants still saw these objects as obstructions to their progress. These are not imposing structures, but even posing a semblance of a barrier is enough to deter some participants from moving towards these objects.

Overview – Implied Lines

Implied lines have not demonstrated to be an effective method for physically drawing in explorers. Not only because of the lack of statistical significance, but because the hallways produced consistently weak modes. Participants certainly did see the implied lines in some scenarios, and were positively influenced by these lines, but these numbers were consistently low, and the success of choice 1 was frequently boosted by environment tidiness.

Perhaps more importantly for this thesis, some participants interpreted the implied lines as artificial, coercive, and even ominous. They were deterred from environments that were clearly organized by a guiding hand. This drove participants to move towards choice 0, as the object layout was relatively natural and organic in appearance. This interpretation is in direct contrast to the mission of this thesis: to increase the number of wayfinding techniques that are environmentally appropriate, and to aid in the establishment of immersion.

If the participants see certain stimuli as assembled by an architect or designer, this directly counters the intentions of the thesis, and will act as a shock to immersion. Ed Byrne suggests that players should not be aware of the hands that assembled game levels: "…the more aware the player is of the level designer's influence, the less fun the level will be, just because it's obvious that things have been engineered to happen artificially."(Byrne, 2005, 65) By using implied lines as a method for guiding the player, we may be pulling back the curtain on environment design, and showing too much of the level designer's influence.

As an unintended side-effect of these tests, it appears that aligning objects in an implied line to direct the player could be used to create an ominous, or creepy game tone. So, if the developer wishes to create a foreboding scene, then use of implied lines may be an effective strategy.

As the arrangement of implied lines in choice 1 often had objects terminating near the exit point, participants saw these objects as obstacles to forward movement. Future tests of this concept should ensure that the implied lines are established well outside of the participants' predicted walking path. Another environmental factor which had a heavy, but unintended influence on participant choices was tidiness. As smooth or straight organization may be a requirement for implied lines, they will naturally be perceived as more organized or tidy than a random distribution of objects. To avoid bias created by environment tidiness, both hallways should produce implied lines. However, choice 0 will not point towards vital scene information or the exit, and choice 1 will continue to highlight the appropriate environment feature. This may remedy any skewing "Tidy" codes.

Due to the lack of success and potential negatives of my implied lines, they cannot be recommend as an effective method for wayfinding in their current state. Unlike material lines, this cannot be suggested as a casually implemented wayfinding cue. Organization of implied lines within the environment often requires a much greater impact of area features. It also may act as a jarring feature that is visually incongruous with the surrounding areas, deterring participants from investigating its destination.

Shorelines

The following two hallways were designed to test the wayfinding potential of indoor, unprimed shorelines. Shorelines can be placed along the ground, or at the intersection of the floor and wall, outlining the bounds of a space and "distinguishing the access path" from its surroundings (Arthur and Passini, 1992, 126). The tests below observed the effects of shorelines, unprimed by positive association, in a baseline and scenario test.

Shorelines 1 - 22nd Hallway - Baseline Test - Standard Hallway

Shorelines 1	Results	Percentage	P Value
Choice 0	16	44	0.618
Choice 1	20	56	

Table 3-19 - Shorelines 1 Results

This hallway presents participants with a basic shoreline hallway (see Figure G-9). Choice 0 has no distinguishable stimuli, and choice 1 contains a simple, dark blue shoreline that runs along the ground/wall intersection towards the exit point. Choice 1 pulled in 56% of the participants, and choice 0 pulled in the remaining 44%. The statistical test of the data produces a P value of 0.618, which fails to reject the null hypothesis.

Shorelines 1 Correct	Choice 0	Ease	Dislike	Size (Larger)	Side	Like	Comfort	Other	Shorelines 1 Incorrect	Choice 0	Like
		5	3	3	1	1	1	1			1
	Choice 1	Like	N/A	Comfort	Interesting	Size (Smaller)	Complexity	Other		Choice 1	N/A
		7	4	3	2	1	1	1			1

Table 3-20 - Shorelines 1 Codes

The questionnaire data produced a fair distribution of rationale, with "Like" as the top code for choice 1, and "Ease" as the top code for choice 0. The most common result for choice 1 suggests that participants made their decision because they liked the room, and had a general preference for its aesthetics. As these environments are free from other stimuli, the shoreline in choice 1 is the only differentiating factor between the two areas. It is unsurprising that participants seem to have a general preference for the environment that offers some visual stimuli when directly compared to a blank room. However, no participants favored the shorelines in choice 1 due to its properties as a line, drawing their eye towards the exit, or physically guiding their movements. The majority of the participants who selected choice 0 did so because the shorelines were perceived as a physical barrier, they disliked its appearance, or they preferred the open space provided by choice 0.

Despite the small amount of selection success experienced by choice 1, it fails to suggest that shorelines would be useful tools for guiding the eyes and movement of those who observe them.

Shorelines 2 - 20th Hallway - Scenario Test - Standard Hallway

Shorelines 2	Results	Percentage	P Value
Choice 0	14	39	0.243
Choice 1	22	61	

Table 3-21 - Shorelines 2 Results

This hallway demonstrates how shorelines could be integrated into a realistic game scene (see Figure G-10). Shorelines within choice 1 run underneath and behind the assets of the environment, moving along the wall/floor intersection towards the exit door. Choice 0 contains the same assets in the same relative location as choice 1, but does not feature the shoreline.

Again, shorelines failed to produce a statistically significant result for the overall group. 61% of participants selected choice 1. 39% of participants selected choice 0. A two-tailed binomial test of these results produces a P value of 0.243, which fails to reject the null hypothesis.

Shorelines 2 Correct	Choice 0	N/A	Size (Larger)	Side	Tidy	Dislike	Like					
		5	3	2	1	1	1					
	Choice 1	Like	N/A	Comfort	Other	Closer	Ease	Dislike	Side	Size (Smaller)	Natural	Size (Larger)
		6	2	2	2	1	1	1	1	1	1	1

Shorelines 2 Incorrect	Choice 0	Comfort		
		1		
	Choice 1	Dislike	Side	Other
		1	1	1

Table 3-22 - Shorelines 2 Codes

This hallway's coded results are similar to those of the previous hallway, with "Like" as the top response for choice 1. Those who liked choice 1's appearance suggested that it was more aesthetically pleasing than choice 0, but also that it appeared to be more stable. This interpretation that the shoreline helps stabilize the features of choice 1 is an understandable, yet unintended feature of the scene. Though the shorelines were meant to add detail to the scene, they were not intended to make it more believable due to its structural properties. Other responses for choice 1 are highly dispersed.

The top code in choice 0, "N/A", shows that the participants were either unable to recall their choices, or were uncertain of the differentiation between the choices. This is obviously a very subtle difference, but this subtlety demonstrates that faint environmental features may actually have a positive influence on the navigation choices of certain participants.

Overview – Shorelines

Due to the lack of statistical significance, and the varied rationale within codes, it is difficult to recommend shorelines as they were represented in this study. Shorelines may work best when paired with other stimuli, acting as a trough for flowing water, a bed for planting flowers, etc. Shorelines may also hold potential as stimuli that continuously remind the participant that they are moving in the correct direction. Referred to by Carpman and Grant as a "continuous cuing device", objects which run along the floor or wall of an environment, such as lines, or other features, can be effective tools for guiding navigators to a limited number of destinations within complex environments (Carpman and Grant, 2002, 431). Shorelines could continually assure the players that they are travelling along the proper path, outlining it with distinctly coloured floorboards, or recognizable piping running along the walls of an interior environment. Over a certain amount of exposure, participants may begin to associate this persistent environmental feature with progression. However, as an unprimed visual cue, shorelines may not be effective for guiding participants' eyes and movements towards a destination.

Future tests for the effectiveness of shorelines should focus on its potential as a primed visual cue, or human tendencies to follow natural features like beaches or river shores. Primed visual cues are outside of the scope of this study, and thus were not examined to great length.

Complexity

The following hallways focus on contrasting visually complex and visually simple regions. Support from the first chapter suggests that humans have demonstrated preferences for scenes that are visually complex, and scenes that are visually simple. Though not necessarily mutually exclusive, the below tests examine if either of these levels of environment complexity may be more effective for pulling the attention of research participants.

Areas high in complexity offer more objects to look at, and a high amount of visual variety (Kaplan, 1988, 48; Doherty, 2005, 24-26). However, areas of simplicity are easier to understand, and can be quickly and effortlessly processed by the viewer (Reber, Schwarz, and Winkielman, 2004, 364). They contain less visual information, and often feature repeating objects. Repeated exposure to the same object may even increase preference for it (Reber, Schwarz, and Winkielman, 2004, 370).

For all other test environments, choice 1 is expected to be the more effective area for pulling in participants. However, due to the extensive support available for both hypotheses, the following hallways were created with much more uncertainty of navigator preference. These hallways were designed to observe if, within 3D environment, participants prefer scenes of high complexity, represented by an area of multiple unique objects, or scenes of lower complexity represented by an area of repeated objects. Due to the consistency of the results, and similarity of the test hallways, the questionnaire and choice data from both trials will be analyzed concurrently.

Complexity 1 & 2 - 8th & 28th Hallway - Baseline Test - Standard Hallway

Complexity 1	Results	Percentage	P Value
Choice 0	19	53	0.868
Choice 1	17	47	

Table 3-23 - Complexity 1 Results

Complexity 1 is populated with basic shapes, each with a consistent material (see Figure G-11). Choice 1 features a series of seven staggered unique shapes lining its outside walls. This choice represented the area of relative complexity. Choice 0 features the same number of objects, in the same relative locations, but all are repeated cubes. This choice represents the area of relative simplicity. Choice 1 was the wayfinding path for 47% of participants, with the other 53% of participants moving towards choice 0's exit. A two-tailed binomial test of this data produces a P value of 0.868, failing to reject the null hypothesis.

Complexity 2	Results	Percentage	P Value
Choice 0	16	44	0.618
Choice 1	20	56	

Table 3-24 - Complexity 2 Results

The second baseline test, Complexity 2, has the same basic features as the previous test, but has greater individualization of the choice 1 objects (see Figure G-12). Choice 1 contains an assortment of unique objects, each featuring different materials. Choice 0 contains a single object, with a single unique material, repeated throughout the choice area. 56% of participants selected choice 1, and 44% of participants selected choice 0. With a P value of 0.618, this hallway also fails to reject the null hypothesis.

Complexity 1 Correct	Choice 0	Tidy	Repeated	Symmetry	Ease	Dislike	Like	Comfort	Consistency	Complexity 1 Incorrect	Choice 0	N/A	Interesting
		5	5	2	1	1	1	1	1			1	1
	Choice 1	Interesting	Like	Complexity	Dislike	Other					Choice 1	Tidy	Symmetry
		6	5	2	1	1						1	1

Complexity 2 Correct	Choice 0	Repeated	Tidy	Symmetry	Dislike	Comfort	Other	Complexity 2 Correct	Choice 0	None
		8	3	2	1	1	1			0
	Choice 1	Interesting	Like	Dislike	Complexity	Colour			Choice 1	Side
		10	4	2	2	1				1

Table 3-25 - Complexity 1 & 2 Codes

The coded responses from the questionnaire suggest that some participants did make their decisions based on the environments' simplicity, and others its complexity. However, the hallways failed to produce a compelling argument of which level of complexity may be a more pulling visual cue within a digital setting.

Both hallways are consistent in their most popular responses. Those who selected choice 0 in both hallways, primarily did so due to the codes "Repeated" and "Tidy". "Repeated" codes explicitly stated that the presence of repeated objects was their reason for moving towards the choice 0 exit. As this is the most common response across both hallways, it suggests that, within a digital 3D setting, some players may prefer environments of simplicity, created by repeating objects. This directly supports the suggestion that humans may prefer environments which are more easily processed and contain less information. One participant even stated that they selected choice 0 because it featured "Less visual stimulation." Though care was taken to ensure that the objects within both choice sections are in the same relative, asymmetrical locations, with the same rotations, some participants still interpreted choice 0 as the tidier, better organized, and symmetrical option.

Across both hallways, the most common rationale for selecting choice 1 was the “Interesting” code, followed by “Like”. Those coded as “Interesting” found choice 1 to be the more visually interesting option due to its varied shapes and materials. The prevalence of “Like” suggests that these participants had a general preference for the aesthetics of choice 1, mainly due to the variance in shape.

Overview – Complexity

Complexity hallways 1 & 2 demonstrate that different environmental features can have differing values to various participants. It may seem that finding a scene more visually interesting, as a result of its features, would be one of the primary driving factors for navigation within a scenario such as this. However, participants can also be physically attracted to spaces which may be less visually interesting, and more easily processed.

It is important to note that participants who selected choice 0, for either of the hallways, may have found choice 1 more visually interesting or intriguing. Almost none of the participants had a general aesthetic preference for choice 0, as coded by “Like”. None of the participants found choice 0 as more “Interesting”. However, their preference for the visual simplicity trumped this visual intrigue, making choice 0 a more compelling navigational option. Finding something visually appealing or visually interesting may not be the ultimate driver for navigational wayfinding. While it may be important that certain visual features within an environment are appealing, this visual appeal does not guarantee that the player will give this visual stimuli top wayfinding priority. This is an especially valuable trait for wayfinding within videogames, as crafting environments from modular art is not uncommon. When creating environments from repeated art assets, participants may not find this environment visually interesting, but nonetheless will find it more appealing to navigate, and thus gravitate towards it.

These hallways ultimately show direct support for both competing hypotheses, simplicity and complexity, as potential wayfinding methods. Some participants preferred the environments which were crafted to be simple, featuring repeating environmental objects. Others prefer scenes which were higher in visual information, and more visually complex, as represented by unique objects and materials. However, the trials were unable to produce evidence on which state of visual complexity will have greater wayfinding success within video games.

The influence of complex or simple environments may be increased if the explorer is exposed to areas of inversed complexity. By exposing gamers to an area of high visual complexity, populated by a high number of unique visual stimuli, the participants may be more likely to move towards areas of repeated objects. Or, when exposed to an area of highly repeated stimuli, players may be more likely to move towards areas that feature unique stimuli. However, based on the information gathered from the research participants, neither simple, nor complex environments are a more coercive visual feature for environmental wayfinding.

Symmetry

The following hallways were designed to examine the pulling power of symmetrical environments when directly compared with asymmetrical areas of similar appearance. Humans have demonstrated favorable reactions to depictions of symmetrical scenes, and symmetrical objects for several reasons, including: ease of processing (Reber, Schwarz, and Winkielman, 2004, 364, 368-369; Joye, 2007, 307), indication of mate health, and detection of predators and prey (Ramachandran and Hirstein, 1999, 27). If the hallways below demonstrate to be effective for physically pulling participants, then areas of symmetry may be used within games to physically attract the player. The effects of these spaces may be heightened by contrasting spaces of symmetry with larger areas of asymmetry or chaos.

Symmetry 1 - 14th Hallway - Baseline Test - Standard Hallway

Symmetry 1	Results	Percentage	P Value
Choice 0	12	33	0.065
Choice 1	24	67	

Table 3-26 - Symmetry 1 Results

This hallway depicts two basic visual spaces, each containing twelve cubes (see Figure G-13). The cubes in choice 1 are uniform in rotation, and symmetrically situated on the outside walls of the hall. Choice 0 features the same cubes, in the same relative location, but each has been offset from their symmetrical point by a small, random amount, and randomly rotated. This produces a scene of asymmetry. Choice 1 physically drew in 67% of the participants, and choice 0 pulled in the remaining 33%. A two-tailed analysis of this data produces a P value of 0.065, which is just shy of rejecting the null hypothesis.

<table>
<tr><td rowspan="4">Symmetry 1 Correct</td><td rowspan="2">Choice 0</td><td>Disorder</td><td>N/A</td><td>Side</td><td>Natural</td><td>Comfort</td><td>Curiosity</td><td rowspan="4">Symmetry 1 Incorrect</td><td rowspan="2">Choice 0</td><td>Side</td><td>Ease</td><td>N/A</td></tr>
<tr><td>3</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td rowspan="2">Choice 1</td><td>Tidy</td><td>Symmetry</td><td>N/A</td><td>Like</td><td></td><td></td><td rowspan="2">Choice 1</td><td>Disorder</td><td></td><td></td></tr>
<tr><td>16</td><td>3</td><td>2</td><td>1</td><td></td><td></td><td>2</td><td></td><td></td></tr>
</table>

Table 3-27 - Symmetry 1

Participants who selected choice 0 had a wide spread of rationale, with the mode "Disorder" only reaching 3 correct codes. Because the results are so inconsistent, there is no single rationale or environment feature that is responsible for the majority of participants' choice 0 selection.

In choice 1, a large number of participants stated "Tidy" as their rationale. Participants noted that the blocks were well ordered, in a straight line, and more organized. This tidiness of the environment, and its appreciation by the participants, is likely heightened by its direct contrast with the asymmetrical, less orderly choice 0. Of the high number who chose the symmetrical environment, only three respondents explicitly stated that it was the symmetry of the choice that influenced them.

As few participants recognized choice 1 as symmetrical, or did not explicitly state this, this suggests that much of the value of symmetrical environments may not be due to its ease of processing, or basic appeal of symmetry. The appeal of symmetrical environments may stem from the symmetrical area's appearance as structured and well organized. It should be noted that female participants account for all "Symmetry" codes within this environment. This may suggest that females are slightly more receptive to symmetry, or assign it a slightly higher value for wayfinding than males.

The results of this hallway can also be interpreted in a different way: though tidiness of choice 1 is its most significant, and perhaps most obvious feature, participants may simply not have recognized its symmetry. Though they may have felt pulled towards choice 1, they may not have noticed that it was the symmetry of the scene that influenced their movement, and made it visually appealing.

Symmetry 2 - 26th Hallway - Scenario Test - Standard Hallway

Symmetry 2	Results	Percentage	P Value
Choice 0	13	36	0.132
Choice 1	23	64	

Table 3-28 - Symmetry 2 Results

Similar to the previous symmetry test, this hallway directly compares a choice of symmetry with a choice of asymmetry, each featuring the same objects and materials (see Figure G-14). Choice 1 contains a series of twelve pillars that symmetrically run along the choice's outside walls. Choice 0 features the same number of the same objects, but they have been assigned a random rotation, and a small random offset from their symmetry point. 64% of the participants moved towards the exit of choice 1, with the remaining 36% selecting choice 0. This produces a P value of 0.132, which fails to reject the null hypothesis.

Symmetry 2 Correct	Choice 0	N/A	Side	Disorder	Closer	Like	Other	Symmetry 2 Incorrect	Choice 0	None	
		5	3	2	1	1	1				
	Choice 1	Tidy	Symmetry	N/A	Natural	Side	Closer		Choice 1	N/A	Natural
		8	4	3	3	2	1			1	1

Table 3-29 - Symmetry 2 Codes

Choice 1 again saw the majority of the participants, but it demonstrates a greater spread in rationale than the previous hallway. The effects of tidiness, still the mode code for choice 1, produced half the responses of the previous hallway. However, when paired with "Symmetry", it still accounts for more than 50% of choice 1 responses. The less concise rationales for choice 1 may be attributed to the additional details and distractions in this hallway, such as the higher detailed objects, and flooring and wall materials.

The seemingly boosted rationale numbers within choice 0 can be directly attributed to the lack of incorrect responses. Eight of the thirteen responses fall under the "N/A" or "Side" codes, suggesting that participants were uncertain of the difference between the hallways, could not recall the rationale for their response, or found their inherent side preference more influential than the hallway's contents. This demonstrates that, while symmetry may be an effective method for pulling attention, it is also quite subtle in appearance. Subtlety supports the creation of a more immersive wayfinding cue, but may reduce some players' perception of the cue.

Again, 3/4 of the participants who noticed the symmetry, and stated this as their rationale for selecting choice 1, were female participants. This, again, suggests that the females in this test were more sensitive and receptive to symmetrical environments.

Symmetry 3 - 3rd Hallway - Scenario Test - Standard Hallway

Symmetry 3	Results	Percentage	P Value
Choice 0	14	39	0.243
Choice 1	22	61	

Table 3-30 - Symmetry 3 Results

Symmetry 3 was different interpretation of symmetry within a digital environment. It creates a symmetry/asymmetry comparison that does not rely on a disorderly organization of objects (see Figure G-15). By removing objects from the symmetrical layout of choice 1, choice 0 creates a space of asymmetry, while still appearing well organized. Participants selected choice 1 on 61% of the trials, and choice 0 on 39% of the trials. A two-tailed binomial test of these results creates a P value of 0.243, which fails to reject the null hypothesis.

Symmetry 3 Correct	Choice 0	Other	Ease	N/A	Like	Comfort			Symmetry 3 Incorrect	Choice 0	Complexity	Tidy	Symmetry
		3	2	2	1	1					3	1	1
	Choice 1	Complexity	N/A	Comfort	Symmetry	Like	Side	Nature		Choice 1	N/A		
		6	5	3	3	2	1	1			1		

Table 3-31 - Symmetry 3 Codes

Though some participants did see the symmetry, this hallway may have been a poor interpretation of the concept. The mode code responses demonstrates that scene complexity was the most motivating factor for participant decisions. Both "Complexity" and "Comfort" are direct results of choice 1 containing more stimuli. "Complexity" is a preference for choice 1 because it is a more visually complex scene, containing a higher number of objects. "Comfort", is a preference for the scene because it contains more benches, which were interpreted as places to rest or sit. The increased number of objects within choice 1 was the primary pulling force for navigation, compromising this environment's ability to measure the significant effects of symmetry on movement. Additionally, a relatively large number of choice 1 respondents were coded as "N/A", suggesting that this environmental stimuli is not necessarily memorable, so it may have inconsistent results if re-tested.

It is possible, like the previous symmetry hallways, that the symmetrical form of choice 1 had a large impact on the participants' navigation. However, during the digital scenario, and perhaps the questionnaire, the participants may not have recognized the scene's symmetry, or failed to notice its impacts on their decisions.

Overview – Symmetry

Overall, symmetry demonstrated success with the research participants. Combining the choice 1 results of all the above symmetry hallways, there is a choice 1 selection rate of 63.89% (69/108). This produces a significant two-tailed binomial result, with a P value of 0.005. The consistent preference for the symmetrical option, choice 1, is very likely not due to chance.

However, Symmetry 3 may not have been the most appropriate test for symmetry. As such, it is sensible to run a statistical analysis of the results exclusively for Symmetry 1 & 2, as they test the same phenomenon through similar means. Combining the results of Symmetry 1 & 2, demonstrates a choice 1 selection rate of 65.3% (47/72). A two-tailed binomial analysis of these results, produces a statistically significant P value of 0.0128. Therefore it is highly likely that participants' preference for choice 1, the symmetrical choice, is not due to chance, and is likely a result of the visual stimuli present in the environment. The consistency of participant preference, and the statistical significance of the symmetrical choices, suggests that when directly compared with an environment of asymmetry, symmetrical environments may be an effective method for influencing a player's movement.

It is important to note that the most common choice rationale was not the recognition of symmetry, but the influence of the symmetrical choices' tidiness and organization. This does not necessarily challenge the hypothesis that humans' preference symmetry, it just suggests that there may be other features inherent to symmetry that are the most immediately perceivable. In the cases above, it is the tidiness of choice 1 that is more easily recognizable than other the potentially attractive features of symmetry.

