Game Design Framework and Guidelines Based on a Theory of Visual Attention

by

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Dissertation Submitted In Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy

in the
School of Interactive Arts and Technology
Faculty of Communication, Art and Technology

SIMON FRASER UNIVERSITY

Summer 2013

APPROVAL

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Degree: **Doctor of Philosophy**

Title of Thesis: **Game Design Framework and Guidelines Based on a Theory of Visual Attention**

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Date Defended/Approved: May 28, 2013

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Abstract

The design of video games has a tremendous impact in shaping our experience, and one area is through their visual designs. Action games in particular engulf the player in highly dynamic and sensory rich environments where challenges can easily be misperceived. For example, the player may feel overwhelmed, fail to notice important elements, or take the wrong course of action as a result of distractions. Pinpointing and solving these problems are difficult without taking into consideration the underlying mechanisms of human visual information processing. In this effort, this dissertation develops a perception-based game design framework supported by a theory of visual attention. This framework was applied to consider perceptual features of motion affecting the visual design, and their effects on the player's experience. Perceptual features of motion are often overlooked in games, but cannot be ignored. Perception and attention researchers found numerous effects of motion on users' task performances and affective responses that are of interest to the game design and user research community. The contribution of this work consists of an investigation of a perception-based framework for elements in motion within commercial and an experimental game called *EMOS (Expressive MOtion Shooter).* This is followed by identifying and validating two perception-based guidelines. The guidelines are novel such they are empirically expressed, based on expert game designers' manipulations of perceptual features in EMOS. This contribution also benefits the design and human computer interaction communities, since results include qualitative reflections from game designers concerning this topic.

Keywords: Visual design, game design, human-computer interaction, user experience, user research, perception, attention, cognition.

Dedication

I dedicate this dissertation to my grandfather, George P. Sutton.

Acknowledgements

I am grateful for the institutions that funded this research. This includes the Natural Sciences and Engineering Research Council of Canada (NSERC), Graphics, Animation and New Media Canada (GRAND), and Simon Fraser University's School of Interactive Arts and Technology (SIAT). I am also indebted to the Games User Research SIG that supported this research effort and helped connect me with game designers. I am delighted the voices of game designers could be shared in this work.

I want to thank individuals that helped me. This includes the continuous guidance from my senior supervisors, Magy Seif El-Nasr and Lyn Bartram. I also owe a great deal of thanks to SIAT associates Thomas Loughin and students Dinara Moura, Bardia Aghabeigi, and Perry Tan in assisting this research effort. Last, but not least, I would like to thank my parents, brother, and close friends for their tremendous support and encouragement.

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1. Introduction

We live in a media saturated landscape and this is most apparent in video games. The design of games has a tremendous impact in shaping our experience through satisfaction and frustration. One of the ways games affect us is through the visual design, or *what players see*. Advances in computer graphics over the last generation enabled games to be as visually stunning as they are entertaining, for instance through lifelike characters, realistic environments, atmosphere, and visual effects. Figure 1 contains screenshots depicting well known and graphically rich 3D action games, including *Alan Wake* (Microsoft Studios, 2010), *Child of Eden* (Q-Entertainment, 2011), *Tombraider Underworld* (Sony, 2008), and *Prototype* (Radical Entertainment, 2009). These illustrations depict the player moving through treacherous areas, spotting deadly traps, searching for rare artifacts or apprehending enemies with peril. They also illustrate the visual richness of the design, comprised of highly dynamic perceptual features including lighting, color, and motion, in association with game elements. Action games in particular routinely engulf players in these sensory rich environments, whereby the visual design influences how we *think* and *feel* while playing.

Game design of course is also concerned with *what players do*, ostensibly through rules, goals, and reward structures tied to game elements that challenge the players' interactions. Part of what makes games so enjoyable is this process of interaction, of seeing and doing, in concert with a dynamic game system. However, this interaction can become a challenge, particularly in games with dynamic visual content. Games such as these rely on the players' ability to perceive and rapidly attend to certain elements in the game in order to execute actions. One fundamental role of game design is to compose elements in such a way that clearly communicates goals, yet action games are entertaining precisely because the presentation of elements are not always intended to be clear. These examples illustrate why game design is often referred to as a "craft" [1], between art and science, as games "contain both artistic and functional elements”. Therefore, one avenue to study the craft of game design in further detail is through the visual design, as this is an important area that influences the player’s interactions and experiences. This work documents a process to develop visual design guidelines defined by the manipulation of perceptual features. Since visual design is a broad field, this work looks specifically at games containing dynamic perceptual features associated elements in motion.