For environments to be depicted as symmetrical, they must be clearly and intentionally assembled, with the architecture and features deliberately placed. This premeditated construction of a scene may influence viewers to interpret the scene as tidy and organized, when in reality it has been arranged for symmetry. The tidiness of the scene was likely the most easily perceivable difference between the areas, and thus the most apparent positive feature of the symmetrical choice. Other features of symmetry, such as ease of processing, may have been a highly influential feature of the hallway, but the participants were unaware of its impact on their decision.

Future studies on the effects of symmetry on navigation should investigate how effectively symmetry can influence movement in environments which cannot be interpreted as "Tidy". This could be produced by creating a scene that features a ground covered in rubble or garbage, but still appearing as symmetrical. Participants' reaction to these scenes may be less positive, as it is far more natural for a hallway of pillars to be symmetrical than a hallway full of litter and rubble.

Within a game setting, developers may be able to influence players to prioritize stimuli or areas through the use of symmetry. This attraction to symmetry may be enhanced by exposing the players to regions of asymmetry, then contrasting these areas with a single area or object of symmetry. These features of symmetry can then lead participants to an important point in the environment.

Though it may be tempting to create environments of continual symmetry to increase its visual appeal, game developer Don Carson warns against the dangers of overusing symmetry:

> Contrast is another tool in the environmental designer's bag of tricks. Whenever possible, create variety in your spaces… Give them the experience of disorder before you deliver them into a place of order. And above all, give them asymmetry whenever possible. The world we live in is far from geometrically perfect, and spaces where every chair, desk, and potted plant is lined up in a grid only helps emphasize how fake your world really is! (Carson, 2000, 3)

By using symmetry sparingly, and as a contrast against a world of asymmetry, symmetrical cues may be highly appealing to players. This visual appeal may be a large influence on player's tendency to investigate certain environmental areas, and in which order they do investigate the environment.

Density

The following hallways continue to examine the effects of scene complexity and simplicity for influencing movement. A scene's complexity can be affected by altering the density of its contents. Environments with a higher density of objects will have a higher visual complexity, and will be more readily attended to than sections of lower complexity (Mather, 2014, 84). However, areas that offer a contrast in aesthetics are often given attention by the viewer, because these regions often contain important information (Ramachandran and Hirstein, 1999, 33). Therefore, both areas of high and low complexity may be compelling visual stimuli when effectively contrasted with the surrounding environment.

By continually exposing participants to environments of high, or low complexity, wayfinders may be more inclined to seek out and travel towards an area of contrasting density. After exposure to an area of high visual complexity, highly dense in stimuli and objects, participants may move towards available areas of low object density. When continually exposed to areas of low object density, participants may seek out additional visual stimulation, and travel towards higher object density. To test this hypothesis, four different hallways were created: two baseline and two scenario. These hallways will push participants through an area of high or low object density, then offer a choice which continues this density pattern, and a choice which contrasts in density.

Density 1 - 16th Hallway - Baseline Test - Elongated Hallway

Density 1	Results	Percentage	P Value
Choice 0	14	39	0.243
Choice 1	22	61	

Table 3-32 - Density 1 Results

Density 1 presents an environment where the entry area is populated with a high number of repeated objects, mirrored across the centre of the hallway (see Figure G-16). Choice 0 continues with the same object density of the entry, and choice 1 provides an area that is free of visual stimuli. Choice 1 pulled in 61% of participants, and choice 0 pulled in the remaining 39% of participants. A binomial analysis of this data creates a P value of 0.243, which fails to reject the null hypothesis.

Density 1 Correct	Choice 0	Consistency	N/A	Size (Larger)	Interesting	Other	Density 1 Incorrect	Choice 0	Tidy	Ease	Side
		6	2	1	1	1			1	1	1
	Choice 1	Ease	Tidy	Side				Choice 1	None		
		18	3	1							

Table 3-33 - Density 1 Codes

Though unable to produce a statistically significant result, the questionnaire responses to this hallway demonstrate a highly consistent rationale for choice 1. Selections of choice 1 resulted in 0 incorrect answers, with 18 of the 22 answers citing “Ease” as their rationale. For an open ended response, this is highly consistent rationale amongst participants. The “Ease” code suggests that the vast majority of participants who selected choice 1 did so because it was easier to navigate, and provided less of a challenge than choice 0. Though not in support of the contrasting complexity hypothesis, the high consistency of answers suggests that ease, when navigating environment, may be a highly important consideration for wayfinders.

The mode rationale for choice 0 is “Consistency”, with a total of 6 responses. These participants preferred choice 0 because it continued the density and visual style established within the entry area. Though this is not a large number of respondents, preference for density consistency does comprise of a notable number of codes. None of the participants explicitly stated that that the contrast in density of objects was their primary rationale.

Density 2 - 6th Hallway - Baseline Test - Elongated Hallway

Density 2	Results	Percentage	P Value
Choice 0	25	69	0.029
Choice 1	11	31	

Table 3-34 - Density 2 Results

Density 2 tests the same theory, in the same format as Density 1. However, it presents participants with an entry area free of visual stimuli, with choice 0 continuing this density, and choice 1 presenting an area of high density (see Figure G-17). Choice 1 only enticed 31% of the participants to travel towards its exit. Choice 0 was able to pull in 69% of the participants. A two-tailed binomial test produced a P value of 0.029. This attains statistical significance and rejects the null hypothesis.

Density 2 Correct	Choice 0	Ease	Tidy			Density 2 Incorrect	Choice 0	Curiosity
		18	6					1
	Choice 1	Interesting	Complexity	Challenge	Curiosity		Choice 1	Ease
		4	3	2	1			1

Table 3-35 - Density 2 Codes

Though the success of the previous hallway did support that participants may prefer an area of contrasting density, this hallway provides greater evidence that contrast of visual density likely plays a small role in choice rationale. Again, “Ease” is the dominant rationale for wayfinding, with 18 responses, and appears to be a far more important navigational feature than density contrast. The second most common response, “Tidy”, with 6 codes, was also within choice 0, where participants saw the lack of stimuli as a more clean and orderly environment than choice 1.

Choice 1 had a greater spread of rationale, with the majority of the respondents stating “Interesting”, “Complexity”, and “Challenge” as their rationale for their decisions. However, each were in small numbers. Based on the hypothesis of contrast density discussed in chapter one, selection of choice 1 as the more “Interesting” area was the expected result. However, importance of visual interest has only played a small role in participant navigation for this category.

Within this hallway, there is an exceptionally adverse response to choice 1 from those who play games for 8+ hours per week. 81.8% (9/11) of those in the 8+ hours group selected choice 0. Of these choices, 7 were coded as “Ease”, and 2 were coded as “Tidy”. As these were experienced gamers, it was expected that this population would be more adventurous in their choices, and not averted by the perceived challenge. But the most experienced gamers within the group were the most likely to avoid the obstacles presented by the high density area.

Participant concern with the ease of navigation is particularly notable as all participants were informed that the objects within the environments could be moved through freely. However, the mere presence of the objects in the high density choice was enough to deter even the most experienced gamers.

Density 3 - 17th Hallway #18 - Scenario Test - Elongated Hallway

Density 3	Results	Percentage	P Value
Choice 0	10	28	0.011
Choice 1	26	72	

Table 3-36 - Density 3 Results

Density 3 is a higher-detailed, more game-like scenario interpretation of the density contrast theory. This hallway depicts an alley scene that appears to be under construction, riddled with bricks, stones, and pieces of wood (see Figure G-18). Choice 0 continues the aesthetic established by the entry area, featuring a high object density. Choice 1 features the same basic visual style of the entry, but has a much lower object density, with less debris scattered throughout. Overall, 72% of the participants navigated towards the exit located in choice 1. The remaining 28% of participants moved towards the exit in choice 0. A two-tailed binomial analysis of this data results in a P value of 0.011, which is statistically significant and rejects the null hypothesis.

Density 3 Correct	Choice 0	Natural	Complexity	Consistency	N/A	Comfort	Density 3 Incorrect	Choice 0	Tidy	Side
		2	2	2	1	1			1	1
	Choice 1	Ease	Tidy	Side				Choice 1	N/A	Consistency
		13	10	1					1	1

Table 3-37 - Density 3 Codes

Similar to the previous Density hallways, “Ease” is the mode code from participants. However, “Tidy”, representing environment cleanliness and organization, nears the navigational importance of ease. “Tidy” was present as the secondary rationale within the previous Density hallways, but the contents of this environment seem to have boosted its importance. This is likely due to this environments' purposeful depiction of disarray. Nonetheless, participants still assigned the greatest value to spaces which were easily navigated, and offered an organized space. Choice 0, in its low number of responses, features a large spread in rationale, with none of the codes gaining more than 2 consistent responses.

Looking further into the metrics of the respondents, there is a high preference across all levels of gamers, with both the 1-7 hours per week, and the 8+ hours per week groups selecting choice 1 in 63.6% (7/11) of responses. Those who play 0 hours of games per week had the most extreme response to this scenario, with 85.7% (12/14) of the participants selecting choice 1.

The different genders also demonstrated a variance in their rationale for choice 1. Only 57.1% (8/14) of the male participants preferred choice 1, but 81.8% (18/22) of female participants made choice 1 their selection. The female participants responded with 9 codes for "Ease", 7 for "Tidy", and 1 for "Side".

Density 4 - 5th Hallway - Scenario Test - Elongated Hallway

Density 4	Results	Percentage	P Value
Choice 0	24	67	0.065
Choice 1	12	33	

Table 3-38 - Density 4 Results

Density 4 is the second scenario test in this category. It features an entry area of relative cleanliness and organization (see Figure G-19). Choice 1 presents the participants with an area of higher object density, depicting a slightly chaotic scene. Choice 0 continues the same aesthetic as the entry area, with the same low object density. Choice 1 was the selection of 33% of the participants, and choice 0 was the selection of 67% of the participants. A two-tailed binomial analysis of these results produces a statistically significant P value of 0.065, which falls short of rejecting the null hypothesis.

Density 4 Correct	Choice 0	Ease	Tidy			
		15	9			
	Choice 1	Challenge	Complexity	Interesting	Other	Disorder
		4	3	2	2	1

Table 3-39 - Density 4 Codes

Again, the results suggest that the majority participants prefer the choice with the lower object density, which is choice 0. Following the trend of all other Density tests, "Ease" comes in as the primary rationale for navigation, with "Tidy" comprising the second most codes and the remainder of choice 0 rationale. The relative ease for navigating a space, and the tidiness of appearance has been the primary rationale for navigation within all of the Density hallways.

Rationale for choice 1 saw a larger spread of codes, with "Challenge" and "Complexity" totalling more than half of the responses. However, these again are relatively low concentrations of responses.

There were no incorrect responses to the questionnaire for this hallway.

Overview - Density

The Density hallways were designed to examine how contrasting densities of environmental objects could be used to influence participant movement patterns. These environments have ultimately demonstrated that the contrasting of environment detail through object density has little direct impact on participant navigation.

Ease of navigation was the most important navigational factor for these environments. Participants consistently moved towards the environments of low object density, as they were perceived as the more easily navigable option. It should be noted that all participants were aware that the objects within the hallways would not have an impact on their movement, but the mere threat of impeding forward movement consistently deterred a large number of the participants from selecting the higher density choice. Even those who play games for many hours a week were deterred by the threat of barriers to movement. These participants likely have extensive experience moving through difficult in-game terrain, but opted to avoid any objects perceived as challenges.

By coding all choice sections with low object density as choice 1, a basic binomial analysis can be conducted for the combined Density results. Participants selected the low density choice at a rate of 67.4% (97/144) for all hallways. This produces a two-tailed binomial P value of <0.0001, suggesting that it is extremely unlikely that the continued success of the low-density choices is due to chance. The rationale for the selections was also incredibly consistent and concentrated. Across the 4 trials, 95% (92/97) of the questionnaire responses to low density choices were coded as either “Ease” (64), or “Tidy” (28). As these were open-ended responses, this is a greatly consistent rationale, suggesting that both ease and tidiness are highly important topographical features to consider when constructing the primary path of game environments.

Fortunately, games can easily harness this preference for ease and tidiness when creating game levels. By pushing the player through environments that may be physically difficult to navigate, such as uneven terrain, the players can be drawn in specific directions by presenting topography that appears relatively easy to navigate. Through continued exposure to these areas of more difficult terrain, players will likely actively seek out areas that can be more easily traversed, using them to avoid the difficult topography of the surrounding environment. These areas of easy travel can then be used to guide the player towards their goal, or to highlight important features; for example, an environment which features a rocky, uneven pathway could feature pockets free of debris, or smoothed pathways that will likely draw in the player. Or, in rubble-filled streets, areas with tall grass or weeds, or a dense forest, providing patches or pathways that are clear and easy to move through will catch the attention of the player, and reel them in. By exposing players to areas high in object density, which can be interpreted as potential obstacles, players will seek out topographical features which appear to be easier to move through.

This strategy gains even greater versatility with the knowledge that the high density terrain, which is interpreted by the player as difficult to move through, does not actually have to be difficult to move through. This is, perhaps, the most important information learned from this set of hallways. It is the player's interpretation that these areas are challenging to move through that pushes them to avoid these regions, not the actual navigational of the terrain; for example, the player can easily run through areas of tall grass, or patches of uneven gravel, but their appearance as difficult terrain will push players to avoid them.

If the developer is to use areas of the map which appear easier or more difficult to move through, it is important that they consider the story implications that these features would have; for example, if the developer pushes the player through an area of tall grass, they may then present the player with a pathway or patch of lower grass, or other easier terrain. However, the developer must consider the reasons why the terrain can exist in these different states. If the vast majority of the field is tall, chest-high grass, but the primary pathway has been trampled down, mowed, or otherwise cleared of debris, what did this? Why does this particular patch or pathway, which we want the player to move onto, exist in a different state than the majority of the environment? This is something that the players will notice, and if the change in state is too obvious, incongruous, or seems to be a trap, then the player may avoid it.

Mystery

Mystery, or promise of additional information within images, have demonstrated to be highly preferable visual features (Kaplan, 1988, 49; Kaplan and Wendt, 1972, 4; Mather, 2014 141; Joye, 2007,312, 307). Humans value scenes of mystery because they offer the potential for discovering more information within an environment (Kaplan, 1988, 49-50), and scratch our evolutionary tendency to search for competition, prey, or predators within the immediate environment (Mather, 2014, 141). Manipulation of an environment's structure can produce sections of mystery that may positively influence a player's exploratory priorities. This may increase the likelihood that players will explore a certain area, and influence the order in which the environments are explored.

Mystery 1 - 11th Hallway - Baseline Test - Custom Hallway

Mystery 1	Results	Percentage	P Value
Choice 0	10	28	0.011
Choice 1	26	72	

Table 3-40 - Mystery 1 Results

Mystery 1 contains two visually basic choice sections that only vary in their physical structure (see Figure G-20). Choice 1 features a "mystery" path which branches out from the back wall, away from the centre of the hallway. This hallway eventually returns parallel to the main area, and leads to an exit point. Choice 0 is a basic straight, short hallway that features no notable visual stimuli, but offers an easily accessible and visible exit point. Overall, 72% of participants moved towards the choice 1 exit, and the remaining 28% moved towards the choice 0 exit. Conducting a two-tailed binomial analysis of these results produces a P value of 0.011, rejecting the null hypothesis.

Mystery 1 Correct	Choice 0	Closer	Ease	Size (Smaller)	Curiosity			
		4	4	1	1			
	Choice 1	Curiosity	Other	Farther	N/A	Side	Interesting	Challenge
		19	2	1	1	1	1	1

Table 3-41 - Mystery 1 Codes

The questionnaire responses to this hallway show a high consistency of results within the choice 1, which were primarily coded as “Curiosity”, with 19 codes. These participants explicitly stated that they were curious about what laid beyond the turns of choice 1, and this was the primary influence on their decision. These responses comprise of a large number of the overall codes, and represents the single highest coded response from any test hallway. This suggests that, in certain scenarios, if mystery or promise of information can excite the player’s curiosity, they may give this environment feature high priority in their wayfinding procedure.

Though mystery was supported as a preferred feature, choice 1 was competing against several influential features of choice 0. At the starting point, participants can clearly see the exit of point 0, and cannot be assured that the exit for choice 1 actually exists. Participants can also be certain that the exit for choice 0 is closer than choice 1, as the beginning of the turn for choice 1 is physically farther from the starting point than the exit for choice 0. Due to the high value that participants have put on ease of navigation in the previous hallways, choice 1’s positive responses are surprising. By seeking out the exit of choice 1, they are guaranteeing themselves a greater investment of time than would be required for choice 0, prioritizing their curiosity over the ease and guarantee of choice 0’s exit. The assured presence and easy access of choice 0 was overridden by the curiosity for the unknown.

For those who did select choice 0, nearly all of the responses were coded as “Closer” or “Ease”. These are not surprising results, as previous hallways have suggested that ease of navigation is a highly important factor in navigation. There were no incorrect coded answers for this hallway, suggesting that this may be a highly memorable visual stimulus.

This hallway not only presents a consistent choice selection, but it presents a highly homogenous rationale for those who selected choice 1. As such, player curiosity within a game setting may be an important tool to consider when designing environments. By stirring curiosity in a player, through the introduction of areas of mystery, or through other means, levels can positively influence player priorities for wayfinding.

Choice 1 was a popular response for groups of all game experiences. However, there is a gap in preference between the male and female participants. Female participants had a choice 1 selection rate of 63.6% (14/22). The males demonstrated a much higher favourability for choice 1, with 85.7%

(12/14) selection rate. However, the coded rationale for the male participants is unsurprising, with the vast majority citing curiosity as their primary driving force.

Though this environment was constructed to be accessible to all, there were 3 participants who stated in their questionnaire that they attempted to move down choice 1, but could not successfully navigate its turns. The participants then moved towards choice 0's exit. If these participants were able to move more freely, the success rate of this hallway would have been 80.5%, and the most successful hallway within the research trial.

Mystery 2 - 19th Hallway - Baseline Test - Custom Hallway

Mystery 2	Results	Percentage	P Value
Choice 0	18	50	1.00
Choice 1	18	50	

Table 3-42 - Mystery 2 Results

Mystery 2 examines the effects of mystery in a similar environment to the previous hallway. The only structural difference between these two hallways is the location of the exit for choice 0. Mystery 2 places the exit for choice 0 farther from the starting point relative to the previous hallway (see Figure G-21). In this hallway, when the participants compare the distance to the exit of choice 0, and the distance to the first turn in choice 1, there is potential that the exit for choice 1 is physically closer to the start point than the exit for choice 0. It is because of this potential distance differential that Mystery 2 was predicted to be the more successful mystery hallway. As can be seen from the results, Mystery 1's choice 1 was much more successful than the choice 1 in Mystery 2. In this hallway, only 50% of the participants selected choice 1. The other 50% selected choice 0. This results in a P value of 1.00, and a failure to reject the null hypothesis.

It is vital to note that Mystery 1 was experienced before Mystery 2 in the research trials. The questionnaire unveils how this ordering caused the huge drop in the mystery option's success.

Mystery 2 Correct	Choice 0	Prime (Negative)	Ease	Closer	N/A	Like	Size (Larger)	Mystery 2 Incorrect	Choice 0	Curiosity
		8	4	1	1	1	1			2
	Choice 1	Curiosity	Further	Interesting	Challenge				Choice 1	None
		15	1	1	1					

Table 3-43 - Mystery 2 Codes

Similar to the previous hallway, "Curiosity" is the mode rationale for navigation, making up the vast majority of the choice 1 responses. However, there is a sizable increase of participants who selected choice 0 in this hallway. This increase results in a shift, between Mystery 1 & 2, from heavy choice 1 preference, to indifference. The shift is largely attributable to the code "Prime (Negative)", which is the mode response for choice 0. The answers coded as "Prime (Negative)" are responses that state that the participants' experiences with the previous mystery hallway had a negative impact on their decision. In this case, their previous experience deterred them from selecting choice 1. Many of these participants stated that they were disappointed or underwhelmed with the contents of the previous mystery hallway's choice 1. Others stated that the previous choice 1 contained nothing interesting, or that they will now select choice 0 because they previously selected choice 1.

Though many participants found the previous mystery hallway to be highly interesting and influential, it failed to reward the participants with additional interesting content or visuals once they put in the effort to see its exit. This failure to reward the explorers is the primary cause of the reduced appeal of choice 1. This demonstrates the importance of positively associating desired environment features with either rewards, progress, or interesting content.

Overview - Mystery

Hallways that create mystery through the promise of additional information pose great potential for game wayfinding, if implemented effectively. Participants' first encounter with mystery showed a highly positive response, with 80.5% of participants attempting to move towards choice 1's exit, and 72% actually reaching it. These positive navigational results were further enhanced by the highly consistent results from the questionnaire. The vast majority of participants who selected choice 1, stated that curiosity, as a result of the mystery, was their primary rationale for navigating towards this exit. Despite the importance of "Ease" as a navigation rationale, the promise of additional information encouraged participants to select the hallways which were clearly more difficult to navigate. Based on the results of the Density hallways, it would not be unreasonable to suggest that the ease of navigation may supersede all other navigation rationale observed in this trial. But it appears that curiosity, if it can be stirred in the participant, will override their preference for taking the easy route.

As hallways of mystery were highly effective at pulling the attention of the participants, using mystery to mark the primary path may be an effective method for guiding the player through a game. This will keep their journey through the environment interesting, increase the likelihood that the players will naturally select the primary path forward, and make wayfinding an organic experience. Or, perhaps more realistically, areas of mystery could be used more sporadically to draw players towards important game features.

The contrast of results between Mystery 1 & 2 demonstrates the importance of positive reinforcement in game wayfinding cues. Though a stimulus may initially be highly influential, if it fails to reward the player, they will be less likely to investigate this cue, or similar cues, in the future. The novelty of mystery, though highly enticing, may not be effective after multiple exposures if it is not bolstered by rewards. The players will learn that the effort spent navigating this mysterious corridor will likely not provide sufficient compensation, and will thus have a lower perceived value.

It is important to note that choice 1 for both mystery hallways had a memory rate of 100%, with only 2 incorrect recalls for choice 0. The vast majority of participants were able to correctly recall which choice they selected, and thus their stated rationale likely reflects their actual rationale. This suggests that this is a highly recognizable visual stimulus. So, if a game positively rewards the player for investigating sections of mystery, they will likely remember these features, and spot them easily when presented again.

Future examination of this topic could introduce several new angles to its investigation. Research could include the addition of “Scenario” tests for this theory. Populating the mystery scene with highly detailed objects and materials could demonstrate its effectiveness when competing with visual distractions. Research could also examine the frequency at which participants return to a mystery section if, in their first exposure to a mystery hallway, they are rewarded with interesting stimuli or a positive sound. Another potential topic of study would examine how participants react to mystery when there is a time limit for reaching a destination. Participants may have radically different navigational priorities if they are under a tight timeline, and must make decisions based on movement efficiency. Investigation of the effects of positive primes on wayfinding, and the forcing of movement impetus were outside the scope of this study.

Nature

The following hallways examine the pulling power of natural objects in a game-type environment. Each of the choice 1 areas within this section will contain an object, or material that is intended to represent nature, such as: bushes, grasses, moss, rocks, and water. These visual stimuli should be valued by viewers over the alternative artificial features (Kaplan and Wendt, 1972, 1; Joye, 2007, 307).

As human attraction to natural stimuli may be attributable, in part, to preferences for colours associated with nature (Kaplan and Wendt, 1972, 4), whenever possible, the natural items were presented against man-made objects of similar colour and size. This ensures that any demonstrated preference for nature is likely due to its natural state, and not other features.

Nature 1 - 27th Hallway - Baseline Test - Standard Hallway

Nature 1	Results	Percentage	P Value
Choice 0	11	31	0.029
Choice 1	25	69	

Table 3-44 - Nature 1 Results

Nature 1 was created to directly compare the visual appeal of natural objects versus man-made objects of a similar size and colour (see Figure G-22). Choice 1 features a row of randomly sized and rotated bushes, representing natural features. Choice 0 features a row of randomly sized and rotated statuettes, which represent man-made structures. The statuettes were altered to resemble the bushes in size and colour, but were selected to be clearly identifiable as man-made. Choice 1 pulled in 69% of participants, and choice 0 pulled 31% of participants. A two-tailed binomial analysis of this data creates a P value of 0.029, which rejects the null hypothesis.

Nature 1 Correct	Choice 0	Like	Interesting	Closer	Colour	Other
		6	2	1	1	1
	Choice 1	Natural	Nature	Dislike	Like	Tidy
		10	7	4	3	1

Table 3-45 - Nature 1 Codes

The questionnaire responses to this hallway, while unsurprising, expose some potential faults of the test environment. The overall mode code is “Natural”, which may be expected for a comparison between natural and artificial objects. However, this code represents that the selected stimuli is more natural or realistic in appearance than the opposing stimuli. In this example, some of the participants interpreted the statuettes as bushes. This was an unanticipated outcome. The statuettes were selected as the man-made features, as they were believed to be clear representations of human constructs. However, by coloring the statuettes to reduce colour bias, and sizing/distributing them to match the bushes, the participants may have interpreted this as a comparison between different depictions of bushes. So, while this environment does suggest that humans prefer more realistic interpretations of natural objects, it may be a less effective examination of human preference for natural or artificial features. Nonetheless, some participants did prefer choice 1 because it features objects of nature, as represented by the “Nature” code.

Those who selected choice 0 primarily did so because of a general preference for its aesthetics, as suggested by the code “Like”. It is important to note that two of the participants who selected choice 0 explicitly stated that the statues were more visually interesting than the opposing objects of nature. This may challenge Kaplan’s suggestion that mundane, common depictions of nature will be valued over uncommon man-made structures (Kaplan, 1988, 54).

The female participants of the study were particularly pulled by choice 1, demonstrating a selection rate of 77.3% (17/22). This high response rate, from a relatively large population within the study, played an important role in choice 1’s success. Also, a high amount of experienced gamers (playing 8+ hours per week) selected choice 1, with a success rate of 81.8% (9/11). However, the selection rationale from both these groups proportionately mirrors the overall participant rationale. This provides little insight on how these populations’ decisions were unique.

Nature 2 - 18^{th} Hallway - Baseline Test - Standard Hallway

Nature 2	Results	Percentage	P Value
Choice 0	10	28	0.011
Choice 1	26	72	

Table 3-46 - Nature 2 Results

Nature 2 continues the examination of natural objects and their influence on navigation. It directly contrasts a water feature which contains a natural interpretation of water, choice 1, with a water feature which contains an artificial interpretation of water, choice 0, in the form of polished marble (see Figure G-23). The marble has be altered to ensure that it is the same base colour as the corresponding water material. Though marble exists in the natural world, its cut, polished state as displayed within this environment is clearly a human construct. Overall, 72% of participants selected choice 1, and 28% of participants selected choice 0. A two-tailed binomial analysis of this data produces a P value of 0.011, which achieves statistical significance and rejects the null hypothesis.

Nature 2 Correct								
	Choice 0	N/A	Like	Nature	Comfort	Other		
		3	2	2	1	1		
	Choice 1	Nature	Natural	N/A	Other	Line (Toward)	Like	Interesting
		11	5	2	2	1	1	1

Nature 2 Incorrect			
	Choice 0	Nature	
		1	
	Choice 1	Side	Comfort
		2	1

Table 3-47 - Nature 2 Codes

The mode rationale for selecting choice 1 is the "Nature" code, demonstrating preference for the presence of real water. There are also a notable number "Natural" codes, preferring the natural appearance of the water in choice 1 over the artificial appearance of choice 0. Participants seemed to largely favor the presence of "real" water over the artificial imitation. The remainder of the questionnaire responses, for both choice 1 and choice 0, had a wide spread of rationales.

This environment showed exceptional success with the female participants of the study, with 90.9% (20/22) selecting choice 1 over choice 0. This becomes more notable when directly compared with the male participants, who demonstrated a 42.9% (6/14) selection rate of choice 1. Of the eighteen female choice 1 responses (2 female responses were incorrect), 77.8% (14/18) were coded as either "Nature" or "Natural". Not only were the female participants far more influenced by the presence of "real" water, but they were far more consistent in their reported rationale than the male participants. There was also an exceptionally heavy preference for choice 1 within non-gamers, with a selection rate of 85.7% (12/14). This is likely largely due to the heavy overlap between the non-gamer category, and female category.

Producing a realistic, natural-looking water source, and comparing it to an artificial environment containing no water, was an effective method for pulling in a large number of participants. As such, presenting water within an environment, in the form of a natural source (river, stream, lake, etc.), or a water feature (fountain, flowing water feature), may be an effective way to grab a player's attention. Water features can take countless forms, and may be applicable in numerous scenarios; for example, a flowing creek could be used to guide the player through a thick forest. Or a large water feature in a modern office could capture the players' attention and draw them in. Water has an endless amount of applicability, and humans' tendency to enjoy scenes of water, and potentially travel towards water, provides a versatile wayfinding tool to help players navigate environments.

Nature 3 - 13th Hallway - Scenario Test - Standard Hallway

Nature 3	Results	Percentage	P Value
Choice 0	16	44	0.618
Choice 1	20	56	

Table 3-48 - Nature 3 Results

Nature 3 was created to test the effectiveness of a "Nature" environment when directly compared to an area that is clearly man-made. As this hallway was a scenario test, the regions were populated with materials and objects portraying an area of nature, and an area of human constructs, with less concern for confounding variables (see Figure G-24). The natural area, choice 1, is populated with bushes, rocks, pebbles, grasses and mosses. The man-made area, choice 0, is populated with tiles, benches, light poles, and waste bins. Unlike the previous tests, this does not compare single artificial or natural objects, but entire areas that are meant to represent one of the two states. Ultimately, choice 1 pulled in 56% of the participants, and choice 0 saw the remaining 44%. A two-tailed binomial analysis of this data results in a P value of 0.618, which fails to reject the null hypothesis.

Nature 3 Correct	Choice 0	Other	Tidy	Ease	Like	Comfort	Farther	N/A	Interesting	Nature 3 Incorrect	Choice 0	Dislike	Colour
		3	2	2	2	2	1	1	1			1	1
	Choice 1	Nature	Colour	Comfort	Dislike	Brighter					Choice 1	Like	
		8	5	3	2	1						1	

Table 3-49 - Nature 3 Codes

Within the coded data, the mode rationale for the hallway is "Nature", stated by those who selected choice 1. There are also a notable number of participants who selected choice 1 because of its attractive colouring. Choice 1 is comprised of mainly greens, which many participants found more attractive than the predominantly grey appearance of choice 0. The coded rationale for choice 0 demonstrates a large spread in participant choices, with no codes receiving greater than 3 responses. However, when combining the relatively low mode, dispersed rationale, and insignificant P value of this hallway, its results do not lend significant support to the theory that humans prefer natural scenes over man-made scenes.

As stated above, nature is likely best used when contrast against man-made environments. The more homogenous the environment, the greater the "pop-out" effect when an object of contrast is present (Ware, 2008, 20). If participants are exposed to large areas of human constructs, any natural features will likely have a positive influence on the explorer. Grass patches or pathways, solitary trees, or spots of parkland, may all be used against an unbroken urban backdrop to more effectively pull the attention of the player. However, if the area is well populated with both natural and man-made constructs, the nature's impact will likely be reduced due to a decreased contrast.

To observe the effects of nature in a contrasting scene, future tests should expose participants to a larger area of man-made structures within the entry. Features or entire sections of nature can then be presented within choice 1 to observe how nature, as a contrasting feature, can effectively pull the attention of the participant.

Nature 4 - 31st Hallway - Baseline Test - Standard Hallway

Nature 4	Results	Percentage	P Value
Choice 0	16	44	0.618
Choice 1	20	56	

Table 3-50 - Nature 4 Results

Nature 4 was created to examine the pulling potential of natural materials (textures and images applied to surfaces) when directly compared to materials which appear man-made (see Figure G-25). To avoid any skewing due to the patterns produced by brick or tiles, the natural materials within choice 1 were overlaid on the man-made materials of choice 0. This creates the same basic lines and patterns in choice 0 and choice 1. The overlaying of natural materials in choice 1 represent that this man-made area had been overgrown with natural moss and grasses. Choice 1 pulled in 56% of the participants, and choice 0 pulled in the remaining 44% of the participants. A two-tailed binomial analysis of these results produces a P value of 0.618, which fails to reject the null hypothesis.

Nature 4 Correct	Choice 0	Dislike	Natural	Colour	Closer	N/A	Like	Prime (Negative)
		6	3	3	1	1	1	1
	Choice 1	Colour	Dislike	Like	Brighter	Comfort		
		13	3	2	1	1		

Table 3-51 - Nature 4 Codes

The responses to the questionnaire reveal that this environment was clearly a poor interpretation of natural vs. man-made environments. The mode response for this hallway was “Colour”, implying that the majority of those who selected choice 1 did so because they prefer the colour green to the colour grey. Not a single participant selected choice 1 due to its natural features, suggesting that this was a weak representation of nature. Additionally, the mode response for choice 0 was “Dislike”, demonstrating that this interpretation of nature was very unappealing to the participants.

This distaste for the materials could be avoided if they were a pure representation of grass or moss, and did not include any features of the underlying bricks or tiles. Overall, this hallway merely asserts that participants prefer the colour green to grey.

There are several different approaches that would better measure human preference for natural materials when contrasted with artificial materials. In future testing, participants could be exposed to an outdoor, man-made aesthetic within the entry area. Choice 0 would continue that visual style, and choice 1 would organically transition into a space with natural materials. If successful, this would suggest that contrasting areas of man-made structures with natural materials may be an effective method for pulling the presence of participants.

Nature 5 - 30th Hallway - Baseline Test - Standard Hallway

Nature 5	Results	Percentage	P Value
Choice 0	12	33	0.065
Choice 1	24	67	

Table 3-52 - Nature 5 Results

Nature 5 was created to be an absolute baseline control test of the effects of natural objects on navigation (see Figure G-26). If choice 1 failed to pull a significant number of participants towards its exit, it would suggest that natural objects, such as bushes, may not be an effective visual cue for influencing wayfinding.

Choice 1 features a row of bushes, evenly placed on the outside of the choice section, randomly sized and rotated. Choice 0 contains no notable stimuli. Ultimately, 67% of participants selected the exit of choice 1, and 33% selected the exit of choice 0. Statistical analysis of these results produces a P value of 0.065, which fails to reject the null hypothesis.

Nature 5 Correct	Choice 0	Dislike	N/A	Ease	Like				Nature 5 Incorrect	Choice 0	N/A	Colour
		4	3	2	1						1	1
	Choice 1	Nature	Complexity	Like	Interesting	Line (Toward)	Closer	Colour		Choice 1	N/A	Dislike
		8	5	3	2	1	1	1			2	1

Table 3-53 - Nature 5 Codes

Unsurprisingly, choice 1, which contained visual stimuli, was the more successful exit. The mode code for the trial and choice 1 was “Nature”, suggests that the natural properties of the bushes was the most influential single feature. Participants were also influenced by the bushes because they add a higher level of complexity, outline the path as a shoreline, created an implied line, and produced a more populated scene. As such, it is not fair to assume that the bushes in choice 1 were pulling participants purely because they represent elements of nature. They pulled participants for a variety of reasons, each represented by different codes in the choice 1 results. Distaste for the bushes and their positioning, along with a variety of other reasons, were the rationale for selecting choice 0.

This hallway plays an important role in tempering the expected success for all other hallways within this research trial. Based on support from the first chapter, the expected outcome for this trial was a heavy favourability for choice 1. When directly compared to choice 0, choice 1 has several features which suggest that it should be preferred: it actually contains visual stimuli, it was more visually complex and unique, it featured natural objects, it was not disorganized or messy, the objects were well aligned, and the objects did not block forward progression. Each of these features, when directly compared with a corridor that contains no visual stimuli, suggests that choice 1 should be highly successful. However, despite these potential positives, it only pulled in 67% of the participants. As such, any other hallways which contain a choice of equal or greater consistency are quite successful.

Overview - Nature

The results from the research trials have demonstrated, with some inconsistency, that the participants preferred environments which were made of, or contained natural features. By combining the choice 1 results, and choice 0 results of all research trials, excluding Nature 5, as it is not a direct comparison of natural and man-made features, participants did demonstrate a preference for natural scenes. Overall, participants selected choice 1 in 63.2% (91/144) of the trials. A two-tailed binomial analysis of these successes produce a statistically significant P value of 0.002. This suggests, with greater than 99% confidence, that the consistent selection of the natural scenes is not due to chance.

Based on the evidence from the first chapter and the trials above, human preference for natural scenes and elements may be used within a game setting to pull players’ attention, and influence their searching patterns. This potential may be most effectively realized when nature is used as a direct contrast to a surrounding man-made environment. As contrast can be produced through visual channels such as shape, size, texture, etc. (Dewitte, Larmann, and Shields, 2012, 58; Ware, 2008, 29), placing natural objects against a background of man-made structures would be an obvious contrast in state.

A tree in the midst of an environment of concrete and paint will not only be valuable because of its natural state, but because of its contrast with the surrounding environment. A park or natural pathway within a concrete jungle may encourage the player to investigate this natural space. Or, pathways of natural textures and objects can be used to lead players towards areas of importance.

It is important to note that the applicability of this visual cue will vary greatly based on the game's setting. It is highly situational, and will not be applicable within all games.

Change Blindness

The first chapter outlined humans' inability to notice small or gradual changes to colours or scenes. This phenomenon is frequently referred to as change blindness (Shimamura, 2011, 18). Due to its flexibility and pervasiveness, this concept may have a large potential for improving immersive videogame wayfinding.

Using colours to highlight the path forwards, or important objects, is an effective method for grabbing and redirecting a player's attention. However, for these colour cues to be effective and easy to see, they may have to be saturated and in high contrast with their surroundings. Brightly coloured objects that outline the direction forward can be thematically inconsistent with the visual style and colour palette of a game. To remedy this inconsistency, it may be possible to expose participants to a highly visible, high saturation colour, and associate that colour with the path forwards. Then, the primed colour's features can be slowly altered until it meshes with the art direction and colour palette of the game. Humans' inherent change-blindness will allow players to recognize coloured objects, despite a change in hue, as the original primed colour.

Additionally, by exposing players to a colour that is associated with progress or rewards, their perceptual system will become more sensitive to that colour's presence in the environment. When humans are looking for a colour or object, they become more aware of its existence in the environment, spotting it more easily (Johnson, 2014, 11-12). By pairing this sensitivity with change blindness, games may be able to produce an effective colour wayfinding cue that is subtle, occupies a small amount of space, exists harmoniously with the game's colour palette, but effectively catches the player's attention and guides them forward.

Change Blindness 1 - 25th Hallway - Baseline Test - Custom Hallway

Change Blindness 1	Results	Percentage	P Value
Choice 0	18	50	1.00
Choice 1	18	50	

Table 3-54 - Change Blindness 1 Results

This hallway is unique from other hallways in its structure. It features four "priming" hallways, each of which contain exit points outlined by doorframes (see Figure G-28). Each of the doorframes are coloured the same base hue, but the colour's saturation is reduced with each exposure. After exposure to the four priming hallways, participants are brought to the decision hallway, which features two door frames (see Figure G-27). The choice 1 door frame features the same hue as the previous priming hallways, but with a reduced saturation. Choice 0 features a frame free of an identifiable hue. After exposing participants to the priming hallways, each choice saw 50% of the traffic. A two-tailed binomial analysis of these results produced a P value of 1.00, which fails to reject the null hypothesis.

Change Blindness 1 Correct	Choice 0	Prime (Negative)	Colour	Side	Dislike	Change Blindness 1 Incorrect	Choice 0	Colour	Interesting
		8	5	2	1			1	1
	Choice 1	Prime (Positive)	Colour	Closer	Like		Choice 1	N/A	
		9	6	1	1			1	

Table 3-55 - Change Blindness 1 Codes

The responses to the questionnaire show a relatively low mode, with the two highest codes, "Prime (Positive)" and "Primed (Negative)" only receiving 9 and 8 responses respectively. However, combining these codes shows that 17 of the total coded responses (43%), have explicitly associated the color of the frame within the questionnaire (which depicts the decision hallway) as the same colour that was present in the priming hallways. The questionnaire image is a simple depiction of the final room, and has no visual representation or mention of the priming rooms. Without prompting, after completion of the test scenarios and a large portion of the questionnaire, nearly half of the participants explicitly stated that the colour of the choice 1 door was consistent with, or the same as the colour in the priming rooms. This demonstrates a notable ability for participants to associate the colour of the priming rooms with the colour in the questionnaire.

As the priming doors were not presented in the questionnaire, the participants made their own association between the image in the questionnaire, and the colours they saw. The colour in the questionnaire was a faint representation of the colour that the participants were initially exposed to. This matching of the colours occurred despite the mental distraction of the questionnaire and the remaining trial hallways. As such, within a game setting, primed colours and change blindness may have an effective potential for wayfinding.

Those who recognized the colour, but chose to avoid it, were coded as "Prime (Negative)". Some of the responses under this code stated that they had been through enough blue doors, and wanted a change. Some felt that were stuck in an infinite loop of blue doors. Others were aware of the repeating colours, and just wanted to try something new. Each of these responses acknowledge that the priming hallway doors and choice 1 were the same colour, but they wanted to avoid this colour.

Answers that were coded with "Prime (Positive)" recognized the choice 1 colour as the priming colour, and this was a positive influence on their decision. These participants stated that after going through multiple blue doors, it felt natural to continue the trend. Or, they selected choice 1 simply because they had already been through multiple blue doors.

It should be noted that the participants' association between the priming doors and the final door was not necessarily a display of change blindness. The participants may not have noticed the change in the colours, which would be change blindness, or they may have simply associated the colours as similar. Whatever it may be, this does not have an impact on its potential for wayfinding. Though true change blindness would aid in maintaining a consistent visual language, it is not imperative for this to be effective.

The second most common code, for both choice 0 and 1, is “Colour”. This code was used when participants’ preference for a door frame colour impacted their choice. As the only differentiating features between choice 0 and choice 1 were the frame colours, this is a natural response for those who may not have associated the priming hallways and the questionnaire image. Though some of the participants may have recognized choice 1 as consistent with the priming colours, they did not mention the priming areas in their response. As such, it could not be assumed that the priming doors had any effect on their decision.

As it is outside of the scope of this thesis, there were no attempts to associate the priming colour with a positive outcome, success, or progression. In a video game setting, this colour could be associated with treasure, items, or quest progression, which would likely make the participant more susceptible to spotting it in an environment, and more likely to actively seek it out. As suggested by Johnson, when primed to look for a certain stimulus, our brain becomes highly sensitive to it (Johnson, 2014, 11-12). This will allow the colour to exist in relatively small quantities, but still be perceivable and sought out by the player.

For this strategy to be effective in games, objects of importance, or objects that mark points of progression, could be textured with a high-saturation, high-contrast colour. If immersive environments are a game goal, this colour should be restricted to objects that would exist in that hue; for example, if red is the designated colour, door frames, pipes, fire hydrants, stop signs, warning signs, etc. could all be believably coloured with a high-saturation red. However, colouring a tree trunk with a high-saturation red will likely be visually inconsistent with the surrounding world. After several exposures to this high-saturation colour, highlighting the path forward or objects of importance, that colour will be associated with progression and rewards. Once this association is made, the properties of this colour can be slowly altered until if fits the environment’s colour palette.

If these changes occur over time, in small increments, the player may be blind to them, and may associate the new altered colour with the original primed colour. However, the developer should ensure that the player is never able to directly compare two states of the colour. If this occurs, players may not recognize these as associated colours due to the disparity between their appearances. If our stored memory of a stimulus is too different from the current representation of the stimulus, we may fail to recognize these stimuli as the same (Mather, 2014, 62).

Region Contrast

This category of hallways was designed to observe participants' responses to changes in the environments' materials, objects, and overall visual style. The change to a contrasting visual style may suggest a shift in regions, or transition to a new landscape, indicating forward progression. If effective, changes of environment aesthetics may pull the player's interest, and highlight the transition as important to investigate.

Region Contrast 1 - 23rd Hallway - Scenario Test - Elongated Hallway

Region Contrast 1	Results	Percentage	P Value
Choice 0	16	44	0.618
Choice 1	20	56	

Table 3-56 - Region Contrast 1 Results

In order to effectively communicate contrasting regions, two visually distinct styles are depicted in this hallway (see Figure G-29). The entry area and choice 0 convey a region of stone and dark wood. Choice 1 continues the object pattern established by the entry, but the objects have been visually and structurally altered to fit a different visual style. The materials in choice 1 are also changed to reflect this unique visual style. Participants are given the option of staying within the aesthetic of the entry area by selecting choice 0. Or, they can select the contrasting visual style of choice 1. Overall, choice 1 pulled in 56% of participants, and choice 0 pulled in the remaining 44%. A two-tailed binomial analysis of these results produces a P value of 0.618, failing to reject the null hypothesis.

Region Contrast 1 Correct	Choice 0	Consistency	Like	Line (Toward)	Dislike	N/A	Other				Region Contrast 1 Incorrect	Choice 0	Consistency
		9	2	1	1	1	1						1
	Choice 1	Like	Colour	Comfort	Interesting	Other	Tidy	Dislike	N/A	Brighter		Choice 1	Consistency
		5	4	2	2	2	1	1	1	1			1

Table 3-57 - Region Contrast 1 Codes

The questionnaire results show a relatively low overall mode, with 9 of the participants stating that choice 0's "Consistency" was their rationale for selection. These participants selected choice 0 because it continued the visual style of the entry area. Other choice 0 rationale were of a low frequency. Choice 1 saw 9 participants making their selection due to a general preference for its aesthetics or colouring. While choice 1's visual style may have been more appealing, its contrast to the main environment may have enhanced visual preference for it.

Ultimately, this environment had such little success that participant rationale for finding choice 1 more appealing is irrelevant. Due to the low navigational success of this hallway and the mode code favoring the consistency of choice 0, this hallway does not support the hypothesis that contrasting environment styles, when unprimed, will be an effective cue for navigation. Though not successful here, visually distinct areas or landmarks within a game are still vitally important for the creation of mental models of game areas. This will help the participants navigate complex environments more easily.

There are several methods that could better examine the pulling potential of contrasting areas. First, the entry area, or the visual style that is continued within choice 0, could be exposed to the participant for a longer period of time before the decision point. This would lend more value to choice 1 as a contrasting environment, as the more homogenous an environment, the lower the contrast needed to pop out (Kopacz, 2004, 39), and the greater the pop-out effect that will occur (Ware, 2008, 20). Also, this test should be conducted over multiple different hallways, each utilizing unique contrasting visual styles. If the participants consistently preferred the contrasting visual style, its success would be more associated with preference for area contrast, and less tied to a preference for visual style.