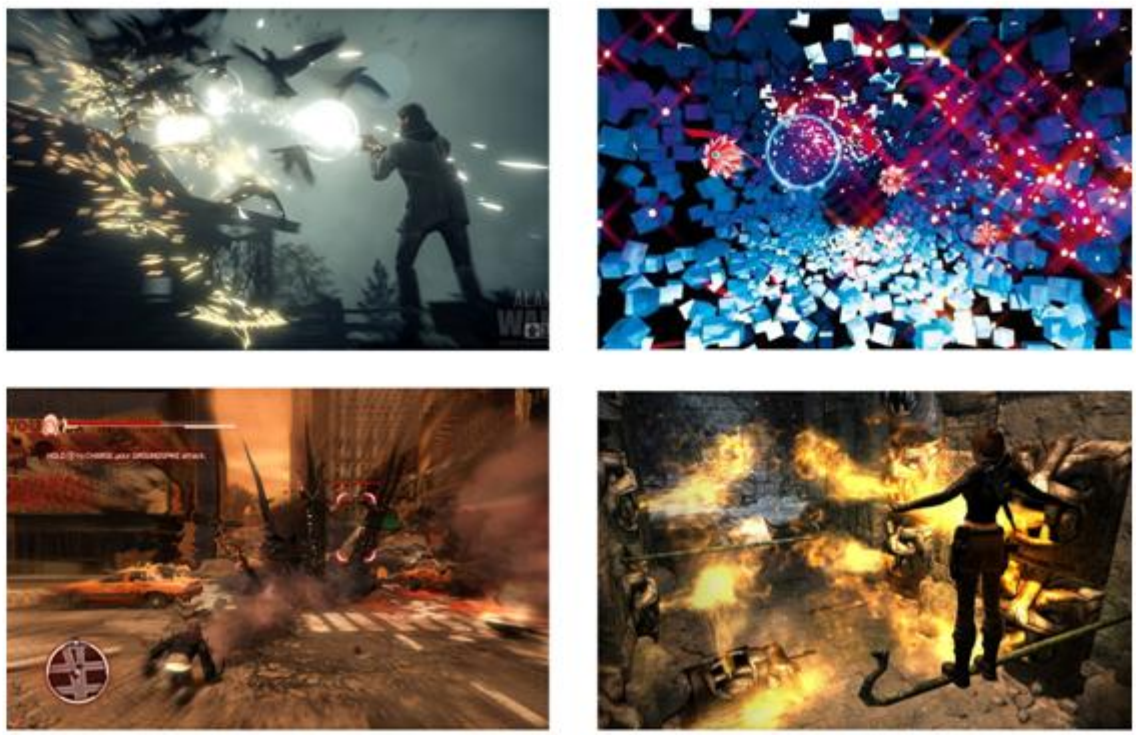


Figure 1: Screenshots of graphically rich commercial games

1.1. Motivations

There are four motivations for this work. The first motivation considers breakdowns [138] in the user’s experience are due to the visual design. Breakdowns occur when players fail to learn strategies as intended by designers, or misperceive characteristics of the environment, an action, or decision-making step. Usability testing and playtesting (user testing in games) are approaches within the field of human computer interaction (HCI) to correct these problems and often leading to a set of best practices, heuristics, or guidelines [30,126,161]. However, existing guidelines are not computationally expressed, nor did they consider the underlying perceptual or attentional mechanisms of human visual information processing. As a practical matter this is not a surprise as the production of commercial games typically relies on rapid production schedules and actionable reporting [57,131]. The perception and attention domains investigated these mechanisms in detail and developed theories that can be of practical benefit in developing and evaluating visual designs in games. Presently however, theories are difficult to transfer into the context of games due to the dynamic visual content and tasks characteristic in action games, particularly in regard to elements in motion.

A second motivation for this work centers on research in game design that fits within a larger domain of human-computer interaction. The HCI community traditionally focused on human factors of users interacting with computer software systems, and more recently expanded into games as an entertainment medium. Previously, this community incorporated many principles of perception and theories of attention into the design of products and experiences [21,39,176]. This theoretical framing can help strengthen the game design practice in the same way as theories in psychology [74,83,102]. Game designers often refer to visual attention in their talks [85,92,137,153], so methodologically we must unpack this motivation by identifying perceptual principles and attentional theories, exploring this framing in the context of video games, and conducting user studies with an experimental toolset and game as a means to identify perception-based guidelines.

It is important to include the voices of game design experts in the process of developing guidelines, given their tacit knowledge in this area, as it complements shortcomings of a purely empirical investigation of the problem [48,179]. Designers' interactions with such a toolset and qualitative feedback regarding the impacts on the player's experience add an important verification step in the development of perception-based guidelines. This approach is beneficial as it allows for surprising and unexpected findings as game designers craft a game with some perceptual constraint while a researcher considers the mechanisms of visual information processing underscoring their designs.

The third motivation is to advance user-centered research in games [10,73,143] as a means to enhance the user's experience. Game researchers recently evaluated player satisfaction and game difficulty [70,82] and devised several models of the user's experience [37,46,69,138]. In sensory rich games with dynamic visual content, a need exists to consider the perceptual effects associated with game elements on the player's performance, perception of cognitive demand and affective. One logical benefit of empirical and perception-based guidelines are game systems to dynamically adapt difficulty in a game, or computational models of the player's experience given specific perceptual conditions.

A fourth motivation considers digital games and interactive entertainment an approachable medium of study for perception and attention researchers. Much research studied the expressive qualities of motion [7,8,9], however few in the context of a game. Expertise effects come to bear on this topic given experienced (expert) and inexperienced (novice) gamers [15,54,56,67,149]. However, attention researchers are always one step removed from the context of a game and instead rely on highly controlled experimental setups and regimented visual tasks. Once again, this control is needed since graphically rich 3D action games are difficult to perceptually evaluate. Since this dissertation scaffolds theories from these domains into a game, perception and attention researchers may find this approach beneficial in understanding the changes in visual stimuli, game task, and structure within this context, for instance in the area of perceptual learning [56,149].

1.2. Research Questions

Based on these motivations, this dissertation asks three research questions:

1. **RQ1:** Informed by a theory of visual attention, what are perception-based guidelines for game elements in motion, validated by expert game designers and users, within the context of a game?

2. **RQ2:** What are the implications of the visual design on task difficulty?

3. **RQ3**: What benefit does this approach have in understanding the player's experience in terms of performance and perceptions of performance?

In subsequent chapters, this dissertation breaks down this topic and develops a series of sub-questions to address these questions in further detail. For instance, what are relevant principles of perception and theories of attention and how might these apply within the context of a game? What effects do visual designs have on the player's experience, specifically in regard to performance, self-report of cognitive workload and affective states? What considerations are necessary in applying a perception-based framework into a game in recognition of existing game development practices, such as design iteration and playtesting? Given this framework, in what way can one evaluate elements in motion and their effects on players? What constraints are necessary to develop an experimental toolset and game based on such a framework and emphasis on motion? What is the process by which expert game designers interact with a toolset as a means to produce games with different levels difficulty? What is the validity of perception-based guidelines given their effects on the user's experience?