Figure-Ground Contrast

The below hallways were created to observe how objects which contrast with their background, but are not necessarily visually appealing, can influence the movement of participants. Relatively small objects of contrast, if used effectively, can create focal points within large environments, which capture and pull viewer attention (Kopacz, 2004, 39). If interesting enough, participants may be inclined to physically approach and investigate this object of contrast.

A single object was created to contrast two different backgrounds, each with varying visual style, and a varying amount of distracting stimuli. As Figure-Ground hallway 1 & 2 were tested in reverse order, and their results are heavily intertwined, these two hallways will be examined together.

Figure-Ground Contrast 1 & 2 – 29th & 4th Hallway – Scenario Test – Standard Hallway

Figure-Ground Contrast 1	Results	Percentage	P Value	Figure-Ground Contrast 2	Results	Percentage	P Value
Choice 0	24	67	0.065	Choice 0	18	50	1.00
Choice 1	12	33		Choice 1	18	50	

Table 3-58 - FIgure-Ground Contrast 1 & 2 Results

Both Figure-Ground Contrast 1 & 2 feature the same high-contrast object situated within hallways of different visual styles. Figure-Ground 1 is a dark, sparsely populated room with sharp corners (see Figure G-30). Figure-Ground 2 is a green, natural scene that is well-populated with assets (see Figure G-31). For each hallway, choice 0 and 1 are identical in features. However, choice 1 options feature the high-contrast object. It is important to note that Figure-Ground 2 was seen prior to Figure-Ground 1 due to hallway order randomization. This plays an important role in the analysis of the results.

In Figure-Ground 2, participants moved towards both choice 1 and choice 2 in 50% of trials. Binomial analysis of these results produces a P value of 1.00, which fails to reject the null hypothesis. In Figure-Ground 1, the majority, 67%, selected choice 0, and the minority, 33%, selected choice 1. A two-tailed binomial analysis of this data produces a P value of 0.065, also failing to reject the null hypothesis.

As Figure-Ground 2 was seen first, it will analyzed first. Its impacts on Figure-Ground 1 decisions will also be discussed.

Figure-Ground Contrast 1 Correct	Choice 0	Dislike	Prime (Negative)	N/A	Comfort	Figure-Ground Contrast 1 Incorrect	Choice 0	None
		19	3	1	1			
	Choice 1	Interesting	Like				Choice 1	Prime (Negative)
		8	3					1
Figure-Ground Contrast 2 Correct	Choice 0	Dislike	Ease	Other	Figure-Ground Contrast 2 Incorrect	Choice 0	N/A	Interesting
		14	1	1			1	1
	Choice 1	Interesting	Curiosity	Like		Choice 1	None	
		15	2	1				

Table 3-59 - Figure-Ground Contrast 1 & 2 Codes

Though Figure-Ground 2 saw an even split of participant selections, each of the choices had a very high concentration of results. The vast majority of participants who selected choice 0 had a distaste for the high-contrast object within choice 1, pushing them to avoid this choice. Conversely, all 18 of the participants who selected choice 1 found the high-contrast item to be interesting, it stirred their curiosity, or they liked its appearance. Only one participant stated that they found the object visually attractive, but the contrast that it held with its surroundings was of sufficient to encourage investigation.

The object was clearly a divisive feature, as approximately half of the participants were pulled in by its presence, and the other half were deterred by it. But even those who avoided it were highly influenced by its presence. They noticed the object's existence and decided that, because it is visually unappealing to them, they should avoid that choice in its entirety. This split in participant rationale demonstrates that contrasting stimuli, used for navigation, may be most effective when they are perceived as attractive.

Player rationale for investigating stimuli within a game environment will likely differ from the participants who took part in this test. Gamers, within a game, would be far more likely to investigate visual oddities despite how attractive they are, than was represented by the participants of this study. The 8+ hours per week gamers were the most likely to select choice 1, with a 63.6% (7/11) success rate. 1-7 hours per week gamers, and non-gamers showed a choice 1 success rate of 36.4% (4/11), and 50% (7/14) respectively. There is also a gap in choice 1 favourability between the female and male participants. Only 36.4% (8/22) of female participants selected choice 1, while 71.4% (10/14) of males selected choice 1.

There was a considerable amount of time and visual stimuli experienced between Figure-Ground 2 (4^{th} hallway), and 1 (29^{th} hallway), but the exposure to the high-contrast stimuli had a lasting impact on participants. In Figure-Ground 1, there was a significant drop in participants who selected choice 1 and found it interesting. These participants moved to select choice 0 and responded with a "Dislike", or "Prime (Negative)" code. These participants may have originally found the stimuli unappealing, but its contrast was enough to encourage their investigation. Those who originally disliked choice 1's appearance, continued to dislike and avoid it. Overall, choice 0 saw a high number of participants who were avoiding the stimulus in choice 1, with a high concentration of “Dislike” rationale, and a small addition of “Prime (Negative)” codes.

The questionnaire responses and navigation results suggest that cues which may appear interesting, can lose their value over multiple exposures if they do not prove to be useful to the participants. Participants who originally found the contrast stimulus interesting, but disliked its appearance on their second exposure, found it interesting enough to investigate despite their distaste for it. Once these participants investigated this object and saw that it provided them with no additional information on the scene, no positive reinforcement, and only existed for the sake of itself, it was less enticing in their next encounter.

Any visual stimuli that may be interesting, or visually attractive to the player in their first exposure, will be much less appealing in future encounters if it does not fulfill any pragmatic purpose. However, if the game rewards the player for inspecting a certain stimulus, they will be more willing to investigate other similar stimulus encountered in the future. This is likely what occurred in the above hallways. Though not visually attractive to most, some found the object’s contrast with the surrounding environment enticing. However, once the stimuli was observed up close, and it failed to produce a reward, many of those who initially found it interesting could not justify revisiting the stimuli when re-exposed to it. This also occurred within the Mystery hallways. This demonstrates the importance of creating attractive wayfinding objects. If the player never investigates the stimulus, because they are not attracted to it, they will never learn of its positive qualities.

Figure-Ground 1 saw a notable spread in choices between male and female participants. A total of 57.1% (8/14) of male participants selected choice 1. Female participants had much more consistent results, with only 18.2% (4/22) selecting choice 1. There was also a large choice gap between the gaming categories. Both non-gamers, and gamers who spend 1-7 hours per week playing games had quite unfavorable reactions to choice 1, recording a selection rate of 28.6% (4/14), and 18.8% (2/11) respectively. Those who played games more frequently, 8+ hours per week, had more favourable responses to choice 1, but were overall indifferent, with a response rate of 54.6% (6/11). Though this is a small sample size, it may suggest that, unsurprisingly, heavy gamers have differing wayfinding priorities than light gamers and non-gamers. It also lends a small amount of support to the suggestion that gamers, within games, would be more likely to investigate landmarks that contrast the environment, even if they are not visually appealing. If this theory was tested within a game setting that featured combat, quests, and treasure, wayfinding rationale may vary even more greatly, with gamers only attending to interesting stimuli after threats have been eliminated and treasure has been gathered.

Overview - Figure-Ground Contrast

These hallways provided two key pieces of information: objects that highly contrast the surrounding environment will be more successful and a higher priority for wayfinding if they were created to be aesthetically pleasing. And, if the developer wishes to reuse objects to grab the attention of the wayfinders, it is important that they give the players a reason to visit this stimulus whenever they see it. If the developer fails to reward the player for investigating a focal point, the players will likely not investigate future instances of like stimuli.

Future testing of this topic should focus on positively associating objects of contrast with positive reinforcement, and observing its rate of retention. Designers could also test the pulling power of high-contrast visual stimuli, designed to be visually attractive, directly competing with an object of high-contrast that has been designed to be unattractive.

Depth

A single hallway was created to observe the navigational priorities when participants are offered a closer, and a more distant exit. If one of the choices was significantly more successful than the other, this may offer a greater understanding of participant navigation in hallways that offer more difficult, or easier to navigate choices.

Depth 1 - 7th Hallway - Baseline Test - Custom Hallway

Depth 1	Results	Percentage	P Value
Choice 0	17	47	0.868
Choice 1	19	53	

Table 3-60 - Depth 1 Results

This hallway was a simple test to observe if participants tended to take the shorter route, or the farther route of travel when directly compared (see Figure G-32). Ultimately, neither of the choices saw a significant number of participants, with choice 1, the shorter option, pulling 53% of participants, and choice 0, the longer option, pulling 47% of participants. This produces a P value of 0.868, which is not statistically significant.

Depth 1 Correct	Choice 0	Farther	Size (Larger)	N/A	Side	Challenge	Depth 1 Incorrect	Choice 0	Closer
		7	3	1	1	1			4
	Choice 1	Closer	Ease	N/A	Size (Smaller)			Choice 1	None
		15	2	1	1				

Table 3-61 - Depth 1 Codes

In choice 0, only 7 of the participants explicitly stated that they prefer the farther distance, with some favoring choice 0's size. However, each of choice 0's incorrect recalls unanimously stated that they selected choice 1 because its exit was closer. Choice 1 sees a more consistent response rationale, with the vast majority of participants explicitly citing the shorter distance to the exit as their rationale. Overall, there was little preference differential between these two choices. Hallways required more than a simple distance variance to pull a significant number of participants.

Overview

Each of the above hallways have demonstrated both varying individual success, and categorical success. Some of the hallways and categories showed consistent influence on navigation, such as Density and Symmetry. Others had more varied success or were reliant on questionnaire data to demonstrate its potential, like Change Blindness. Each hallway's potential as immersive, in-game wayfinding cues will be briefly summarized in the conclusion.

Conclusion

This thesis was created to examine the current state of video game wayfinding strategies, document the importance of in-level cues, and propose a variety of new cues. It outlines various theories from disciplines outside of video game design, such as psychology and fine art, and reinterprets and applies these theories as environmentally appropriate cues of varying subtlety. These new cues can be used in combination with pre-existing in-level cues to reduce the reliance on incongruous wayfinding cues, and intrusive UI wayfinding systems. By encouraging the player to navigate based on environmental stimuli, the game is creating an immersive and cohesive game world, and thus a more enjoyable game experience.

The pre-existing in-level cues were divided into several main categories: Light, Breadcrumbs and Landmarks, Physical Barriers and Choke Points, Colour, High Ground, and Motion and Sound. Each of these strategies have been featured in modern games, and documented by game design books, websites, and other sources of information. Some of these strategies demonstrate great versatility and effectiveness. Light, for example, is a highly adaptable wayfinding cue. It is ever-present in games, emanates from countless sources, and can enhance wayfinding through both key lighting and path highlighting. Other pre-existing strategies, like High Ground, are far more situational, but still have great potential. All of these above strategies have been used in modern games to aid the player in wayfinding through the environment.

To expand upon the current library of in-level wayfinding cues, and to encourage the use of environmentally appropriate, immersive wayfinding systems, various new wayfinding strategies were formulated and tested for effectiveness. They were crafted from theories from various practices, including: environmental and perceptual psychology, fine art, architecture, design, and urban planning. Each of these practices have theories on human attention, preference, or navigation, which are applicable to videogame wayfinding. The cues formed from these theories fall under several categories: Material Lines, Implied Lines, Shorelines, Complexity, Symmetry, Density, Mystery, Nature, Change Blindness, Figure-Ground Contrast, and Region Contrast. Each of these categories have demonstrated a varying amount of success for influencing game navigation.

As an overarching theme, Lines were generally unsuccessful. Though material lines demonstrated potential as a subtle, unobtrusive method for drawing attention to a destination, shorelines and implied lines both failed to positively impact wayfinders. Implied lines showed a great deal of theoretical applicability to games, but its presence within the testing scenarios was seen by some as a coercive, foreboding cue. This is in direct contrast to the mission of this thesis. Shorelines merely failed to have any positive impact on wayfinding.

The Complexity category was a unique series of scenarios, as it tested contradicting theories on human scene preference. Various sources have suggested that humans prefer scenes which are high in complexity, containing unique and varied stimuli. However, other theories suggest that humans are physically attracted to areas of relative visual simplicity, as they are easier to understand and process. Within the testing scenarios, participants failed to demonstrate a significant preference for either level of complexity. Though some explicitly stated that they preferred an area's complexity, or its repeated objects, neither cue influenced the wayfinding of a high number of participants. As such, using various levels of visual complexity may not be an effective method for pulling attention within a game.

Symmetry demonstrated to be an effective category of wayfinding stimuli. A significant number of participants consistently found areas of symmetry preferable and more enticing than areas of asymmetry. However, this was a very subtle cue, as few participants explicitly stated that it was the symmetry of the chosen environment that influenced their wayfinding decisions. Though the participants may have been influenced by symmetry and ease of processing, they interpreted the tidiness of the area as their primary navigation rationale.

The Density category of wayfinding cues demonstrated the highest category-wide consistency with participants. However, its success was not due to anticipated factors. This category was tested to observe if participants would find areas of contrasting object density to be visually appealing. However, participants consistently demonstrated a preference for the areas of lower density. As the lower density sections contained fewer objects that could be perceived as obstacles, participants found these areas easier to move through. This ease of navigation consistently influenced a large number of participants' movements.

Mystery demonstrated to be a highly effective cue for influencing navigation, with great potential application in games. When initially exposed to the area of mystery, participants were enticed by its presence, as the first mystery hallway was the single most influential tested cue. However, when exposed to the second representation of mystery, many participants lost interest. This was likely due to the initial hallway's failure to reward participants for their effort. As it did not contain any unique stimuli or positive reinforcement, participants did not see future instances of mystery as a valuable investment of their time.

Much like Symmetry, the Nature category demonstrated natural cues' potential for influencing navigation. Though not all nature hallways showed statistical significance, the combined results of all nature tests demonstrated a consistent and significant preference for scenes with nature, over scenes with man-made structures. Water was particularly effective at physically pulling participants.

The wayfinding results of the Change Blindness hallway did not demonstrate statistical significance. However, the questionnaire responses showed that this cue has great potential for games. Nearly half of the participants explicitly associated the colour seen in the questionnaire representation of the hallway as the same colour that was seen within the original priming hallways. This association occurred after participants had completed the digital trials, and the vast majority of the questionnaire. As the questionnaire responses were open, this is a large number of participants who associated these visually distinct colours, and cited this association as the rationale for their navigation.

Though landmarks have demonstrated to be an effective cue for game navigation, the tests of Figure-Ground Contrast and Region Contrast did not exhibit powerful wayfinding influence on participants. None of the hallways within the contrast theme were effective at pulling participants.

The research trials also demonstrated some important overarching design implications that must be considered when crafting environments with in-level wayfinding cues. Both the value of positive reinforcement, and ease of navigation are two of the most significant lessons learned from the research trials.

The lack of positive reinforcement was a highly influential factor in some of the wayfinding tests. When participants navigated towards a stimulus, but this stimulus failed to provide rewards, there was a notable drop in interest at the second exposure to the stimulus. Even the most effective cue, Mystery, showed a sharp decline in participant selection after its first exposure. This was also seen in the Figure-Ground Contrast category. If an interesting stimulus does not positively reinforce a participant's decision with rewards, they will likely cease attending to it in the future. However, by creating a positive association between a wayfinding cue and rewards, participants will be more likely to actively seek it out, and they will also be more aware of its presence in the environment.

Ease of navigation also demonstrated to be a massive influence on wayfinding. As demonstrated in the Shorelines, Implied Lines, and most notably, Density sections, participants were wary of moving through environments that appeared to present any navigational challenge. Any objects between the participant and the exit could have been interpreted as an obstruction. As these objects posed no actual threat to forward progression, it is the mere appearance of difficult navigation that was such a massive deterrent. Within a game level, the aversion to difficult navigation could be harnessed to guide players towards a predetermined location. Providing areas or paths of perceived navigational ease, within an area that appears difficult to navigate, will likely pull in a large number of players.

This strategy is particularly valuable, as terrain only needs to appear to be difficult to navigate to deter explorers.

Based on the strong responses favoring ease in many of the hallways, it may not be unreasonable to suggest that ease of movement is the most important navigational influence. However, if the player is curious about a scene's contents, the difficulty of navigation is not an obstacle. This was demonstrated in the Mystery hallways.

This thesis has outlined a variety of tools that can be utilized to guide video game players to a predetermined destination, using only features that could naturally occur within a game environment. Material Lines, Symmetry, Density (ease of navigation), Mystery, Nature, and Change Blindness have all demonstrated some potential as immersive in-level wayfinding cues. When integrated and combined with the pre-existing in-level visual cues, and theories on searching and attention described in the first chapter, these new cues may be used to create more immersive and navigable game levels. Extensive use of in-level, environmentally appropriate wayfinding cues will reduce a game's reliance on incongruous wayfinding cues, and intrusive UI wayfinding features. This will aid in producing a more immersive and enjoyable game experience.

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Appendix A: User Interface Wayfinding Examples

Figure A-1 - Screenshot of Dishonored's floating point UI wayfinding system (see above). This directional point is always active, updates as the player's objective changes, and demonstrates the location and distance of the current objective. - Bethesda Softworks, 2012.

Figure A-2 - Screenshot of Deus Ex: Human Revolution's UI wayfinding display (see above). This system shows the destination, and distance from multiple objectives. - Eidos Interactive, Square Enix, 2011.

Figure A-3 - Screenshot of Mass Effect 2's manually engaged dynamic directions (see above). At the player's request, a small compass will appear at the bottom right of the screen, signaling the path forwards. - Electronic Arts, 2010

Figure A-4 - Screenshot of Dead Space 3's manually engaged dynamic directions (see above). A blue streak of light, requested by the player, highlights the path to the objective. - Electronic Arts, 2013

Figure A-5 - Screenshot of Bioshock Infinite's manually engaged dynamic directions (see above). When engaged by the player, a large arrow will spawn along the ground, extending out from the player, highlighting the path forwards. - 2K Games, 2013

Figure A-6 – In game screenshot of Dead Rising 2. It features a persistent dynamic direction wayfinding system (see above). The arrow, located at the top of the screen, will dynamically rotate to point the player towards their goal. – Capcom, 2010

Figure A-7 – Fable 3's persistent dynamic direction (see above) is represented by a glowing trail that will continually update, showing the best route to the player's objective. – Microsoft Studios, 2010

Appendix B: Colour Creation and Effective Use

Though game design literature does mention the importance of colour as a wayfinding tool, the application of colour for grabbing attention and creating focus is very well documented in fine art and design. Writings dive into great detail on how colour can be used to draw the attention of a viewer. In the practice of real-world design, colour can be used to establish differing areas within an environment, highlight landmarks and routes and evacuation paths, camouflage objects, or place emphasis on individual items (Kopacz, 2004, 107-109).

To use colour effectively, it is important to have a basic understanding of colours and their properties. Wayfinding designer David Gibson, provides an effective general overview of the creation of colours:

> Colors are also distinguished by three properties: hue, intensity, and value. Hue refers to color variation, such as pure redness or greenness. Intensity is the saturation or density of a color. Value refers to its relative lightness or darkness. (Gibson, 2009, 88)

Combining hues with different saturations and values can create vastly different colours. With a basic understanding of colour creation, and how they interact with other colours, we can use various techniques to create focal points within scenes. One of the most important methods for focussing attention through colour, is contrast. Simply put, colour contrast occurs when colours that are paired together "display distinct variation" in their appearance (Kopacz, 2004, 33).

Understanding both the properties of a colour, and where the hue rests on the colour wheel, is an important factor for determining its effectiveness for drawing the eye. The color wheel is a visual representation of all hues in the visible light spectrum, depicted in a wheel shape to demonstrate colour harmony and contrast. The farther the distance between the colours on the colour wheel, the greater the contrast will be. Hues that are directly opposite on the colour wheel are complementary hues, and will have the greatest contrast when presented together (Dewitte et al., 2012, 136; Kopacz, 2004, 35). This is referred to as complementary contrast. Kopacz states that although this is the most dramatic contrast of hues, it is "easy on the eyes", and thus a popular design choice (Kopacz, 2004, 41). The basic complementary colour combinations are: blue-orange, red-green, and yellow-violet. Using complementary colours in tandem with relative occupancy of a scene is an effective method for emphasizing target colours. In a scene of predominantly yellow, a smaller violet feature will have a large visual impact, and act as the scene's focal point.

For all contrasts of hue, the higher the saturation of the compared colours, the stronger the contrast will be (Kopacz, 2004, 35). We can even create contrast between colours of the same hue by radically altering the colour's saturation (Kopacz, 2004, 43). Adjusting saturation values can greatly impact the appearance of a colour, creating profoundly varied representations of the same base hue.

Contrast can also be created through harmonious pairings of colours. One of the methods of categorizing like colours is referred to as *colour temperatures*.

> Color establishes an impression of temperature according to its hue characteristics… Hues in the yellow, orange and red range are considered warm, while colors ranging from blue to green are considered cool. Yellow-green and violet can seem either warm or cool depending on the relative temperature of the adjacent colors in view. (Kopacz, 2004, 9)

While the perception of a colour's warmth and coolness is subjective, colours of the same temperature can be used together without inducing contrast if they are adjacent on the colour wheel, or analogous colours.

Colours of different temperatures can be paired to create contrast. Colours of opposing temperatures, a warm background with a cold focal point, can be used to highlight areas or objects within a scene (Kopacz, 2004, 40). Graver et al. suggest that scene emphasis can be created by surrounding the focal object with colours of the opposing temperature. Or, we can mute the effects of a colour by placing it within colours of its own temperature (Graver and Jura, 2012, 79). The effects of the colour temperature contrast can be intensified by increasing the saturation of the contrasting objects (Kopacz, 2004, 41).

Kopacz suggests that the strongest colour contrast available is a value, or "light-dark contrast". This involves presenting a scene that features objects both high and low in value, creating a contrast between dark and light areas. By grouping objects of vastly different values, we can create contrasting colours that feature the same hue.

It is important to note that the closer in proximity the contrasting objects are, the stronger the contrast will appear. Kopacz states that the strongest contrast appears when the objects actually share borders or overlap. The larger the shared border, the greater the contrast (Kopacz, 2004, 49).

Appendix C: Computer Specifications, Testing Setup, Camera, and Lighting

The game scenarios have been built using a combination of custom scripts, custom materials and objects, and stock Unreal Engine 4 materials and objects. In the testing room, Unreal Engine 4 is installed on 4 computers, each with the same specifications: iMac with a 3.4 Ghz Intel Core i7 Processor, 8 GB 1333 MHz DDR3, AMD Radeon HD 6970M 2048 MB Graphics Card, 27" 2560X1440p display. Before each participant's arrival, the screen brightness of each monitor is standardized. However, the participants are encouraged to adjust the brightness to a comfortable level. All computers are paired with matching chairs to create the most consistent experience possible. Computer positions, orientation, and seating were all distributed to minimize occurrences of distraction.

To provide an optimal view of all the environment's content, while maintaining a first-person viewpoint, the in-game camera is positioned 99cm above the centre point of the body capsule, placing it approximately 1.9m above the ground. The camera is also approximately 22cm behind the centre of the capsule, and rotated 5° toward the ground.

To illuminate the test environments, individual lights stretch the length of each side of the hallways. They run the entire length of the hallway, unless otherwise stated, and are aligned with the centre of the choice and entry sections. Lighting in the hallways was tuned to provide participants maximum visibility of the environments. As none of the environmental wayfinding theories that were tested were associated with variance in lighting, lighting was portrayed as consistently as possible in each hallway. Unreal Engine 4 lighting features such as eye adaptation, bloom, lens flare, and others were reduced or disabled to ensure maximum visibility. The majority of the rooms had a total of 100,000 lumen value, featuring a 50,000 lumen light on each side of the hallway. Some environments did vary from this basic standard, but this variance will be highlighted for each applicable hallway.

Appendix D: Research Trials Documents

UNIVERSITY OF ALBERTA

Experiment Protocol:
Visual Cue Influence on Way-Finding Tendencies in Digital 3D Environments

Investigator: Brett Nisbet

Tests will be held in room 434 Old Arts building. This is a private computer lab run by Dr. Maureen Engel. It contains four high end iMac computers that are capable of running the required software. Up to four students at once can participate in the studies simultaneously. Using the research participation template, directional signs will be placed around the Old Arts building at every entrance to ensure that all participants are able to locate the testing room. To allow all students to arrive to the study, the start of the session will be delayed 2-5 minutes, as recommended by the Research Participation policies and procedures guide. As students arrive at room 434 Old Arts Building, they will be seated to await the start of the verbal introduction, attendance, and other items (e.g., informed consent, etc.). As required by the Department of Psychology Research Participation Program, attendance will be taken to confirm which students will receive their research participation marks. In accordance with FOIPP, the attendance sheet will not feature the students' ID numbers.

Below is the script that will be used to verbally introduce the students to the study:

"Hello, and welcome to research participation for the study titled "Examination of Visual Cue Influence on Way-finding Tendencies in Digital 3D Environments". My name is Brett Nisbet, and I am the principle investigator for this study. If you have any questions at all during this introduction, please simply raise your hand. This is a one hour, one credit research participation project that takes approximately 35 minutes to complete. In this study, we are investigating the impact of various visual cues in 3D environments on the way-finding tendencies of participants. The information gathered during this test may ultimately be used to further our understanding of human way-finding and visual preference in 3D environments. This could provide new and valuable information to the fields of psychology, game design, architecture, and more! Loaded on the computers in front of you is a program that contains a series of various digital hallways. Each of these hallways contains different visual cues and appearances. Nearly all of the hallways will have two exit doors, marked by a white square. Using the computer's keyboard, you will guide an on screen camera through these environments.

Once the experiments have started and you're at your computer, please explore these environments, and ultimately select the hallways that you're most drawn towards. ***It's important to note that there are no correct answers, and the choices you make will not have an impact on which hallways you see next.*** *Try to treat every hallway as an individual experience, using the visual information available in the current scenario to make your decision on which hallway you will choose. Please take your time to look at the environments, and make your decisions on which to choose based on the visual stimulus that is immediately present. After each hall choice, your camera will be transported to a blank room, free of visual stimuli for several seconds. This room is intended to refresh your senses, and reduce associations between scenarios. Again, we ask that you choose hallways that you feel drawn towards based on the visual stimuli that is available within the immediate environment.*

You will control the on screen camera using either the direction (arrow) keys, or the W, A, S, and D keys. The directional (arrow) keys will move the camera in the corresponding direction, with the other keys controlling movement as follows: W-forward, S-backwards, A-left, D-right. Please note that you can use either set of keys to fully control your camera. All objects in the environment, apart from walls, can be moved through and will not hinder progress. During your time with the digital environments, please avoid pressing the escape key, or the tilde key.

Once you reach the digital room that says "Thank you for your participation!", please raise your hand so that the investigator can confirm that the scenario portion of the test has been completed and provide you with the questionnaire. This questionnaire will be a digital form that requires you to type into pre-made fields. It will ask you about your experiences and choices with each of the hallways. Upon completion of this questionnaire, you will receive debriefing forms and a verbal debriefing. Once you've received the debriefing forms, you will have completed the examination.

All the actions you take on screen and in the scenario will be recorded by automated scripts. All data collected during this test will be anonymized, and only accessible the investigator and his supervisory team. Ultimately, this data will be used as a basis for my personal thesis project, but again, all data collected will be anonymized, and will not identify the participants.

If you have any questions at all during the testing process, please just raise your hand and I will answer any of your questions. Any questions?

At any point in the study you are free to withdraw your consent, or request an alternate task. By completing an alternate task, you will still be awarded full credit for research participation. The alternate task will consist of reading an article associated with the project, and answering a series of questions based on the article. Please note that you're free to withdraw consent or request the alternate task even after you've started the computer scenarios. You will also be free to withdraw your consent up to 72 hours after the completion of your test. Simply contact me using the email that is provided on the debriefing forms, and I'll destroy any information associated with your test. You will also be more than welcome to contact me by email at any point to request further information on the study.

Please do not tell any of your classmates the details of this study. We have a very small testing pool this year, so there is a good chance that a large amount of your classmates will also participate in this study at some point. By not telling your classmates about the contents of this study, you're helping us get the best data possible.

At this point, I will be handing out the consent for participating in this study. Please take a few minutes to read it over, and if you consent to the study, sign at the bottom. If you do not consent, or have any questions at all, please just let me know. *Once you have completed the consent forms, or requested the alternate task, we will begin the study."*

The wording of the above script may change slightly to better communicate the purposes of the test to the participants.

After consent forms have been signed, and any questions or concerns have been attended to, I will initialize the digital scenarios. The participants will then have 30-40 minutes to complete the tasks. Students who quickly make decisions may be done the hallway scenario tests in as little as 5 minutes. Those who take their time exploring the environments may take 15 minutes. Once the participants have completed the study, as indicated by the "*Thank you for your participation!*" screen, I will provide the participants with a questionnaire. This questionnaire will provide images of all hallways within the test, ask the participants which hall they chose and why. The questionnaire will also ask basic questions about the participant's gender, age, dominant hand, etc. This questionnaire should take no longer than 15 minutes. Once this questionnaire is completed, the participants will be provided with their debriefing forms, and informed that they've completed the trials. Once all students have completed and left the rooms, all data will stored on a secure hard-drive, and any residual data will be wiped from the lab computers. Hard copies of documents will be stored in a locked drawer for later processing.

UNIVERSITY OF ALBERTA

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS & FACULTY OF SCIENCE

Research Information and Participants' Consent Form:
Visual Cue Influence on Way-Finding Tendencies in Digital 3D Environments

Principal Investigator	Supervisor
Brett Nisbet	Dr. Maureen Engel
Humanities Computing Program	Humanities Computing Program
University of Alberta	University of Alberta
Edmonton, AB T6G 2E9	Edmonton, AB T6G 2E9
BNisbet@UAlberta.ca	Maureen.Engel@UAlberta.ca

Purpose: You are invited to participate in a study being conducted by Brett Nisbet from the Humanities Computing program. This project is a part of his graduate thesis project. This study examines how subtle and obvious visual cues in a 3D environment can affect participants' way-finding tendencies.

Study Procedures: Your participation in this study will involve using a keyboard to navigate through 3D environments. While in the digital environments, you will be faced with multiple way-finding choices in the form of branching hallways. You will be presented with two different intersecting hallways, in multiple different scenarios. Please choose the hallway that you feel the most drawn towards. You will select hallways by using the keyboard to advance the camera towards the end of the selected hallway. Upon reaching the door at the end of the hallway, your camera will be transported to a blank room for a brief period, then automatically moved to a new navigation scenario. Please note that there are no right or wrong answers. Please avoid looking at the computer screens of the other participants. When operating the scenario, please avoid pressing the escape key (esc) and the tilde key (~). Once the digital scenarios have been completed, participants will be provided with a digital questionnaire. This questionnaire will gather additional information on the participants' experiences in each of the hallways.

Benefits: This research can potentially contribute to the advancement of our understanding of human way-finding tendencies. Information from this study may aid in the development of more effective and efficient visual navigation cues for architecture, design, and video games.

Risks: There are no foreseeable risks to this study. If any risks should arise, the researcher will inform the participants immediately.

Voluntary Participation: Your decision to participate in this study is entirely voluntary and you may decide at any time to withdraw during the duration of the study. You may choose to withdraw your consent at any time during the study, with no justification required. If you should decide to withdraw, please notify the research investigator, and all the data collected will be destroyed immediately. If you wish to withdraw information after the completion of the study, you will have a seventy-two hour window to contact the research investigator and request a withdrawal. The researcher's contact information can be found in the "Further Information" section. If you choose not to participate in this study, or withdraw during the duration of the study, you may complete an alternative educational activity.

Confidentiality and Anonymity: The results of this study will be published in a publically accessible thesis project. Only grouped data will be presented within the thesis, with no possibility for individual identification. No names or identifying information will be published in the thesis project. Decisions made by participants on the test will remain confidential throughout the analysis process. Only researchers associated with this study will have access to the tests results. Digital data will be stored on an encrypted USB drive for a minimum of five years, then safely deleted. Paper documents will be stored in a locked drawer or storage container for a minimum of five years, then shredded.

Alternate Task: Students are free to withdraw their consent or choose not to participate in the study at any time during its duration. For those who choose not to participate in the planned research activity, they will have the option to earn research credit through the completion of an alternate educational activity. The activity will be equivalent in length to the original project. This alternative task will consist of reading an excerpt from Dr. Stephen Bitgood's "An Attention-Value Model of Museum Visitors" and answering questions related to the reading.

Further Information: If you have any questions or comments about this study, please contact the researcher, Brett Nisbet, at BNisbet@ualberta.ca or his supervisor, Dr. Maureen Engel, at Maureen.Engel@ualberta.ca. If you have any questions or concerns about your rights as a participant, or how this study is being conducted, you may contact the Research Ethics Office at (780)492-2615.This office has no affiliation with the study investigators. Additionally, you may contact the Research Participation Coordinator at rescred@ualberta.ca or (780)492-5689.

Consent Statement

I have read this form and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I agree to participate in the research study described above and will receive a copy of this consent form. I will receive a copy of this consent form after I sign it.

Participant's Signature | Date

Researcher's Signature | Date

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DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS & FACULTY OF SCIENCE

Debriefing Sheet:
Visual Cue Influence on Way-Finding Tendencies in Digital 3D Environments

The Purpose of the Study: The aim of this study is to observe the effects of subtle and obvious visual cues on the way-finding decision making of participants. Using theories from perceptual psychology, fine art, architecture, and various forms of design, visual cues designed to influence decision making were implemented in traversable digital environments. We are interested in seeing if participants in this study reacted to any of the cues positively by walking towards that cue's hallway exit. By making decisions based on your surroundings, you're providing information on the effectiveness of visual cues of various types. This information can then be applied to various areas of study, including psychology, video game design, architecture, design and more. We expect that some of our experiment hallways containing research-supported visual cues will have an influence on participants' behaviour, and draw them in a certain direction.

The Background of Research: This study pulls information from multiple disciplines, each with their own theories and explanations of human way-finding and visual preferences. The majority of the theories and techniques tested in this study are unique to digital 3D environments, and have not been tested in a research setting such as this. However, videogames, where 3D environments are often present, employ multiple strategies for influencing player way-finding. Some of the most common and effective methods for guiding users through environment include: use of strategic lighting, sounds emitted from an origin point, using classic colour cues (red, yellow, green), and employing dynamic maps and arrows.

For further reading on human way-finding and visual preference from a perceptual psychology perspective, I suggest the following readings:

Bitgood, S. (2013). *Attention and value: Keys to understanding museum visitors*. 1630 North Main Street, #400 Walnut Creek, CA: Left Coast Press, Inc.

Golledge, R. G. (1992). Cognition of physical and built environments . *Environment, cognition, and action : An integrated approach: An integrated approach* (Garling, Tommy; Evans, Gary W. ed.,) Oxford University Press.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364-382.

For further reading on existing visual cue strategies in video games, I suggest:

Bates, B. (2004). *Game design* (2nd Edition ed.). Boston, Mass: Thomson Course Technology.

The Design of the Study: After extensive research into multiple disciplines, numerous theories for stimulating visual preferences and way-finding choices were gathered. These theories were then interpreted and adapted into visual cues that could be implemented in simple 3D environments. Environments were crafted to support each visual cue that was to be tested. Each scenario hallway branched off into two choices: one which contained a supported visual cue, and another which may or may not contain a researched visual cue, but often had a great resemblance to the other hall. Participants travelled through the digital environment by guiding the camera and selecting the hall they felt more physically drawn towards by walking to the hall's exit. Once the camera approached the exit door for the chosen hallway, the participant was then transported to the next hallway scenario to make their next decision. The blank room is used as a buffer, providing little stimulus in an attempt to remove associations between scenarios and "refresh" the user's senses. When all of the scenario halls were completed, the participants were provided with a questionnaire. This questionnaire presented the participants with photographs of all the hallways experienced, and asked them to recall and explain their decision making behaviours. This questionnaire will give insight on the decision making process of the participants, and demonstrate their ability to recognize the cues that were implemented. Participants' hall choices were recorded by "in-game" scripts that stored each of the hallway choices. These choices will be coded and analyzed to observe the impacts of the visual cues.

Alternate Task: Students were free to withdraw their consent or choose not to participate in the study at any time during its duration. For those who chose not to participate in the planned research activity, they were provided the option to earn research credit through the completion of an alternate educational activity. The activity was equivalent in length to the original project. This alternative task consisted of reading an excerpt from Dr. Stephen Bitgood's "An Attention-Value Model of Museum Visitors" and answering questions related to the reading.

Withdrawal Policy: Your decision to participate in this study was entirely voluntary and participants may have decided at any time to withdraw during the duration of the study with no justification required. If participants chose to withdraw during the session, any data collected was destroyed immediately. If you wish to withdraw information after the completion of the study, you will have a seventy-two hour window to contact the research investigator and request a withdrawal. If you have any questions, concerns, or would like to withdraw your data, please contact the primary researcher, Brett Nisbet, by email at BNisbet@ualberta.ca

We would like to thank you very much for participating. Without the help of people like you, we couldn't empirically address the most important questions in psychology. We have one last request: ***Please don't tell other people about what we asked you to do in this study because other students may participate in this study and it is very important that they approach it as you originally did, i.e., without expectations and without full awareness of our objectives.*** *This is important because it is the only way we can obtain objective and valid information.*
If, after this session, you have any questions about this study, please contact Brett Nisbet at BNisbet@ualberta.ca. If you have general questions about your research participation, contact the Research Participation Coordinator at 780-492-5689, or e-mail questions to the Research Participation Coordinator at rescred@ualberta.ca.

If you have any questions or concerns about your rights as a participant, or how this study was conducted, you may contact the Research Ethics Office at (780)492-2615.This office has no affiliation with the study investigators.

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Appendix E: Questionnaire Information

After the completion of the digital trails, all participants are required to complete a questionnaire. The questionnaire presents the participants with images that represents each hallway, in the order that they were experienced. Two versions of the questionnaire were produced to ensure that the images accurately reflected the actual state (correct siding) of the environments. Below each image is box with the following text:

"State which hallway you selected (Left or Right). Briefly describe your rationale for selecting that hallway. If you're unable to recall why you selected that hallway, please type "N/A". If you're unable to remember the hall that you chose, please make your best guess, justify the guess, and state that you are guessing."

Below this text is an empty box, where the participants can type in their rationale for why they selected a particular hallway exit.

Unfortunately, this system relies on the participants' memory for their rationale. This could have been bypassed by providing the participants with a paper copy of the questionnaire to fill out as they move through the environment. However, this system was avoided for two main reasons: if the participants had a copy of the questionnaire while they were moving through the trials, they would have freely accessible visual representations of all the hallways that they had passed through, and will eventually experience. As one of the prompts encouraged the participants to make their decisions in each hallway purely based off the visual stimuli that are immediately available in that environment, providing the participants with visuals of all hallways at all times would likely impede their ability to follow this suggestion.

Also, if the participants were exposed to a hallway, then had an extended period of time explaining their decision within that hallway, that environment would likely be very salient in the mind of the participants. This memory of the previous hallway, and the reflection on the decision making process, would likely influence the participants' decisions in the following hallway. As such, the questionnaire was reserved until after the participants had completed their digital trial, and the refresher room was implemented to try and reduce the priming that may occur between hallways.

Appendix F: Test Randomization, Inversion, and Versions

The hallway's number (16th Hallway, 6th Hallway, etc.) is representative of the order in which it was experienced during the research trial, starting with the 1st Hallway, and finishing with the 32nd Hallway. This ordered structure was consistent across all participants in the study, and not uniquely randomized for every participant.

To help participants remember their exit choice rationale, the hallway order of the questionnaire mirrors that of the research trial. It may have been possible to randomize the hallway order for each individual participant, but this would have been difficult to recreate in the questionnaire.

The side on which choice 0 and choice 1 are located is also randomized. All of the hallways were designed to have the choice 1 content, the content in support of the wayfinding hypothesis, on the right side of the hallway. The choice sides were then randomized. The hallways which were to have choice 1 located on the right side remained unaltered, and hallways where choice 1 was on the left side had all of its contents (materials included) inverted on the Y-axis. This mirrored the appearance and content of the environments, relocating all the necessary objects, materials, and trigger boxes. After inverting the content, choice 0 is located on the right side, and choice 1 is on the left.

A study conducted by Taylor and Sucov (1974), found that when participants were presented with an environment that did not visually differentiate its left and right hallways, participants chose the right hallway at a rate of 69% (Ginthner, 2002, 2-3). In this research trial, if participants are undecided on which direction to travel, unable to locate differentiating details in the environment, or are just choosing randomly, right side bias may have a skewing impact on the results of this test. Whatever choice is located on the right side of screen may have increased chances of being selected due to right side bias.

To combat this, two versions of the test were created. Version 1 features the randomly ordered hallways, and the randomly placed choice 1 and choice 0 discussed above. Version 2 features the same hallways in the same order, but the choice 1 and choice 0 sides have been inverted on the Y-axis. If choice 1 is on the left side in version 1, it will be on the right side in version 2. This inversion occurred for all the hallways in version 2. If there is a right, or left side bias in the test group, it should not have a skewing impact on the results of the tests. The 21st Hallway (No Differentiating Stimuli) was the only hallway that was not inverted, as the choices for this hall were coded as L, and R, to indicate the direction that the participants travelled.

Appendix G: Hallway Images and Supporting Text

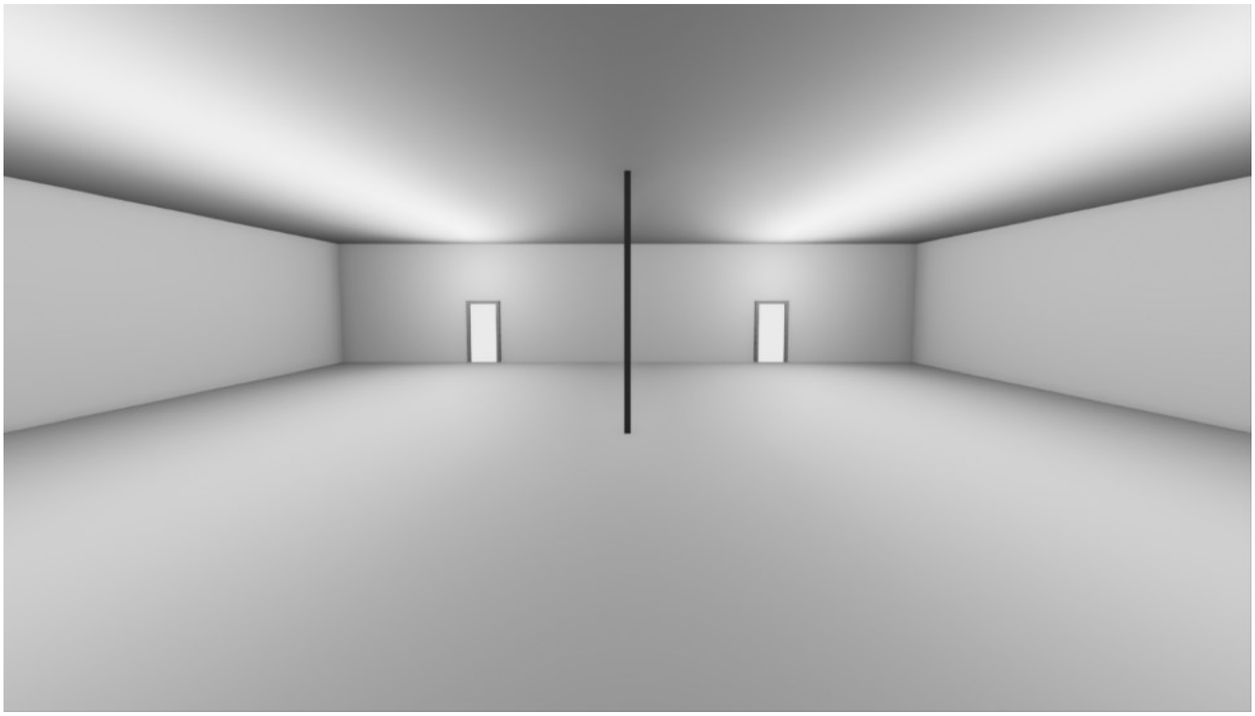

Figure G-1 - No Differentiating Stimuli - 21st Hallway - Standard Hallway - See above for the hallway's design details.

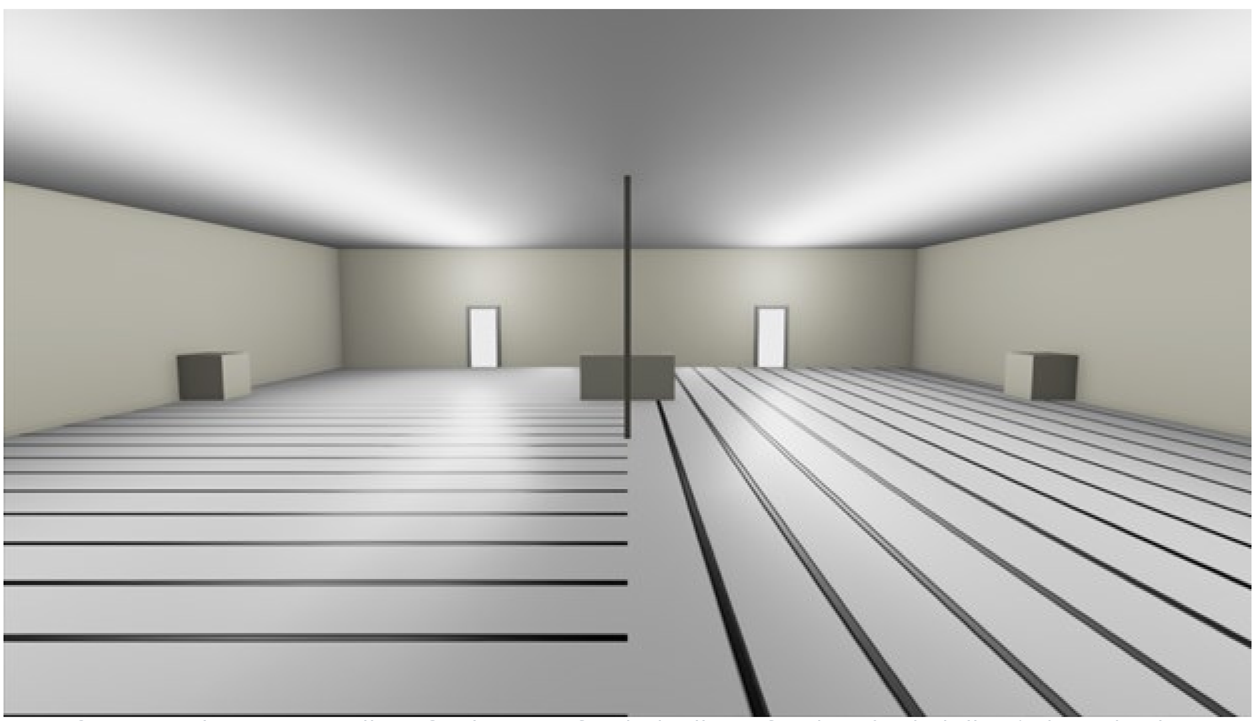

Figure G-2 - Material Lines 1 - 1st Hallway -Baseline Test - Standard Hallway - See above for the hallway's design details.