1.3. Contribution of the Results

1.3.1. Methodological: Research through Game Design

Game design is epistemologically pragmatic in worldview [25] and the artifacts created are considered a central accomplishment [48]. Design researchers recognized the ability of designers to apply theories into a new context as a means to develop solutions to difficult problems [180]. Therefore one contribution of this work is methodological, in that a framework and theories of visual information processing are examined in a game, in accordance with established game development methodologies such as design iteration and playtesting [45,139]. This dissertation therefore documents the process of exploring these theories in commercial video games and iterative development of an experimental toolset and railed-shooter genre game called *EMOS (Expressive MOtion Shooter).* Both toolset and game artifacts created are the subject of much design reflection [48,179] that may have been overlooked using scientific modes of inquiry alone. One of the strengths that designers bring to the HCI community is the ability to leverage tacit knowledge and reframe a problematic situation under scrutiny in the production of artifacts that seek a preferred state. Contributions in this area may be incorporated back into commercial games, as was done in closely related lighting toolsets [145,181], and inform new patterns of gameplay [87], or types of games, such as procedural games [151].

1.3.2. Perception-based Guidelines for Elements in Motion

The second contribution is the integration of a perception-based framework to discuss the visual design in a game, followed by two empirically validated perception-based guidelines for elements in motion. This theoretical scaffolding, emphasis on motion, and implications for design has not been addressed in the game design, user research, or HCI communities. Although many in this community presented models, frameworks, and guidelines to improve design, they either did not address perceptual features or did not include user studies with designers and players to address this topic. The work presented here develops guidelines based on designers' intended effects in the EMOS experimental toolset and game. The guidelines *Targeting Task* and *Interference* are based on the manipulation of three perceptual features over time: *speed*, *size*, and *density* of game elements in continuous motion. The manipulation of these features show evidence of the similarity theory of attention [34], defined as the degree to which elements that share a common feature are perceptually similar. These guidelines were validated in a user study given their effects on the player's game performance and perception of cognitive workload. Empirical perception-based guidelines are an important first step in modeling the player's experience, or adapting game difficulty, in regard to perceptual conditions.

1.4. Dissertation Overview

The thesis is organized into ten chapters:

1. **Chapter 1 Introduction:** The introduction motivates the topic of inquiry, outlines the research questions, and contribution of the thesis.

2. **Chapter 2 Theoretical Background:** The theoretical background introduces three main arguments. The first includes a theoretical framing of game design as fitting into a larger debate of the contributions of design to address difficult problems in human computer interaction (HCI). The second point recognizes that design is often reinforced by theoretical scaffolding outside of the design domain. The third point is a recommendation to include expert game designers in this discussion as they are skilled practitioners who can address problems of the visual design, given their familiarity with the medium and the user's experience.

3. **Chapter 3 Previous Work:** This chapter includes previous work that discussed the visual design in three related domains. The first section provides an introduction to games, the game designer, highlights visual traditions, and outlines models, frameworks, and best practices. The second section outlines contributions in HCI and games user research that addressed this topic, in the area of user experience, design tools, and work that considered related theories of attention. The third section includes relevant work in perception, attention, and cognition that were not studied in the context of a game.

4. **Chapter 4 Methodology:** This chapter introduces the pragmatic philosophical stance and methodology to address the research questions. The methods undertaken in this area first include exploratory user study, followed by iterative design to develop a prototype, and concludes with two additional user studies that employ mixed and triangulation methodologies with expert game designers and players, respectively.

5. **Chapter 5 Commercial Game Analysis:** This chapter contains an exploratory user study that evaluates the visual design of commercial video game clips

according to a perception-based framework. The framework consists of a classification of game elements in association with expressive perceptual features of motion, specifically flicker, speed, shape, and repetition. Results identify perceptual features and elements that contribute to users' rankings of high cognitive workload. The success and limitations of the perception based framework are discussed and include qualitative guidelines to organize motion. This chapter informed development of the EMOS experimental toolset and game.

6. **Chapter 6 Experimental Toolset and Game:** This chapter applies a perception-based framework in the design of an experimental toolset and game, called *EMOS (Expressive MOtion Shooter).* Design iteration and agile software development methods are used in the documentation of the game. The final prototype consists of three perceptual features that can be manipulated in the toolset, consisting of *speed*, *size*, and *density*, and three fixed features, including *circle*, *expansion*, and *linear* trajectories of motion. Additional constraints of the game, optimization, and instruments to collected data are discussed.

7. **Chapter 7 Designer Study:** This chapter describes the second user study comprised of eight game designers that interacted with the EMOS toolset. Their goal was to manipulate features over time coinciding with games suitable for inexperienced (novice) and experienced players (expert). Mixed and triangulation methods are used that include quantitative toolset measurements and designers' qualitative feedback. Results include designers' intended effects in manipulating features and show evidence of the similarity theory of visual attention in their designs.

8. **Chapter 8 Perception-based Guidelines:** This chapter condenses the results gathered in the previous chapter to produce three perception-based guidelines: *Targeting task, interference,* and *accessibility*. In particular, the interference guideline is informed by the similarity theory of visual attention. Each guideline is empirically expressed by the manipulation of select perceptual features in association with game elements, and their intended effects on game difficulty. This chapter also documents the process of revisiting the EMOS game,

discussed in Chapter 6, and applying guidelines to experimental conditions in preparation for the Chapter 9 Player Study.

9. **Chapter 9 Player Study:** The third user study recruited players to play the EMOS game in three experimental conditions. The goal of the study is to evaluate effects of the perception-based guidelines on the player's experience. Mixed and triangulation methods are again used and include the player's gameplay performance, physiological performance via pupillometry, and qualitative self reports of cognitive workload, satisfaction and expertise. Results also include qualitative feedback with three expert game designers. Results speak to the validity of the guidelines congruent with the similarity theory of visual attention and usage of pupillometry instrumentation in a game.

10. **Chapter 10 Discussion and Conclusions:** This chapter includes a closing discussion for game design practitioners and researchers. In summary, the perception-based framework and validated guidelines developed can be used to evaluate the visual design of a game, and their effects on the player's experience. The methodology employed to reach these conclusions, via an experimental game and expert feedback is also a contribution. Future work considers enhancements to the toolset, temporal resolution of analysis, and modeling the player's experience in consideration of the visual design.