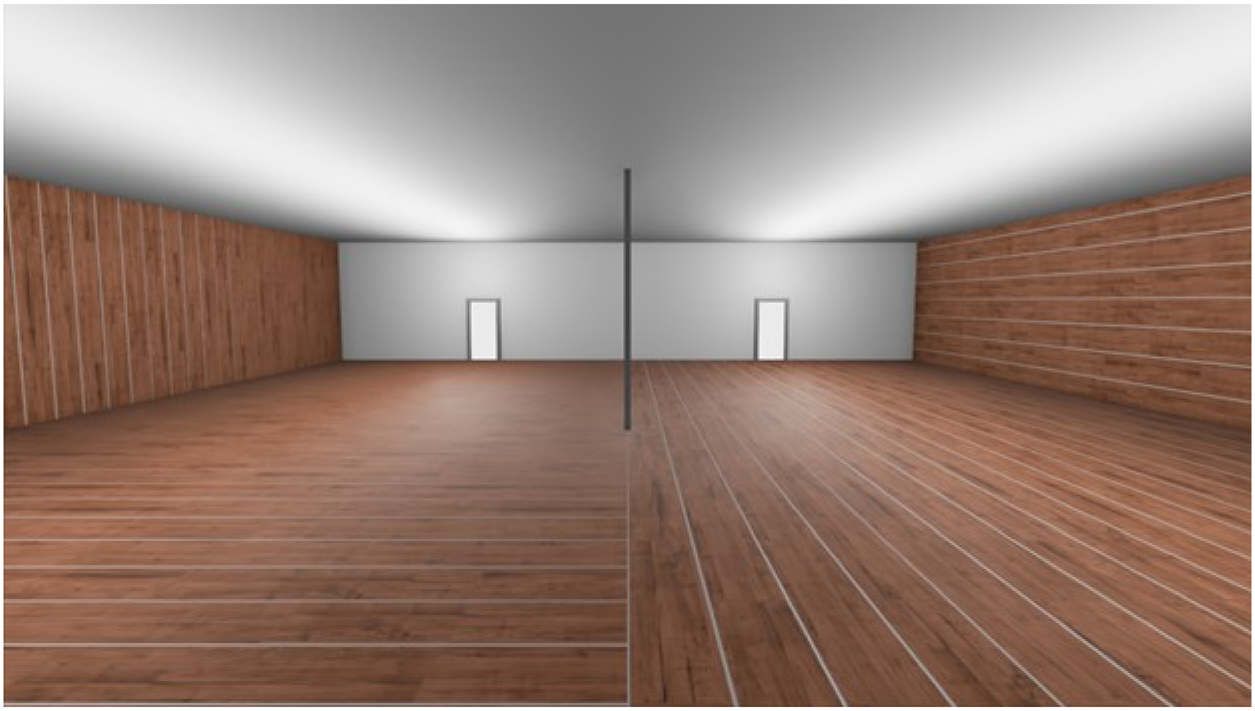

Figure G-3 - Material Lines 2 - 12th Hallway - Scenario test - Standard Hallway - See above for the hallway's design details.

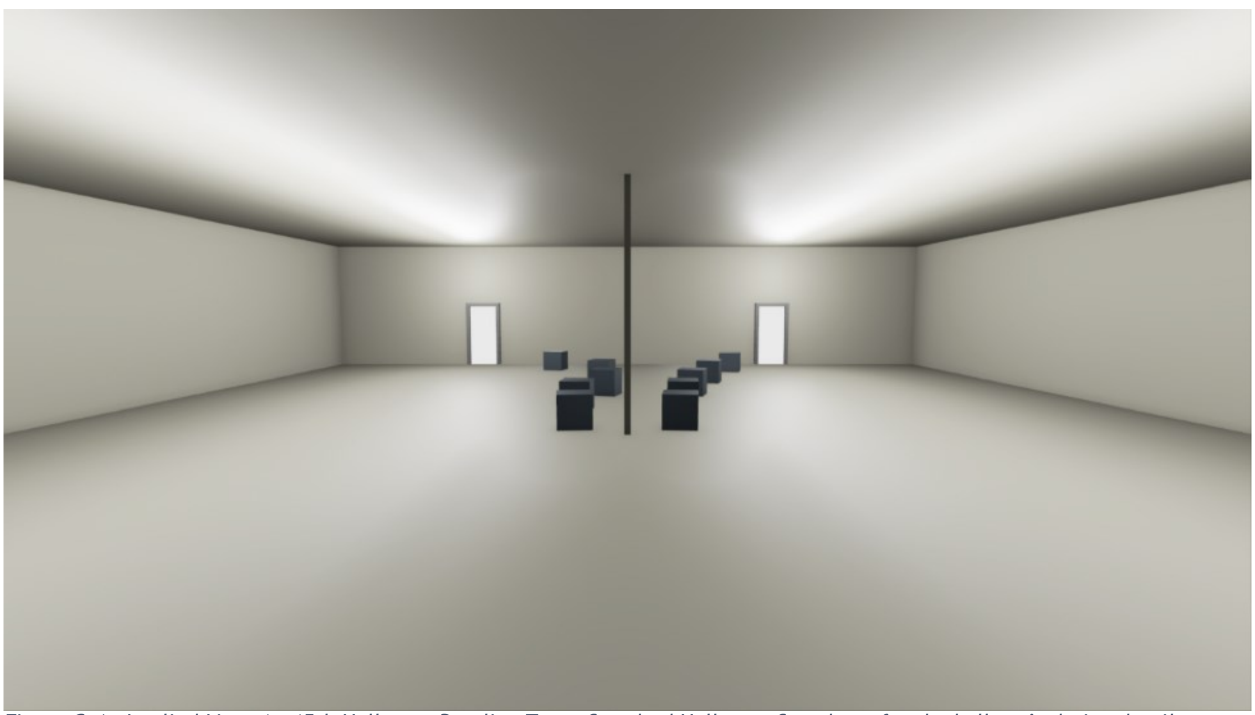

Figure G-4 - Implied Lines 1 - 15th Hallway - Baseline Test - Standard Hallway - See above for the hallway's design details.

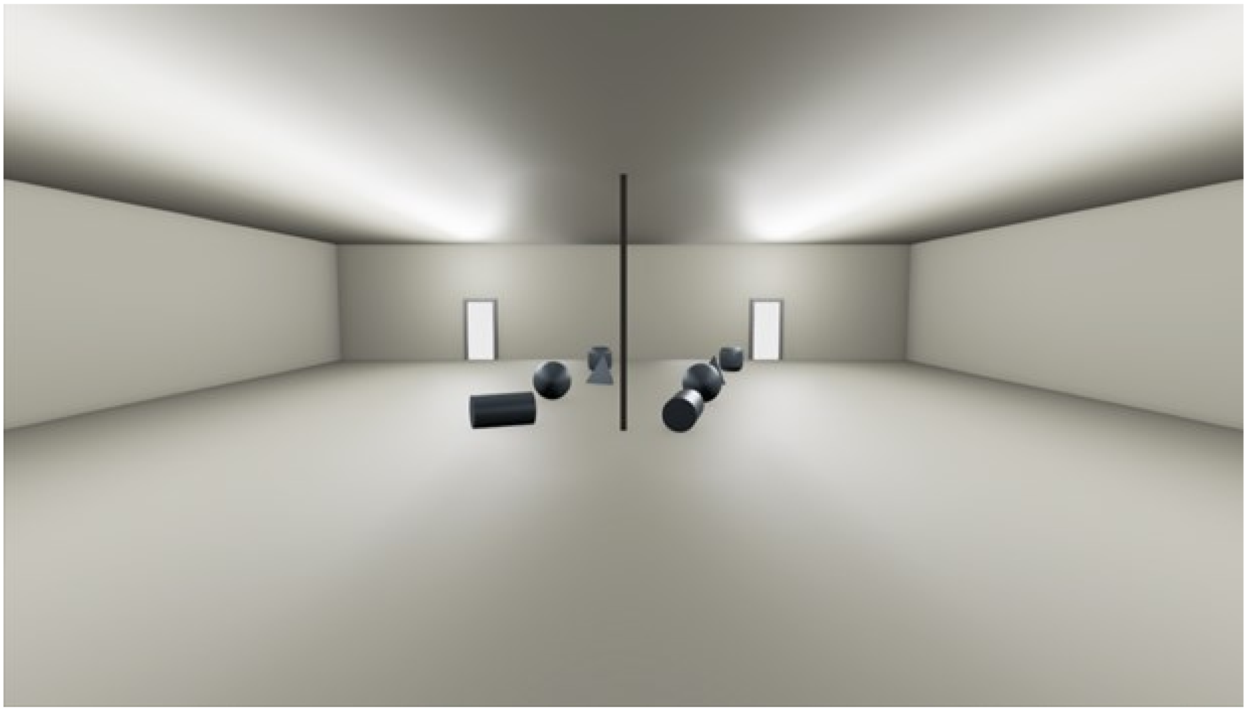
Figure G-5 - Implied Lines 2 - 24th Hallway - Baseline Test – See above for the hallway's design details.

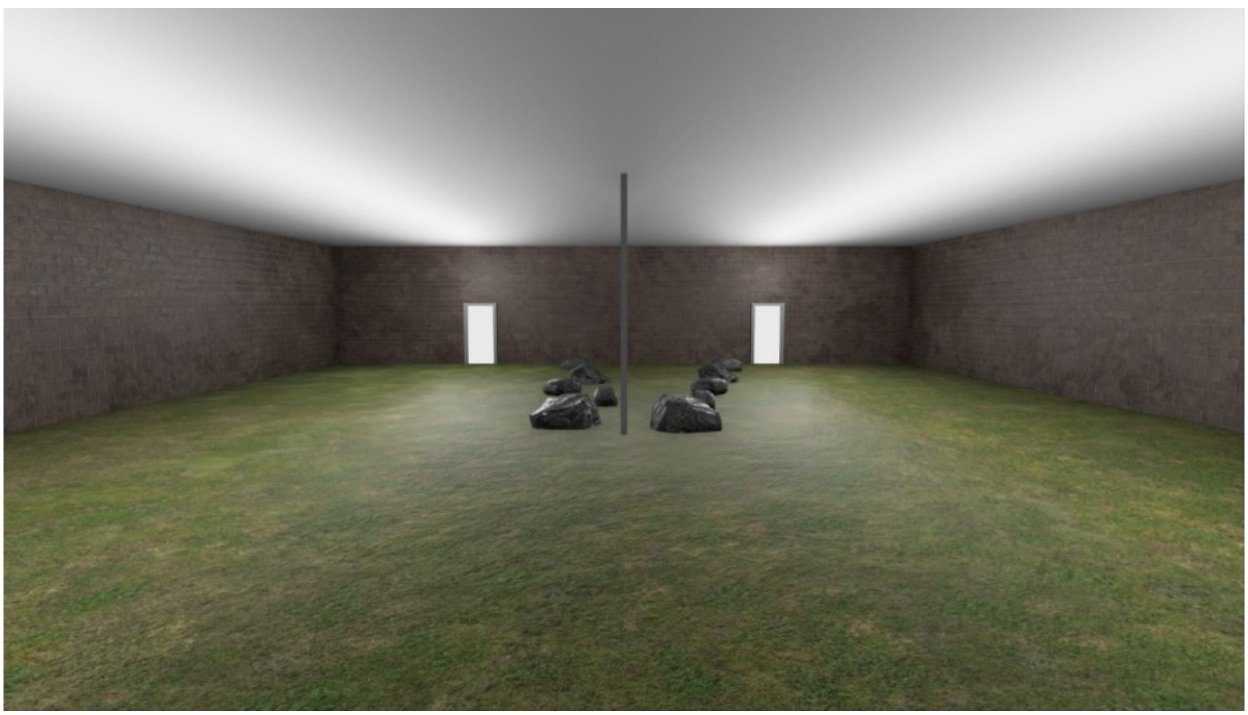
Figure G-6 - Implied Lines 3 - 10th Hallway - Scenario Test - Standard Hallway – See above for the hallway's design details.

Figure G-7 - Implied Lines 4 – 2nd Hallway - Scenario Test - Standard Hallway – See above for additional hallway design details.

The light props are spaced out with approximately 4 meters between the centre points of each light in the sequence. The lighting in this hallway is produced from 5x10,000 lumen lights in each choice. The light source location and length suggests that the light was emanating from the fluorescent light props. In reality, the light source is located 2m below the fluorescent light prop. This is to give a more clear and coherent reflection of lighting on the ground material. This floor material, included in Unreal Engine 4, was altered to ensure that the lighting from the sources was properly reflected on the ground, creating a second set of potential implied lines. Each light is oriented to match the rotation of the light prop that it is attached to.

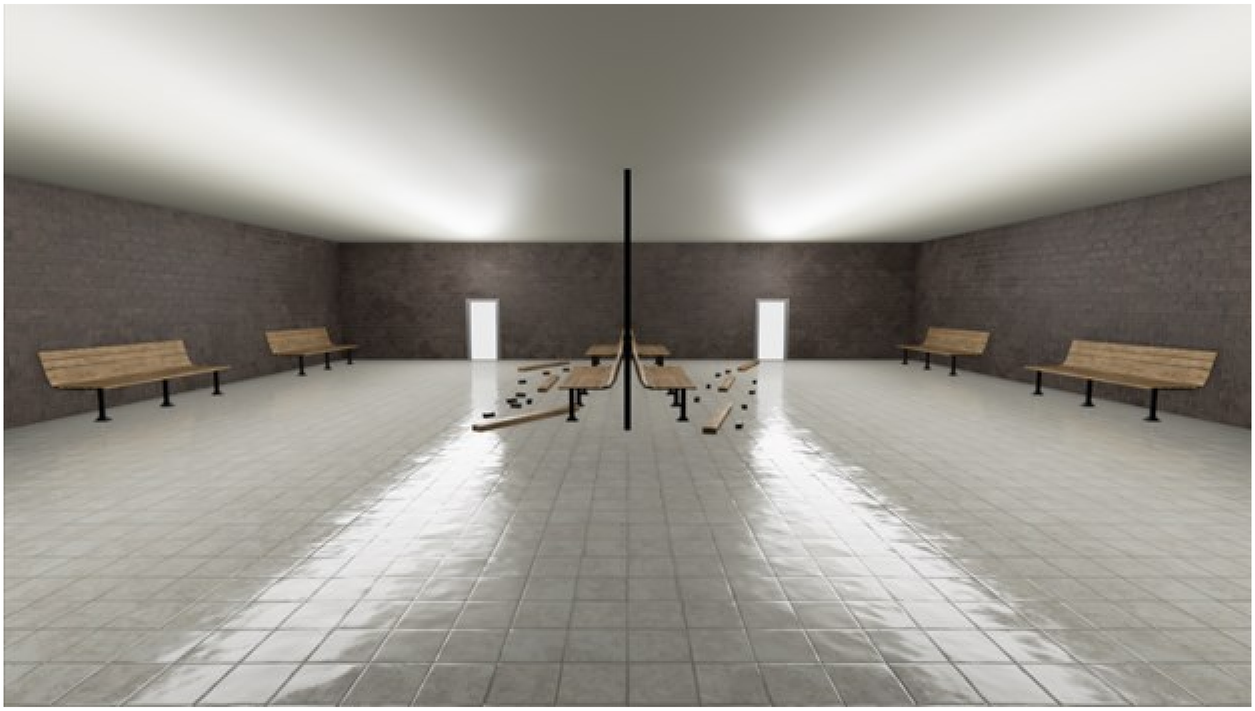

Figure G-8 - Implied Lines 5 - 9th Hallway - Scenario Test - Standard Hallway – See above for the hallway's design details.

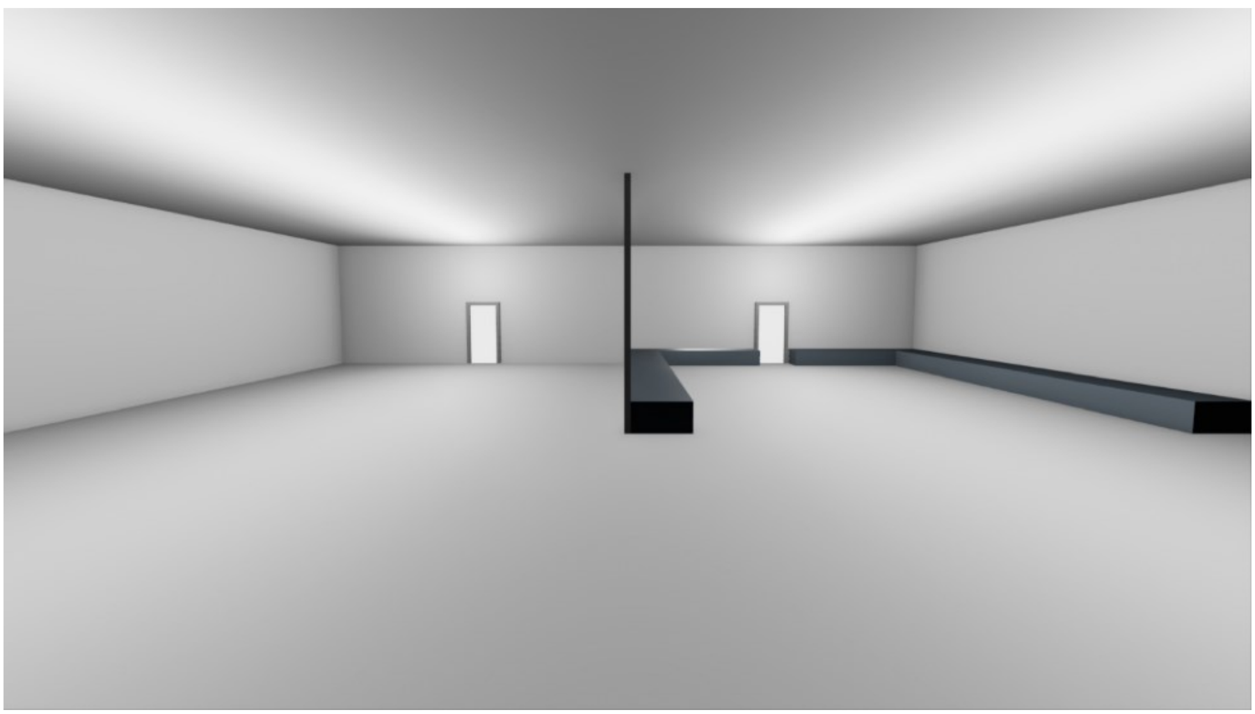

Figure G-9 - Shorelines 1 - 22nd Hallway - Baseline Test - Standard Hallway – See above for the hallway's design details.

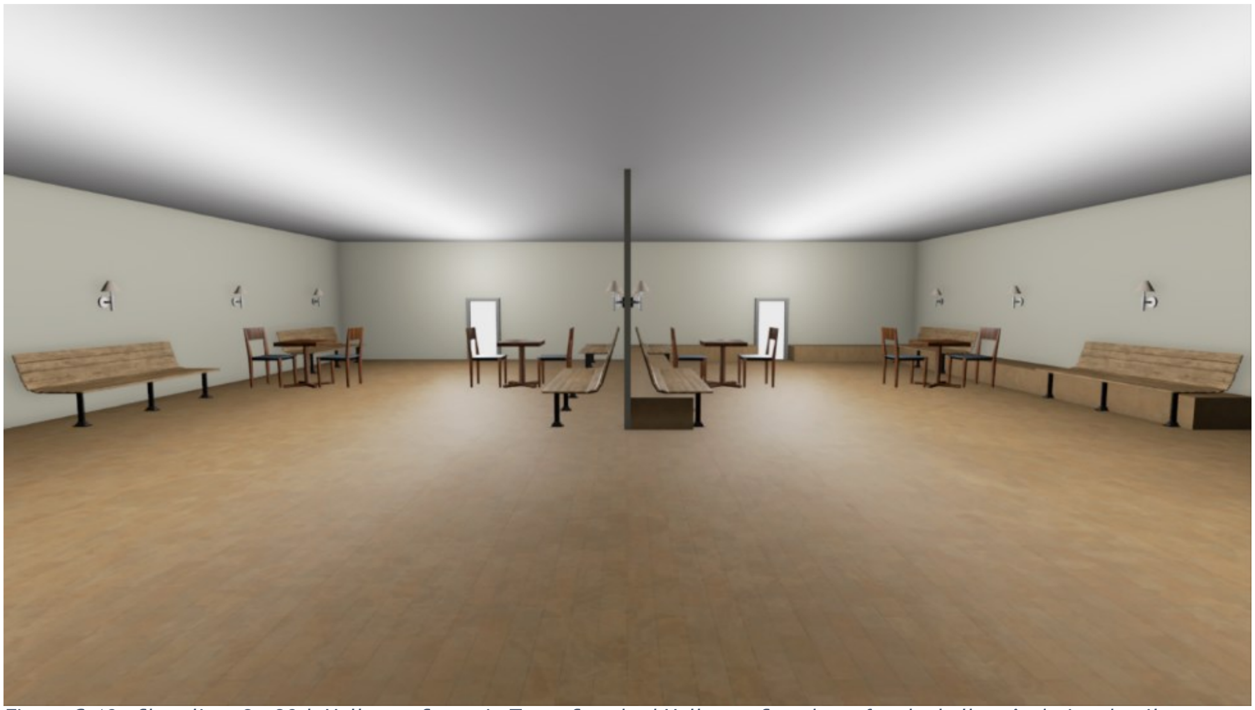

Figure G-10 - Shorelines 2 - 20th Hallway - Scenario Test - Standard Hallway - See above for the hallway's design details.

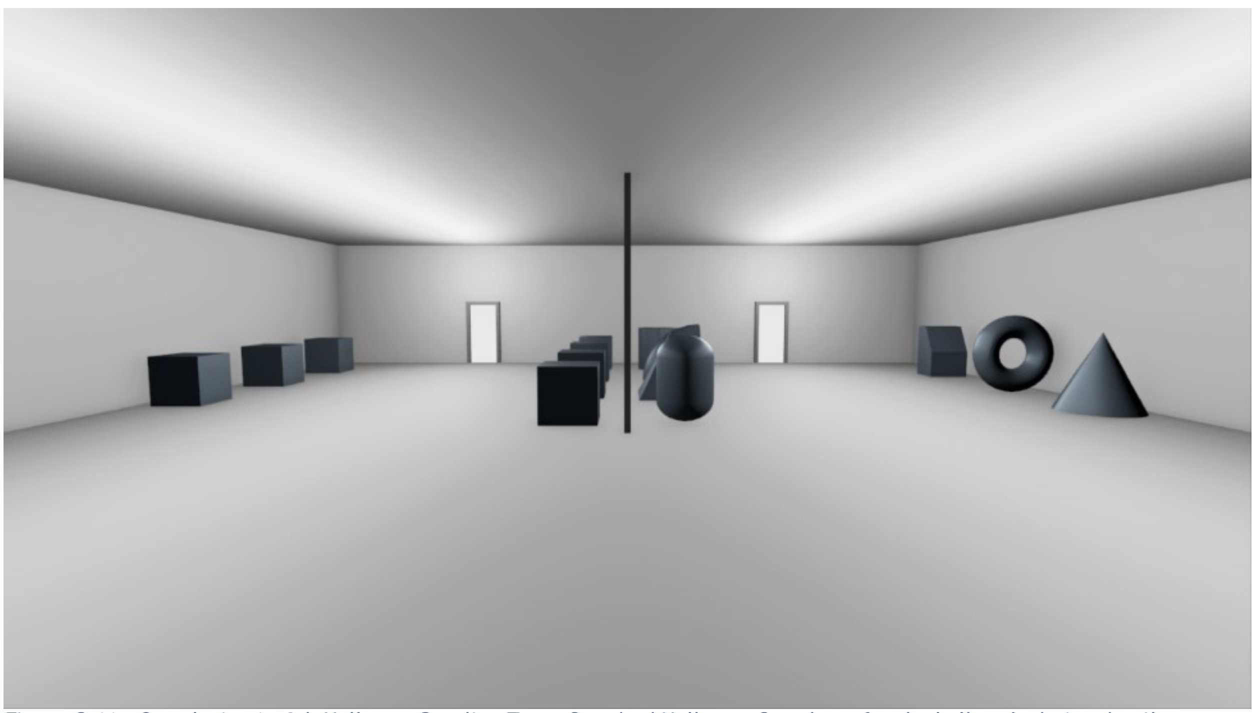

Figure G-11 - Complexity 1 - 8th Hallway - Baseline Test - Standard Hallway - See above for the hallway's design details.