2. Theoretical Background

This chapter introduces three main points that define the theoretical contribution for this work. The first includes a theoretical framing of game design as fitting into a larger debate about the contributions of design to address difficult problems in human computer interaction (HCI). In accordance with this view, a need exists to articulate design choices, processes, methodologies, and artifacts created that lead to innovative solutions to difficult HCI problems. The position taken considers research through game design as a contribution within this community. The second point recognizes that design is often reinforced by theoretical scaffolding outside of a design domain. For instance, user-centered designs considered the user's psychology in order to evaluate design quality. In regard to the topic of visual design in games, we must consider the relevant theories and mechanisms in visual information processing, corresponding to what the player's *see*, and how this influences the way they *think*, and *feel*. This means scaffolding principles of perception and theories of attention to dissect what is a visual design, in consideration of effects on the player's performance and perception of performance (i.e., cognitive workload and affective states). The third point is a recommendation to include discussion from expert game designers as they are skilled practitioners to address problems of the visual design given their familiarity with the medium and the user's experience. The purpose of this research is to introduce these stakeholders to the theoretical scaffolding of this work in visual information processing. These topics are discussed in more detail in this chapter.

2.1. Theoretical Framing

Design is a difficult term to define as there is no universal language or theory for design. The term is nebulous, even to the design community [5]. As a noun or a verb, the definition of design depends on whether design is considered to be an idea, a practice, a process, a product, or even a 'way-of-being’ [38]. Design has different connotations depending on the field, for instance in graphic, architectural, software, and yes, game design. The outcome of design is different for each field, for instance an image, blueprint, object, or an experience. Given these different contexts, design generally has a human being at its core. The HCI community includes a large design community and has much to gain from a design perspective. Given this introduction, it is important to observe a difference in theoretical framing in the design domain, in comparison theories based on the scientific method. As discussed by Friedman [44]:

> *The distinction between a science and a craft is systematic thought organized in theory. Craft involves doing. Some craft involves experimentation. Theory allows us to frame and organize our observations. Theory permits us to question what we see and do. It helps us to develop generalizable answers that can be put to use by human beings in other times and places* (page 7).

Given this distinction, Friedman broadly defines theory within a design domain as a model describing process of action, or showing how elements work in relationship to one another as part of a larger structure, in order to reach a preferred state. Lunenfeld [97] describes design research as “creating a place to braid research with practice to make the work stronger (page 10)”, often through pluralism and serendipity. Gaver [48] argues against theories of design as they are provisional, contingent, and aspirational at best, in comparison to hypothesis-driven theories based on the scientific method. The reason for this claim is that a design theory cannot be falsified or refuted. Given this limitation, design researchers can view theory as an annotation to realized design artifacts. A design research community should "take pride in its aptitude for exploring and speculating, particularizing and diversifying, and - especially - its ability to manifest the results in the form of new, conceptually rich artifacts (page 1)”. As Zimmerman [179] points out, the design artifact is a result of a design process of action that “can be seen as a proposition for a preferred state or as a placeholder that opens a new space for design.” Other designers can make artifacts that better define the relevant phenomena.

Given the above limitations, one of the strengths of design research is to consider solutions to "wicked problems” [16], or under-constrained problems in the scientific community with a “great deal of uncertainty” [160]. These problems are by definition not approachable using scientific modes of inquiry alone. Design researchers acknowledge that the solutions to problems such as these are optimal for the current situation or artifact created and not a focus on the discovery of truth. Nevertheless, design solutions entail the assignment of concrete values to variables based on human workers' knowledge or intuition with the problem. This is a process whereby preferred solutions are made among multiple possible solutions that can be later checked and modified in order to find an optimal solution for a given problem. As stated by Schön in *The Reflective Practitioner* [141]

> *Problems are interconnected, environments are turbulent, and the future is indeterminate […]. What is called for, under these conditions, is not only the analytic techniques which have been traditional in operations research, but the active, synthetic skill of designing a desirable future and inventing ways of bringing it about* (page 16)*.*

Several authors discussed challenges in evaluating a design research process and artifact. Gaver highlighted that design research must clearly articulate the methodological and conceptual features throughout the design process, and consider the artifacts created as its fundamental achievement. The design artifacts reflect the choices made by designers; reveal both the issues they think are important, and their beliefs about the right way to address those issues. Frayling [41], elaborated upon three distinct activities of a design research investigation of benefit to the HCI community. This includes *research about design*, *research through design,* and *research for design*. Research about design focuses on understanding the human activity of design. Research for design focuses on improving the design practice, for instance through design recommendations or methods. Research through design allows iteration of artifacts as creative solutions to address design problems. An finally, Zimmerman [180] presented a model to evaluate contributions in design research within the field of HCI. The researcher integrates theories from the sciences with context specific technical knowledge. "Through a process of iteration and critiquing potential solutions, design researchers continually reframe the problem as they attempt to make the right thing. The final output of this activity is a concrete problem framing and articulation of the preferred state, and a series of artifacts—models, prototypes, products, and documentation of the design process." To this extent, Zimmerman presents four lenses to evaluate a design research contribution:

- **Process:** There is no expectation that reproducing the process will produce the same results. Instead, part of the judgment of the work examines the rigor applied to the methods and the rationale for the selection of specific methods.

- **Invention:** The contribution must constitute a significant invention, based on a novel integration of various subject matters to address a specific situation. An invention is significant in demonstrating advancement in the current state of the art in the research community.

- **Relevance:** Scientific research has a focus on validity so work in design research must be documented in such a way that peers can reproduce the results. As mentioned in process above, this does not make sense to have as a requirement for a research through design approach. There can be no expectation that two designers given the same problem, or even the same problem framing, will produce identical or even similar artifacts. Instead of validity, the benchmark for interaction design research should be relevance. This constitutes a shift from what is true (the focus in the sciences) to what is real (the focus of anthropologists).

- **Extensibility:** means that the design research has been described and documented in a way that the community can build on the resulting outcomes, and leverage the knowledge derived from the work.

2.2. Theory Scaffolding

Design is well known for borrowing theoretical perspectives from other disciplines, and games are no exception. There exists extensive documentation by designers, scholars, and researchers to enhance the quality of design in reference to a theory. For instance, games as a conduit to deliver a narrative and elicit emotion [17,77,101,109,146], or to support instructional designs for learning [31,43,62,63,99], with well known examples by Koster's [85] *Theory of Fun* and Gee's [49] discussion of literacy in games. Additional examples include game theory [128] based on mathematics and rational decision making, meaning making from semiotics [49,110], enjoyment based on theories of flow and positive psychology [162], gratification and motivation [58,82,83,147], and persona theory [6,19] from psychology. The work by Bjork et al. [87] argues that such theoretical scaffolding offer designers a means to generate innovative new patterns of game play, in addition to the hundreds of patterns developed already [13]. For instance, this approach identified game designs informed by theories in psychology, cognition, film studies, social network, analysis, actor network theory, and philosophy of mind. Many of these works are discussed in more detail in Chapter 3: Previous Work. Game designers often refer to the impacts of visual designs on the player's attention [13,70,92,93], however theories and perceptual features are not discussed in detail. The interest in this dissertation adheres to a design research framing supported by a theoretical scaffolding of principles of perception and theories of attention.

2.3. Human Computer Interaction

The field of human-computer interaction studies the intersection of humans and machines, including interaction design, computer sciences, human psychology, perception and attention, cognition and affect. Norman's work [119] is well known in this community in considering the user's psychology in evaluating designs, for instance when design unintentionally alienates users by elevating aesthetics over usability, failing to recognize that designers are experts, rather than typical users, and when designers' clients are not the end user. Norman outlined several guidelines in this effort to make design friendlier, such that usable designs should make use of constraints and make things visible among many others. Game designers built upon user-centered approaches in several ways, for instance through *playtesting* game prototypes [45,139] and these works are discussed in further detail in Chapter 3. However, reflections by designers regarding game artifacts appear at industry events, such as the Game Developers Conference rather than HCI conferences. Instead, usability practitioners identify guidelines for games or game heuristics [30,126,161] to support the design process. These works are also discussed in further detail in Chapter 3.

Since we consider theories in visual perception and attention in the context of games, we must consider the impacts on users' cognitive demand and affective states. Neisser [114] defines human cognition as "all processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used". Cognition is thus the mental processes underlying our ability to think and feel, and includes perceiving the world, learning from our experiences, and forming memories. Yet as Soraci states [154] "the distinction between perceptual and cognitive processes is not always clear, and that these processes interact in several different ways, underlining complex behavioral repertoires (page vii)." In recognition of this topic, Norman highlights interdependent issues in cognitive science [118], including perception, attention, thought, learning, and emotion. No individual issue is independent from the other as they are all parts of a whole, and so researchers may consider integrating issues when addressing challenging problems. To this extent, this section unpacks the impacts of visual designs in games on users in three sub-sections; the first is concerned with *seeing*, and includes theories of perception and attention. The second section includes *thinking*, or cognitive processes respective to task demands. The third section includes *feeling*, or processes associated with emotion and affect.

2.3.1. Perception and Attention

Human vision is one important mode of sensory input in affective and cognitive processes. This is considered a process as it includes subconscious and conscious filtering of visual stimuli in our environment, corresponding to perception and attention, respectively. Tufte [167] and Ware [172] discussed visual thinking, and implications for design in regard to visual information processing. The design implication is to use clear perceptual features with distinct processing channels, as they are less cognitively demanding to perceive. For Ware in particular, our attention is continuously biased to accomplish actions and complete tasks, and therefore these processes inextricably inform our everyday activities.

Researchers in perception and attention study the mechanisms of visual information processing by manipulating select bottom-up features (stimuli driven) in highly controlled top-down visual search tasks (goals). Low level perceptual features include color, shape, brightness and contrast, and motion. This kind of stimuli is rapidly perceived preattentively and without conscious thought. Tests in visual attention assign specific perceptual features to task oriented target elements and irrelevant non-target elements. Using this perceptual framework, whereby features are associated with target and non-target elements, a number of theories of visual attention were validated, and summarized below:

- **Saliency** [165] is defined as an area of a visual composition that attracts our attention (i.e., pops out) through activation of one or many perceptual features. Saliency may be associated with task relevant or irrelevant stimuli (i.e., a non-target distraction).
- **Guided Search** [175] assigns attentional priority to specific low-level features and forms the basis of goal-oriented behavior within an environment. In this case, the user has the ability to selectively control attention on specific visual features associated with a task.
- **Change and Inattentional Blindness** [150] is the study of visual memory and our inability to fully perceive and retain visual information when perceptual features of the scene change. Inattentional blindness can also be found in perceptually and cognitively demanding tasks whereby our ability to detect less relevant changes to the environment deteriorates.
- **Similarity** [34]: The degree to which elements that share a common feature are perceptually similar. A visual search task decreases in efficiency and increases in reaction time as non-targets become similar in appearance to targets (T-NT similarity). This definition also holds true for non-target element dissimilarity (T-

NT dissimilarity). In other words, as the non-targets become increasingly heterogeneous, even if each differs from the target, task performance will still decrease. Both factors (T-NT similarity and NT-NT dissimilarity) interact to scale one another's effects.