Figure G-12 - Complexity 2 - 28th Hallway - Baseline Test - Standard Hallway - See above for the hallway's design details.

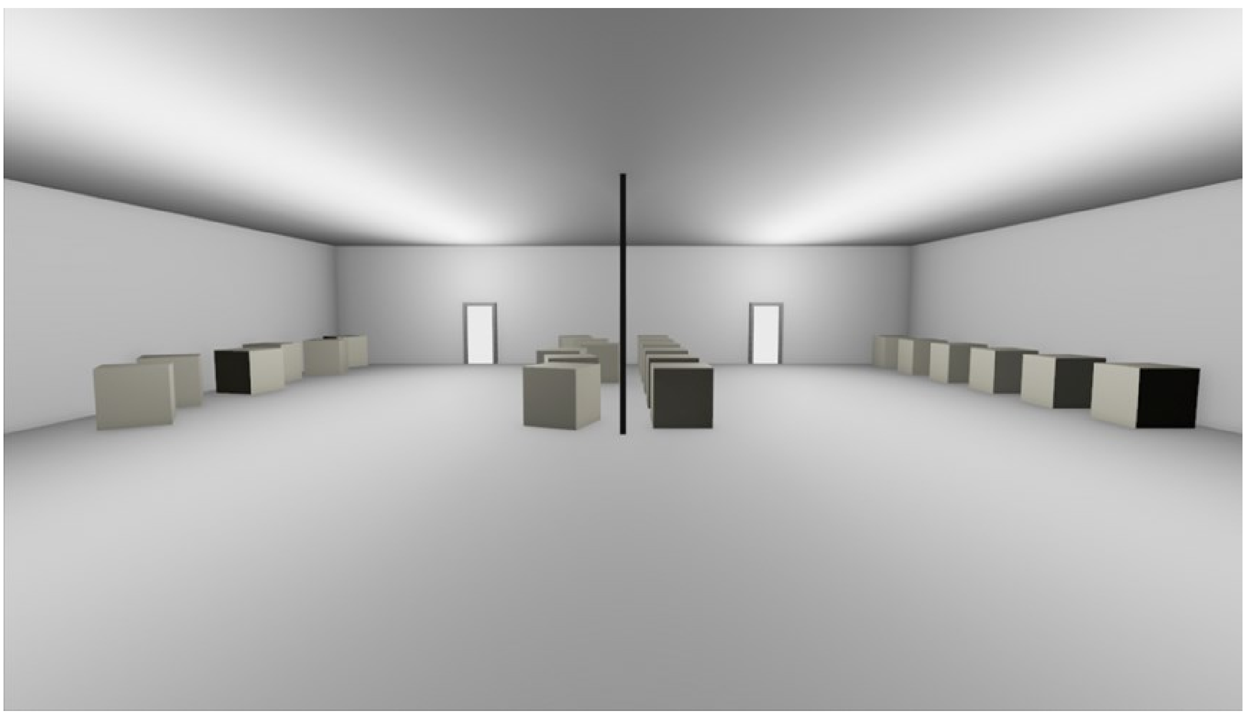

Figure G-13 - Symmetry 1 - 14th Hallway - Baseline Test - Standard Hallway - See above for the hallway's design details.

Figure G-14 - Symmetry 2 - 26th Hallway - Scenario Test - Standard Hallway – See above for the hallway's design details.

Figure G-15 - Symmetry 3 - 3rd Hallway - Scenario Test - Standard Hallway – See above for the hallway's design details.

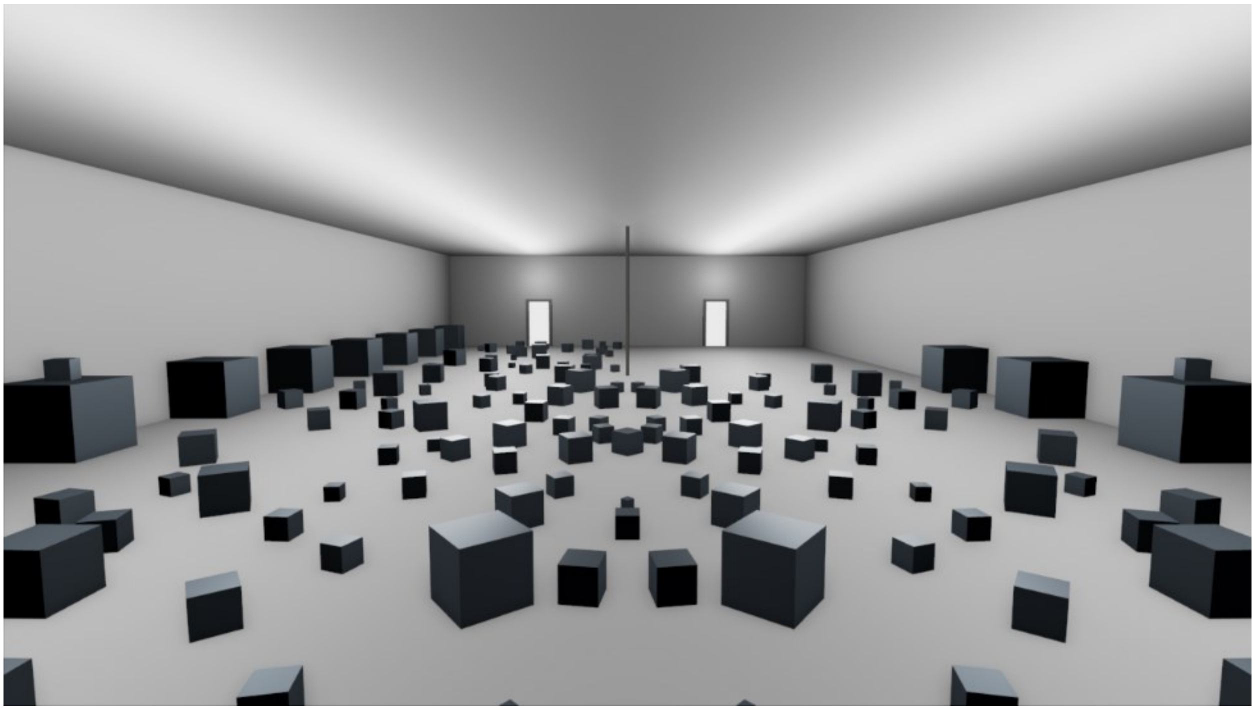

Figure G-16 - Density 1 - 16th Hallway - Baseline Test - Elongated Hallway - See for above additional hallway design details. - Note: This test hallway extends further behind the camera. The camera was positioned for optimal viewing of the choice sections and entry.

Large, consistently placed cubes line the outside walls of both entry areas. These cubes continue with a consistent pattern into choice 0, while terminating in choice 1. The smaller, more frequent cube objects are randomly placed in the environment with Unreal Engine 4's foliage tool. This allows the "painting" of objects, providing a specified object density, object size range, and orientation. These objects were spawned with a random orientation, and a random size range between 0.1m and 0.5m. This technique was also used for Density 2. To ensure symmetry in the environment, cubes were painted on a single side of the entry, then mirrored to the other side. Objects were then hand placed in the centre of the entry to fill gaps in space. Choice section 0 continues the visual style established by the environment, painted by the same foliage brush used in the entry. Choice 1 highly contrasts the object density contained in the environment, featuring no objects.

Figure G-17 - Density 2 - 6th Hallway - Baseline Test - Elongated Hallway - See above for the hallway's design details. - Note: This test hallway extends further behind the camera. The camera was positioned for optimal viewing of the choice sections and entry.

Figure G-18 - Density 3 - 17th Hallway #18 - Scenario Test - Elongated Hallway - See above for the hallway's design details. - Note: This test hallway extends further behind the camera. The camera was positioned for optimal viewing of the choice sections and entry.

Figure G-19 - Density 4 - 5th Hallway - Scenario Test - Elongated Hallway - See above for the hallway's design details. - Note: This test hallway extends further behind the camera. The camera was positioned for optimal viewing of the choice sections and entry.

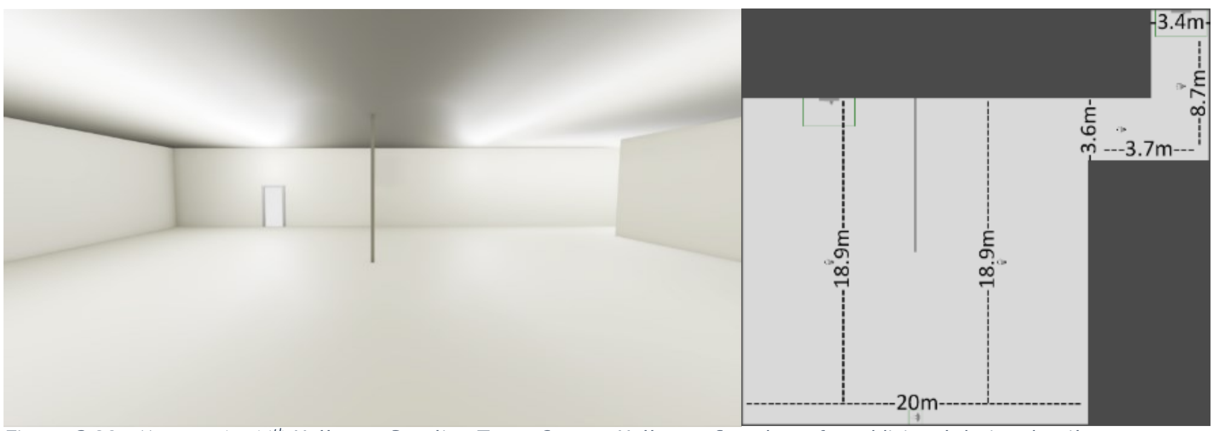

Figure G-20 - Mystery 1 - 11th Hallway - Baseline Test - Custom Hallway - See above for additional design details.

When creating both Mystery 1 & 2, the first goal was to ensure that, unless the participant commits to traveling down the mystery hallway, they will be unable to see that it returns parallel to the main room. From the camera's starting position, and all other points in the main room, the camera is only able to see that the mystery hallway branches away at a right angle, continuing on in this direction for an undetermined distance. Both the width, and length of the branching mystery hall was fine-tuned to ensure that the branching hallway could be as short as possible, while still concealing the second turn.

It was imperative that the branching hallway, travelling perpendicular to the main room, was as short as possible. As the camera is fixed in a forward position, the participant must sidestep through this short branching hallway. Though the control scheme makes this a simple task, the camera's position, and the lack of patterned materials on the wall creates some issues. As the camera is sidestepped through this small passage, it is difficult to determine that the participants' camera is still in motion while moving horizontally. Implementation of a wall material may have better communicated the lateral movement. However, as this is a baseline test, any visual features that make the mystery choice more visually diverse than the alternative, could influence the participants' hallway choices. As such, it was critical to make the perpendicular hall as short as possible, while still restricting lines of sight. It was determined that a hall width of 3.6m, with a depth of 3.17m is the minimum hall size to restrict the camera's view of the parallel mystery hall in choice 1.

Due to the unique layout of the mystery environments, the lighting had to be altered to best fit the shape of the hallway. The two mystery scenarios are the brightest hallways within the test. Replication of the lighting conditions seen in other environments was originally attempted: 100,000 total lumens, with 50,000 total lumens per side. However, to properly illuminate all of the turning halls in choice 1, 3 separate lights were required.

The lighting of the environments had to be visually balanced, presenting two choices that had the same appearance in luminance. Ultimately, choice 0 was supplied with a single 100,000 lumen light extending the length of the hall. Choice 0 was populated with 3 lights, each 50,000 lumens in value, extending the length of their appropriate section. With these lighting values, both hallways appear similar in illumination, reducing the possibility of lighting bias from impacting the choices in the room.

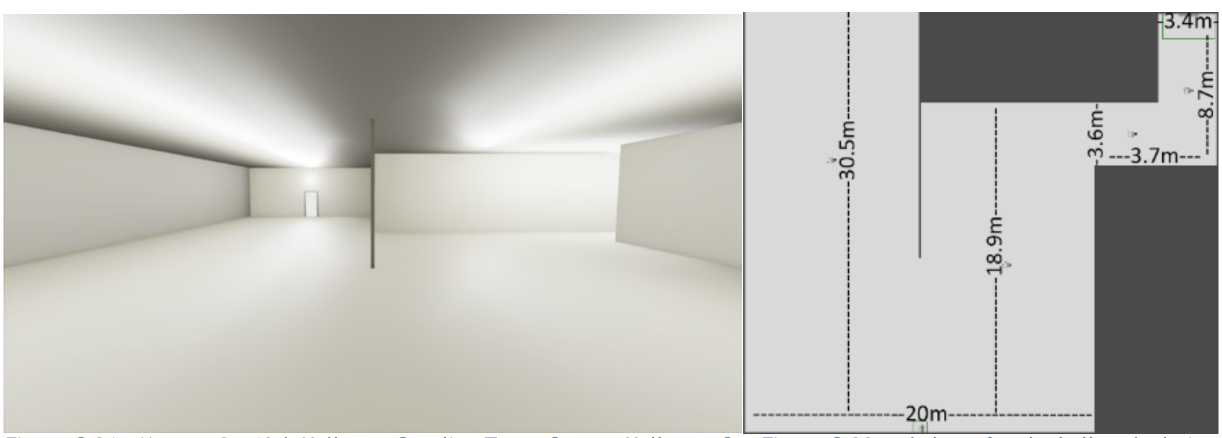

Figure G-21 - Mystery 2 - 19th Hallway - Baseline Test - Custom Hallway – See Figure G-20 and above for the hallway's design details.

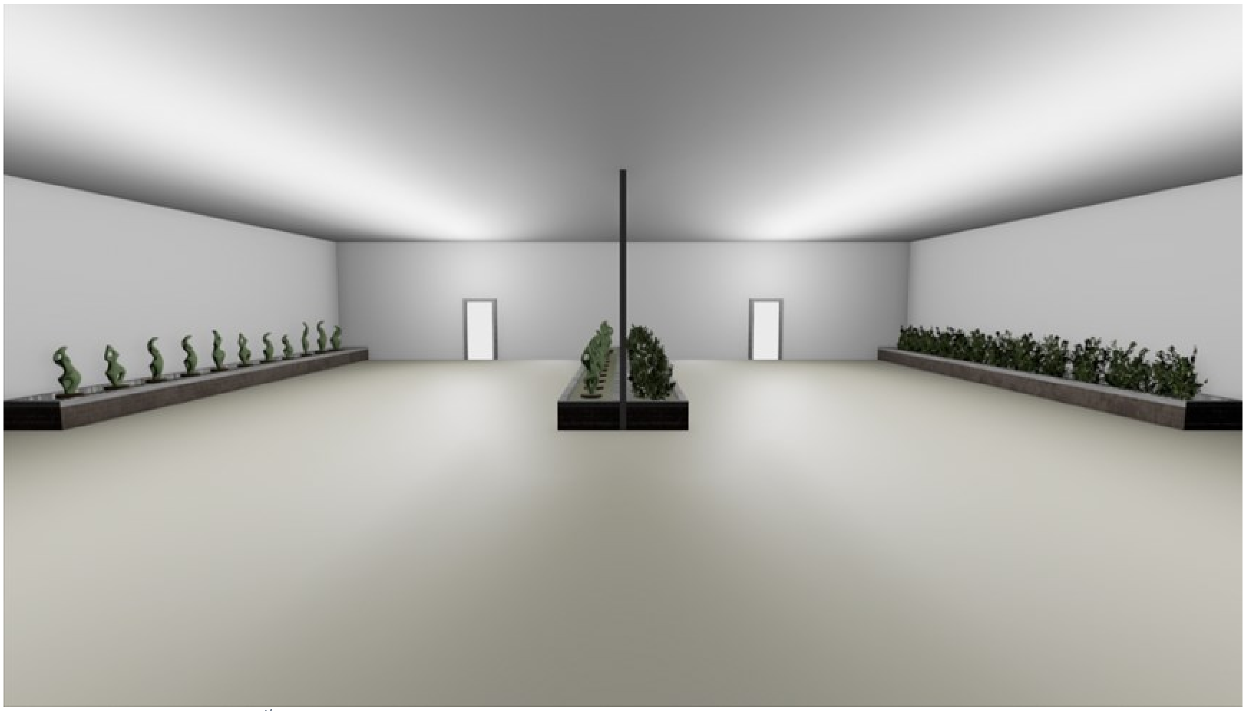

Figure G-22 - Nature 1 - 27th Hallway - Baseline Test - Standard Hallway – See above for additional design details.

Both the statuettes and bushes models were created by Unreal's artists, and featured in Unreal Engine 4. Several other statuettes were custom made, however, the statuettes that came standard in Unreal Engine 4 best represented a man-made structure that has a high level of detail.

As the bushes were non-reflective in appearance, the material of the statue was altered for maximum roughness. This ensures that both the bushes and the statuettes would not reflect any light from the environment. Additionally the material applied to the statuettes was modified to reduce the potential of colour bias affecting the choices of this hallway. The bushes' material was randomly sampled, then applied to the statuettes. This creates a statuette that is primarily the same green as the bushes. The base of the statuettes are also coloured to match the branches of the bushes.

The planters/platforms that contain the statuettes and bushes are 1m in width, and 0.5m in height. They travel the length of both choice sections, located on both the interior and exterior walls. All of the planters are identical in appearance.

Each planter contains 11 meshes. Both the bushes and the statuettes were assigned a random orientation. The statuettes were also randomly scaled between 1.2x-0.5x their original size. This increases the visual variety of the statuettes, differentiating each object, and reducing the likelihood that the participants will interpret the statues as a repeated objects. All of the bushes remained the same physical size. As the bushes are more intricate in appearance, rotating each bush was sufficient to create visual variance between each stimulus. All bushes and statues are placed in the same relative location in their planters.

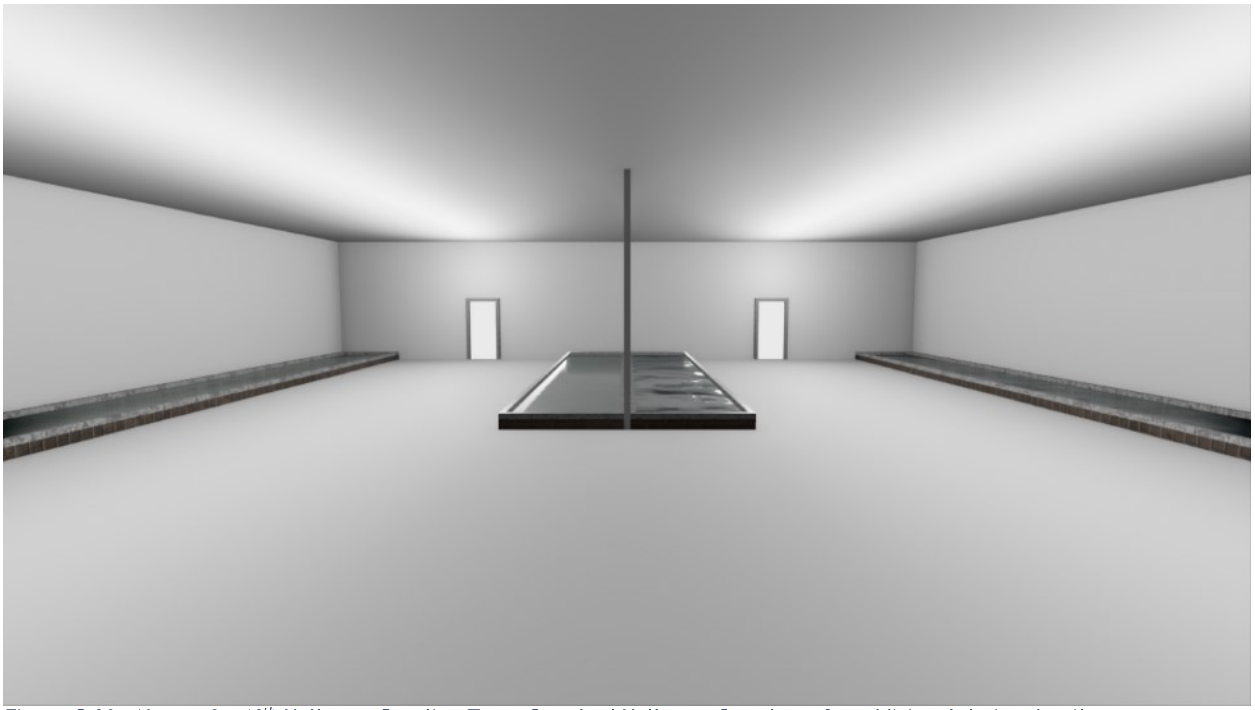

Figure G-23 - Nature 2 - 18th Hallway - Baseline Test - Standard Hallway – See above for additional design details.

The above channels are 2m in width, and 0.25m in height. This gives explorers an overlooking view of the contents of the channels.

In choice 0, the material applied to the base of the channels is a custom made stone material that resembles polished marble. The appearance of this stone needed to communicate two main properties: it was clearly manmade, but must feature similar visual properties to the water material. The colour for the polished stone was sampled from the base texture of the water material. This will reduce any bias due to positive colour reactions. The stone was also given a high reflectivity to ensure that it reflected the light of the environment similarly to the water. This light reflection reinforces that this is a static object, differentiating it from the flowing, natural water.

To better emphasize the difference in states between the channels, the lighting for this environment was altered. Each hallway choice has 2x25,000 lumen lights. These lights are centered over the channels of each choice. This highlights the channels, and increases the light reflected from the material. The reflection better communicates the contents within the channel, as the reflected light shimmers and moves on the water, and is static on the marble.


Figure G-24 - Nature 3 - 13th Hallway - Scenario Test - Standard Hallway - See above for additional design details.

To best depict a natural appearing wall, and to reduce bias, choice 1 uses the same brick wall material used in choice 0. However, the bricks have been overgrown with a natural, mossy material. This was a sensible way to communicate the presence of rigid, angled walls, which still represent nature.

Neither of the choice sections are symmetrical in features. Though it may be appropriate for the man-made environment to feature a symmetrical layout, providing one choice section that is symmetrical may create unnecessary bias.