In contrast to empirical approaches in visual perception, several principles of perception are phenomenological in nature [26] and based on the “universal essence” of an object. These include Gestalt principles [173] and theories of affordance [51]. These approaches are holistic as they embrace the inherent complexity of our everyday visual environment and seek invariant structures to organize this complexity. In other words, the human visual system is hard-wired to automatically and unconsciously sort and structure the complex visual environment around us. For example, one of the most important tenets of Gestalt principles is that perception of the whole is greater than the sum of its parts acting in isolation. These principles are shown in simple and compelling visual examples, such as the figure and ground relationship shown in Figure 2, where one image can be viewed in two different ways. Wertheimer’s laws of grouping [173] also include *proximity*, *common fate*, *continuation*, *similarity*, and *closure* (the tendency to see a completed figure whenever possible). It is important to note here that similarity is both a theory of attention and principle in perception. Examples of similarity in shape, along with size, color, and proximity are shown in Figure 3.

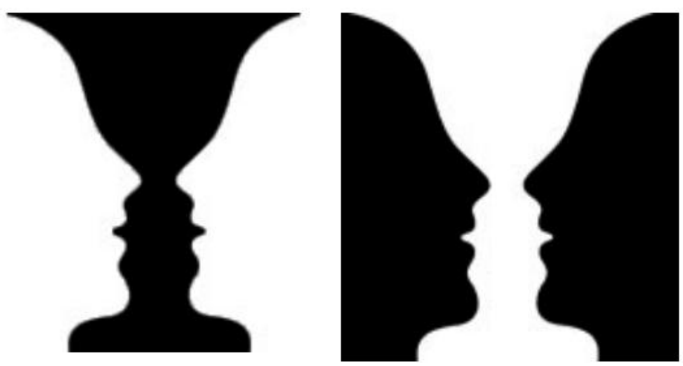


Figure 2: Figure-Ground Relationship

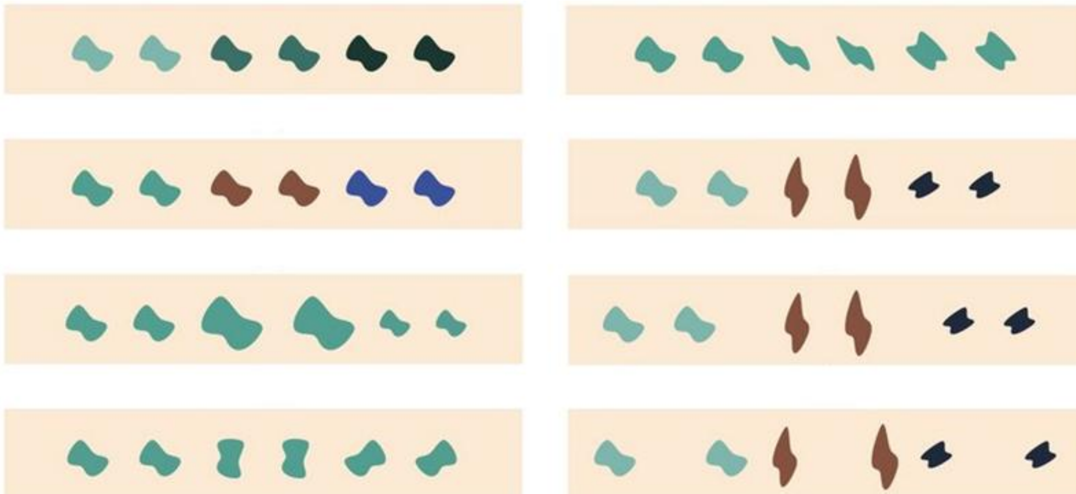


Figure 3: Examples of Similarity in Shape, Size, and Color [1]

Like Gestalt principles, affordance theory also applied a holistic approach that relies on “direct perception” of the environment [51,52]. Direct perception is the idea that seemingly abstract properties of things and events are invariant, that is can be perceived without additional synthesis or analysis. Affordance is defined as what elements in the environment offer, furnish, or provide, for good or evil. Given this view, affordance theory is much broader than perceptual stimuli in the visual system and concerns physical properties of elements in an environment. In this view, an organism is inseparable from the environment and therefore perception is inseparable from action. An organism processes information transmitted by elements in the environment and acts accordingly in order to survive, such as seeking nourishment, or avoiding predators. Gibson’s theory of affordance was later extended into human perceptual learning [50], whereby sensory inputs received over time by an organism activate memory centers, and lead to the development of perceptual schemas for behavior and action.

[1] Gestalt Principles by Dejan Todorovic: http://www.scholarpedia.org/article/Gestalt_principles
Permission to use image granted by author.

2.3.2. Cognitive Workload

Cognitive scientists coined the term cognitive or mental workload to describe mental states during problem-solving tasks. Hart et al [60] define workload as the following:

> *Workload is a user-centered construct that represents the cost incurred by a user to achieve a particular level of performance [...] Thus, workload is not an inherent property, but emerges from the interaction between the requirements of a task, the circumstances under which it is performed, and the skills, behaviors, and perceptions of the operator.*(page 2)

Given this definition, the cost on the user can be a source of variability, even if task demands are objectively defined, such as the resources provided, objectives, task duration, and structure. In other words, a task defined as low demand may be perceived as high demand by the operator in certain situations. The NASA TLX index introduced by Hart et al. introduced several categories to measure workload, including mental demand, physical demand, effort, success, and frustration. Sweller [163] considered this variability as part of a cognitive architecture, comprised of tasks and workload supporting instructional designs. The theory behind cognitive workload assumes a user's limited capacity working memory in information processing, and this capacity determines the effectiveness of an instructional design or task. Information contained in such tasks can vary on a continuum from low to high in element interactivity. This interactivity can be intrinsic to the task or extraneous, thereby hindering or interfering with the task. Working memory can offset this limited capacity through expertise and familiarity with schemas of the instructional design. Schemas are defined as cognitive constructs that incorporate multiple elements of information into a single element with a specific function. As Sweller et al. state:

> *Cognitive load imposed by instructional designs should be the pre-eminent consideration when determining design structures. Limited working memory is one of the defining aspects of human cognitive architecture and, accordingly, all*

instructional designs should be analyzed from a cognitive load perspective (page 12).

2.3.3. *Affective States*

Games are perceived by the positive or negative feelings they evoke, such as enjoyment, satisfaction, and frustration. Therefore, an incomplete view of what is a game only considers objective tasks and instructional lessons for the user to complete. As noted previously, this is especially true in eliciting emotions, for instance in the delivery of narrative. Many authors discussed the importance of *feeling* in information processing, for instance through emotion or affective states. Affective states can be defined as unconscious or instantaneous feelings that lead to conscious emotion. For example, Damásio [29] argues that rational human thought requires emotional input, and that these inputs (i.e., gut feelings) allow us to simplify among complex logical choices. Picard's early work on affective computing [124] and later book [125] also agrees with the view that emotion is inextricably intertwined with cognition. The domain of affective computing is concerned with instruments to measure and categorize feelings and emotion in information processing in high detail. Well known affective measurements include valance (positive attractiveness or negative aversiveness) and arousal (calm or exited) [86,124] that can describe emotions such as fear, anger, sadness, and joy. In fact, the cognitive workload assessment introduced previously includes frustration, which clearly has an affective implication of diminishing task performance. As Picard discussed, there are practical implications to consider the user's affective processes in entertainment computing, such as designs incorporating expressive forms of communication, affective environments, and aesthetic pleasures.

2.4. Discussion and Conclusion

This chapter presents a theoretical foundation to investigate visual designs in the context of games and the implications of visual designs on the user's experience. The theoretical framing identifies game design as fitting into a broader domain of design practice. Within the field of HCI, this practice is often concerned with integrating domains of knowledge and scaffolding theories from outside design in order to address a difficult problem. The intent here is not to identify a universal truth as is concerned with scientific modes of inquiry, but to develop artifacts as desirable solutions that could not be found with purely scientific modes of inquiry alone. Game designers are highly skilled practitioners to address the practicality of theories of attention, however, their voices are rarely featured in the HCI community. The goal for this dissertation therefore includes their voices, and the artifacts created in the investigation of these theories in the context of a game. In line with this investigation, effects of visual designs on the user's cognitive workload and affective states are considered, as thinking and feeling are intertwined in the context of a game intended for entertainment purposes. Previous work that addressed this topic in the design, HCI, and visual processing communities are discussed in further detail in Chapter 3.

3. Previous Work

This chapter includes previous work that discussed the topic of visual design in three interrelated domains: game design, games research and HCI, and visual processing domains, shown in Figure 4. Once again, the research goal is to develop perception-based guidelines within the context of a video game, and to study implications of these guidelines on task difficulty and the player's experience. This requires some documentation from each community that discussed visual designs, and acknowledges the current limitations to address this research goal. The first section provides an introduction to games, the role of the designer, highlights the importance of visual traditions in game designs, models and frameworks, and best practices supporting the design process. The second section reviews research that addressed this topic within the HCI and games community. This section identifies relevant research that considered the impact of design on the user's experience, tools to support design reflection, and work that considered visual designs in relationship to theories of attention. The third section includes relevant work in perception, attention, and cognition that were not studied in the context of a game, and therefore do not belong in either of the previous categories.

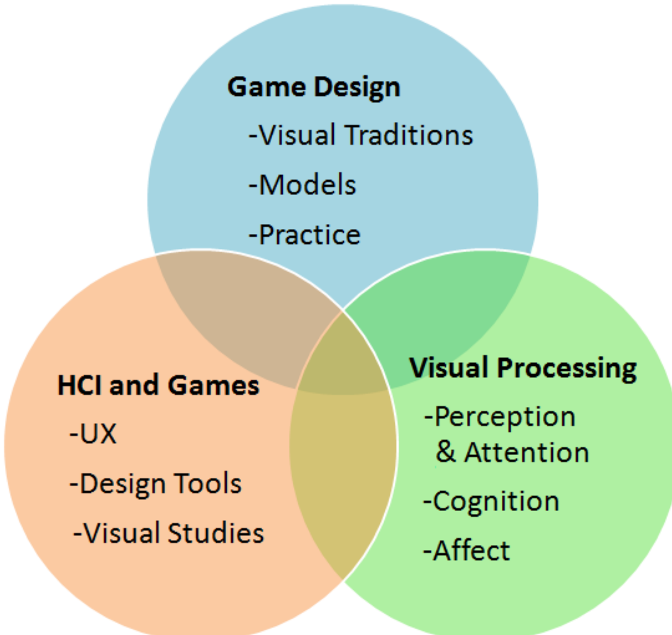


Figure 4: Game design, HCI, and visual processing multi-disciplinary approach

3.1. Game Design

The game development industry is quite large and design is only one component in a larger production effort to release a game. The annual Game Developers Conference is a well-known industry event for the game design community, and covers major integrated aspects of design, including production, programming, visual arts, and audio. The focus for this section is to review definitions of what a game is, and common roles for a game designer. This is followed by a brief review of visual traditions in game designs, well known models and frameworks, and processes to enhance the quality of design. While some work in the game design community referred to perceptual features underscoring the visual design, or discussed the influence of designs on user's experiences, effects of visual designs are only verifiable and not validated, as perceptual features underscoring the visual design were not evaluated in an experimental setting.

3.1.1. Definitions

Many in this domain offered definitions for game designs. For instance, Juul [78] describes six features of a game, based on a review of several authors. Games are:

1. A rule-based system,
2. with variable and quantifiable outcomes,
3. where different outcomes are assigned to different values,
4. where the player exerts effort in order to influence the outcome,
5. the player feels emotionally involved in the outcome, and
6. the consequences of the activity are optional and negotiable.

Fullerton [45] describes similar features in a game, defined as:

- A closed, formal system,
- that engages players in structured conflict, and
- resolves in an unequal outcome.

Both definitions are based on a formal system, and include effort, consequence, or conflict on the part of the user as part of the outcome. Many defined the term game design since a rule-based system can be defined in an infinite number of ways.