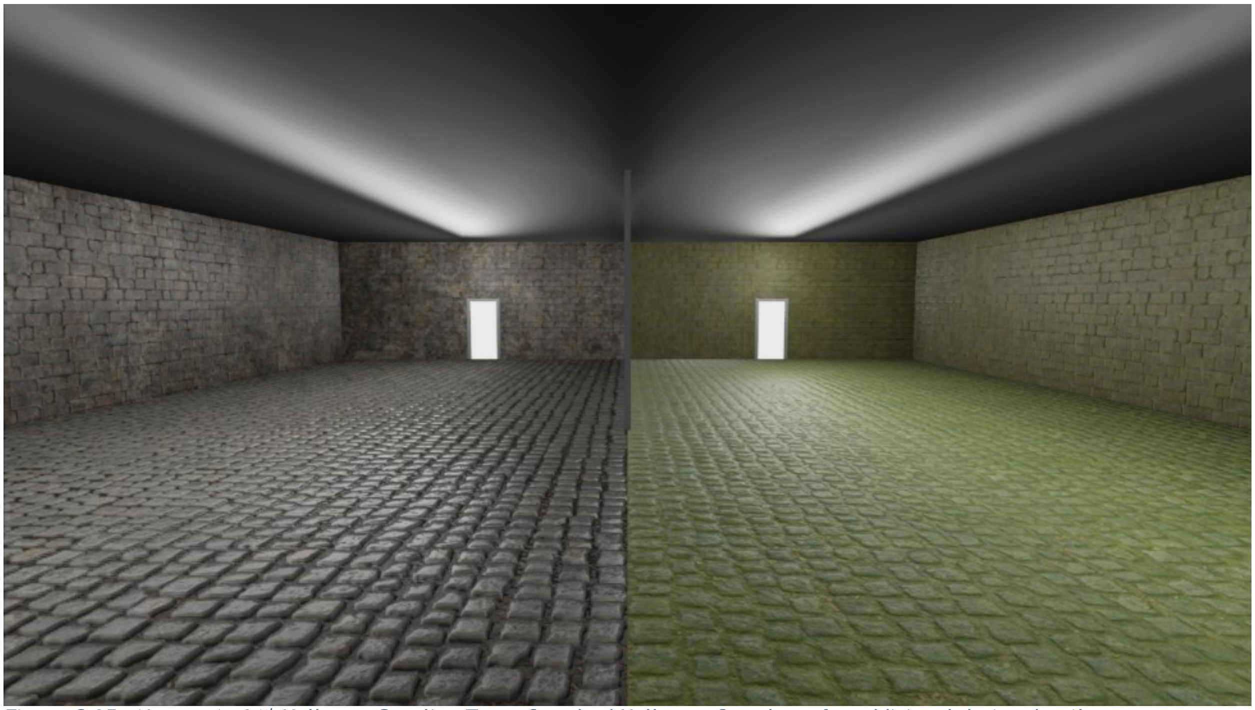

Figure G-25 - Nature 4 - 31st Hallway - Baseline Test - Standard Hallway - See above for additional design details.

To better communicate the direct contrast between natural and artificial flooring and walling, pure natural materials could have been used to populate the floor and walls of choice 1. However, to avoid any bias from the lines, level of detail, or other features on the man-made materials, the natural materials were overlaid on the man-made materials. The only differentiation between the two choices are the textures that represent natural features in choice 1.

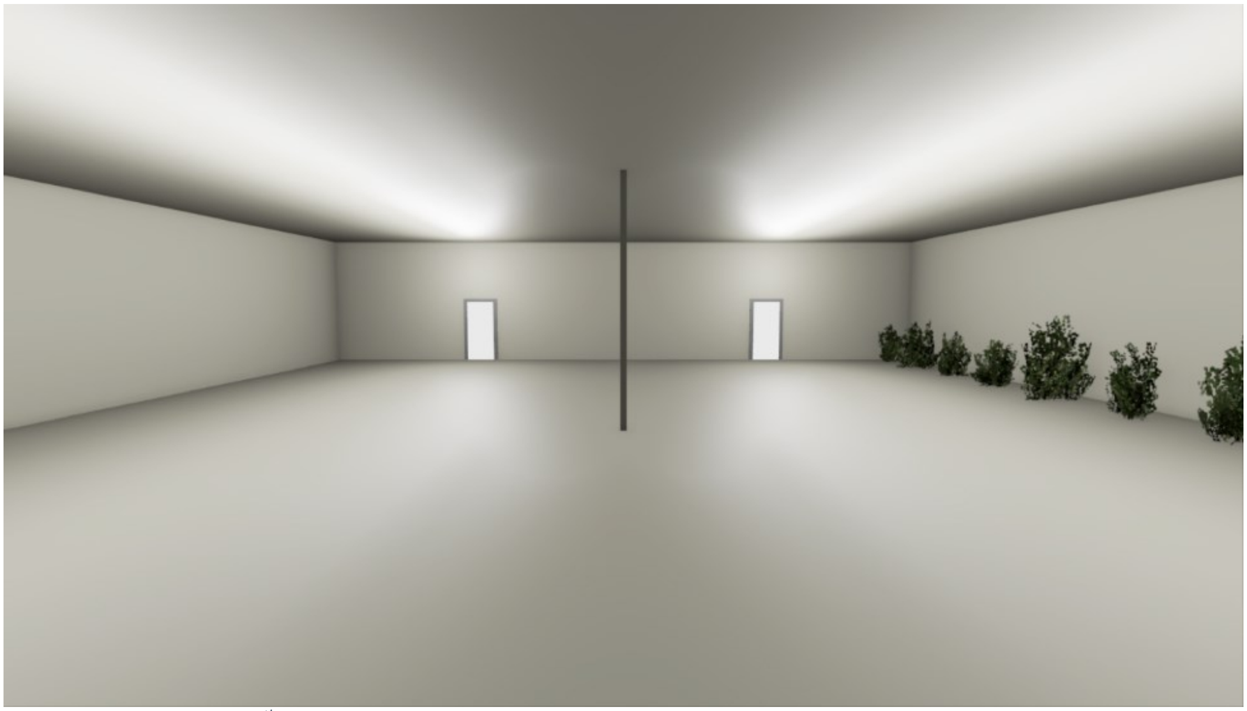

Figure G-26 - Nature 5 - 30th Hallway - Baseline Test - Standard Hallway - See above for additional design details.

The bushes are spaced 2 meters apart on the x-axis. Each bush has a randomized Z-axis orientation, and a random scale between 0.75 and 1.25.

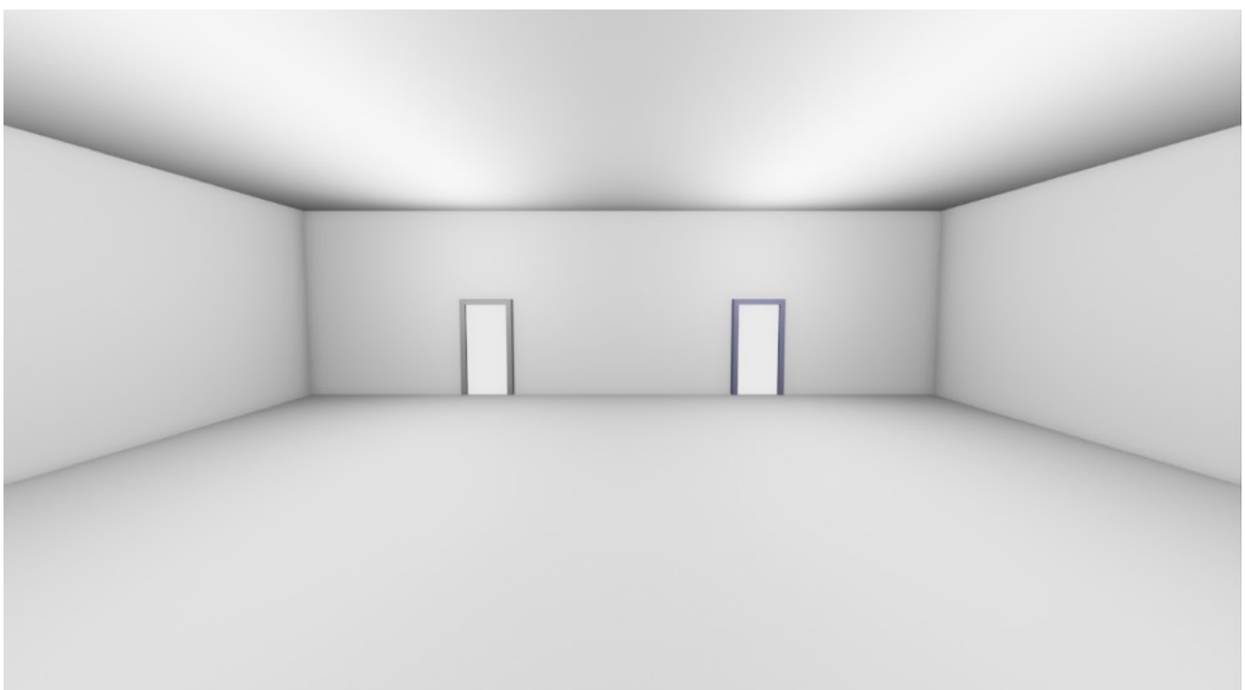

Figure G-27 - Change Blindness 1 - 25th Hallway - Baseline Test - Custom Hallway - See above for additional design details.

To better communicate the variance in appearance between choice 0 and choice 1, choice 0's frame was originally coloured red. However, a more neutral tone was chosen to reduce any effects from the novelty and contrast of the new colour. If the frame for choice 0 was in high contrast with choice 1, this could have impacted participant decisions. The centre wall was removed from this final decision room to allow participants a closer comparison of choice 0 and 1.

As the refresher rooms were designed to discourage associations between hallways, no refresher rooms were used during this series of hallways. This was done so that participants would associate all of the priming rooms, and the decision room, as a single environment, increasing the effects of the prime.

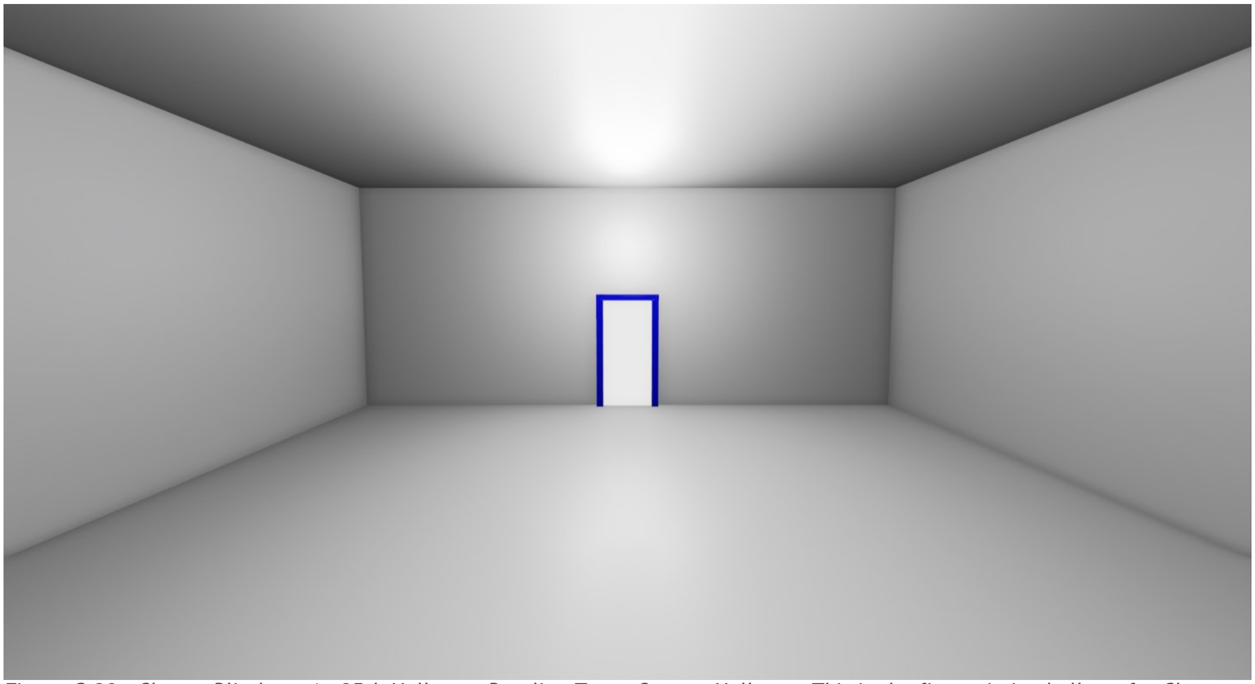

Figure G-28 - Change Blindness 1 - 25th Hallway - Baseline Test - Custom Hallway - This is the first priming hallway for Change Blindness 1. Each priming hallway is 12m in length, and 10m in width. See above for additional design details.

Below is a numeric representation of the colour value for each priming door, and choice door in the change blindness hallways. All values are on a scale of 0-1.					
	Red Value	Green Value	Blue Value	Saturation	Brightness
Prime 1	0	0	0.35	1	0.35
Prime 2	0.053	0.053	0.35	0.85	0.35
Prime 3	0.105	0.105	0.35	0.7	0.35
Prime 4	0.157	0.157	0.35	0.55	0.35
Choice 1	0.21	0.21	0.35	0.4	0.35
Choice 0	0.35	0.35	0.35	0	0.35

Table G-1 - Colour values for all coloured door frames within the prime hallways, and the choice hallway for Change Blindness 1. As saturation of a colour is reduced, its RGB values will naturally level out. For a visual representation of the door frames, see Figure 2-6.

Figure G-29 - Region Contrast 1 - 23rd Hallway - Scenario Test - Elongated Hallway - See above for design details.

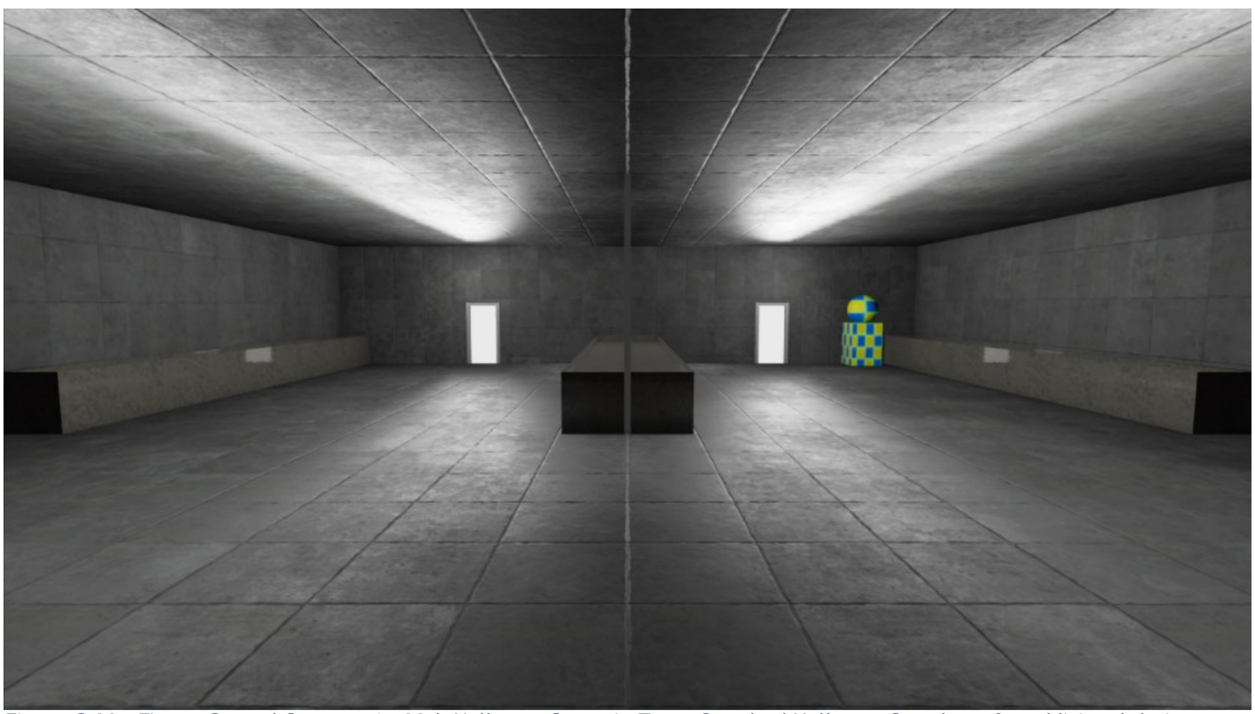

Figure G-30 - Figure-Ground Contrast 1 - 29th Hallway - Scenario Test - Standard Hallway - See above for additional design details.

The contrast object is approximately 1x1x2m in size. Platers, 1x1m extend the length of the hallway, and help to emphasize the sharp corners of the environment.

Figure G-31 - Figure-Ground Contrast 2 - 4th Hallway - Scenario Test - Standard Hallway - See above for design details.

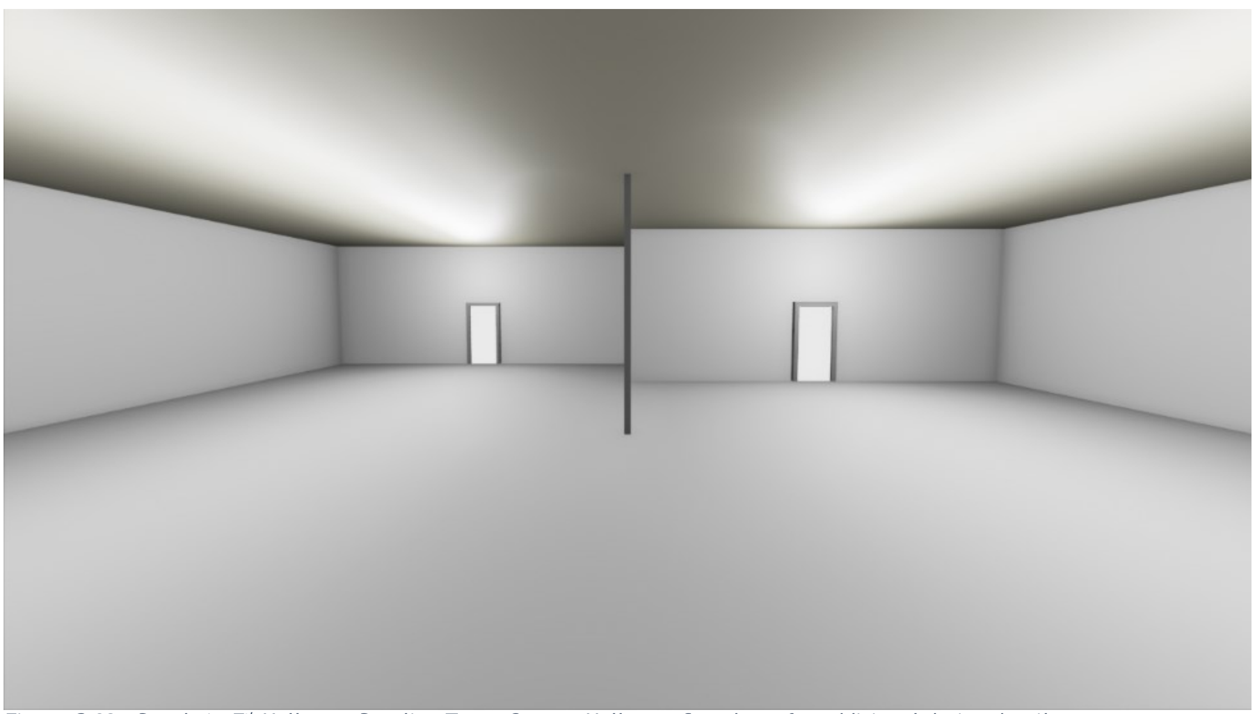

Figure G-32 - Depth 1 - 7st Hallway - Baseline Test - Custom Hallway - See above for additional design details.

Lighting in the hallway was adjusted to appropriately match the length of both choice sections. It has a standard layout, with the exit for choice 1 (17m from start point) resting 5m closer to the participant start point than the exit point for choice 0 (22 m from starting point).

Appendix H: Testing Procedure

Prior to the arrival of participants, the computers and appropriate programs were prepared for the upcoming trials. Each computer was loaded with three different windows: a blank Microsoft Word document, the questionnaire, and the Unreal Engine 4 editor running the test program. Both the questionnaire and game engine were placed behind the blank word document, obscuring them from participants until the appropriate time.

Four computers were available for testing within the lab, with two computers running each version of the program and questionnaire. In an attempt to have an equal number of results from each test version, minimizing the potential right side bias, the participants were assigned to alternating test versions. As four participants could take the tests simultaneously, participants were seated to minimize distractions. All registered participants needed to be seated prior to commencing the research trials. As required by the Department of Psychology's Research Participation Program, initialization of the research trials was delayed by five minutes past the registered start time to allow for late arrivals. Once all registered students were present, the research trials began.

After all the timeslot's participants were seated, the researcher introduced himself and described the study through a prepared script. This ensured that all research participants received consistent instructions and information. The script described the goals of the study, what was required of the participants, how the participants interact with the program, how to withdraw and give consent, participant privacy and data anonymization, and the availability of an alternate task. To view the introductory script, see Appendix D: Research Trials Documents.

After the script was completed, each participant was provided two copies of the study's consent forms. One copy was signed by both the researcher and the participant, and was kept by the researcher for documentation. The other copy was kept by the participants to supplement the information provided by their debriefing form. The consent form that was kept by the researcher was numbered so, in the case of consent withdrawal, the participants' data could be compiled and destroyed.

Once a participant had completed the consent form, the research trials were initialized. Unreal Engine 4 was brought to the front of the screen, and the digital scenarios was launched. The digital scenario was run directly out of Unreal Engine 4, and is not a standalone program. This enables the direct printing of participant decisions to the game engine's output log.

With the instructions on how to interact with the program provided in the introductory script, the participants were free to complete the digital trials. After making their decision in the final test hallway, the participant's' camera was transported to a blank room, containing the text "Thank you for your participation! Please raise your hand to notify the researcher that you've completed this portion of the test." When the participants raised their hand, the researcher manually closed the simulation program. The results of the tests (which hallways they chose) were printed to the game engine output log as coded text. These results were then copied immediately over to the blank word document. Following this, the researcher maximized the questionnaire portion of the test, and provided the participants a hard copy of the questionnaire instructions. Though available on screen in the questionnaire, the instructions were provided on paper to ensure that the requirements and procedures of the questionnaire could be seen at all times by the participants. Participants indicated that they had completed the questionnaire by raising their hand. The researcher then quickly scrolled through the questionnaire, ensuring that all questions had been answered.

If more than one participant was present in the room at a single point, those who complete the trials first were taken out of the room for a verbal debriefing, where the researcher re-disclosed the goals of the test. The participants were informed that no misinformation was used within the initial prompting script, and that the true purpose of the test was disclosed in the consent form and introductory script. Participants were then free to ask questions on the study before leaving. Once all of the participants were debriefed and had departed, the information recorded during the trials (questionnaire and choice results) was stored on an encrypted USB for transportation. The choice data was then analyzed for statistical relevance, and the questionnaire was qualitatively analyzed for rationale trends.

One of the participant's results was omitted from the final data analysis. The participant exclusively chose the left exit of every hallway and attempted to justify these choices within the questionnaire with wildly varying rationale. It was clear that the participant simply did not follow the test procedure, failing to make selections based on each environment's contents. While it may be argued that these choices were based in a heavy personal bias for the left side of the environments, the participant's responses to the questionnaire demonstrated an inconsistent rationale, grasping for justification for their homogenous responses. This data will not be included in the research analysis.