- For Zimmerman [139] game design is a "process by which a designer creates a context to be encountered by a participant, from which meaning emerges."
- For Rouse III [135] "the game design determines what choices players will be able to make in the game-world and what ramifications those choices will have on the rest of the game. The game design determines what win or loss criteria the game may include, how the user will be able to control the game, and what information the game will communicate to him, and it establishes how hard the game will be. In short, the game design determines every detail of how the gameplay will function." Later on Rouse discusses game design as an "organic process" that develops in "incremental steps".

- For Adams [1] game design is “a process of imagining a game, defining the way it works, describing the elements that make up the game (conceptual, functional, artistic and others), and transmitting that information to the team that will build the game.”

- For Fullerton [45] “The game designer envisions how a game will work during play. She creates the objectives, rules, and procedures, thinks up the dramatic premise and gives it life, and is responsible for planning everything necessary to create a compelling player experience. The game designer plans the structural elements of a system that, when set in motion by the players, creates the interactive experience”.

These definitions affirm game design as both a process by the designer and an artifact to be experienced by the player. The process involves multiple iterations and feedback from users in preliminary steps before delivery of a final game (or artifact). Each step in this process requires design thinking in the development of a rule-based system, the variables and outcomes of such a system, and in what way the manipulation of variables influences the player’s experience. Iterative and user-centered designs are important methodologies in this process and these are discussed in more detail later in this section.

3.1.2. Influence of Visual Traditions in Games

Many game designers refer to previous visual traditions in games, often in the form of post-mortems [92,107,174]. Visual traditions in the arts are beyond the scope of this work, yet elemental foundations of visual design are frequently brought up in such presentations, such as line, shape, negative space, volume, value, color, and texture [61]. The visual design of any image (i.e., content and form) can be described using these elements and principles in application. Traditions in visual arts in games serve an important function in games, especially in communicating emotion [42,164] enabling the delivery of narratives [12,105,109], and imagining fictional worlds [77,137,152].

Techniques in film and television are frequently brought up in the context of games, particularly in discussions of the cinematic virtual camera [136,157]. Informed by cinema, Logas referred these techniques as mise-en-scène of level design [96] (e.g., three-dimensional game levels). In film and television, Ward [171] regarded documented an invisible technique to solicit viewers' attention shot by shot. This is accomplished by controlling the picture content through subtle manipulations of the camera position, and framing of subjects on screen. Ward's book prefaced these techniques by an introduction to human visual perception, again with emphasis on lighting, color, and movement. Practical techniques to manipulate perceptual features are discussed in regard to the visual design, and include movement, grouping, balance, figure and ground, shape, line, rhythm, pattern, direction, color, and scale. Many of the same features are discussed in Block's [14] compositional guidelines in film, that include space, tone (brightness and contrast), line, shape, color, movement, and rhythm.

The visual design of any three-dimensional space can be described by many of the same rudimentary perceptual elements in a 2D scene [22]. The mechanics of human vision can only see in two dimensions with depth cues that our brain uses to create an illusion of 3D. Countless scholars discuss the spatial arrangement of visual elements in game environments. Byrne [18] discussed the process of placing and stringing together meaningful elements along the player's "critical path" of travel in the level, whereby not all elements should demand attention so to not confuse the player. Some of these ideas are picked up by practicing game designers. For Smith and Worch [152], a game environment constraints and guides player movement through physical properties, communicates simulation boundaries and affordances, reinforces and shapes player identity, and provides narrative context. Upton [169] applied urban planning principles [98] to organize the player's views and movement through an environment. The principles include paths, edges, nodes, districts, and landmarks and play a crucial role in shaping the players experience, such as tension, rhythm, triumph, and wonder. Theme parks are well known to apply these principles in the same way [35]. Rogers discussed the same planning principles in further detail. For instance, landmarks provide a reference point for visual orientation, foreshadow events to come using signposts, and structure long and short term goals by visual distance. Varying thematic elements along paths offers an opportunity to influence movement through unique encounters with the environment, for instance to suggest danger, support escape or exploration.

3.1.3. Models and Frameworks

Several authors introduce models or frameworks of game design. These works are summarized below:

- Hunches' *MDA Framework* (Mechanics, Dynamics, and Aesthetics) [69,91] is a schema to understand games. The player's experience (aesthetics) emerges through interactions (dynamics) with the game rules (mechanics).

- In Dormans' *Machinations Framework* [32]*,* rule-based structural features support dynamic and emergent gameplay. Diagrams are utilized to represent the flow of tangible and abstract resources through the game system.

- Church's *Formal Abstract Design Tools* [23] consist of *player intention*, *perceivable consequence*, and *story*. *Intention* is making an implementable plan of one's own creation in response to the current situation in the game world and one's understanding of the game options. *Perceivable consequence* is a clear reaction from the game world to the action of the player. *Story* is the narrative thread, whether designer-driven or player-driven, that binds events together and drives the player forward towards completion of the game.

- Schuytema's [142] game design theory includes understanding the "atoms" of a game (i.e., the element properties and functions), how the interaction with these elements creates challenge, influences the player's perceptions, and emotions.

- Ermi and Mäyrä's *SCI model* (*Sensory, Challenge,* and *Imaginative Immersion*) [37] considers the impacts of different designs on the player's experience. *Sensory Immersion* is the audiovisual execution of a game. *Challenge Immersion* is the feeling when one is able to achieve a satisfying balance of challenge and ability, such as mental or motor skill in strategic thinking and problem solving.

Imaginative Immersion is when the game allows the player to use her imagination, empathize with the characters, or enjoy the fantasy of the gam*e.*

- Sweetser's model of *Gameflow* [162]*,* based on flow psychology [27] consists of eight elements – concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. Each element includes a set of criteria for achieving enjoyment in games.

- Björk and Holopainen's *Game Design Patterns* [13] is informed by pattern languages in architecture [2] and software engineering [47]. A pattern language is a method consisting of a syntax and grammar to explain invariant components of a domain. Each pattern follows the same template, including definition, description, application, consequence, and relationships with different patterns. Hundreds of game design patterns exist and catalog the most common game functions and the types of gameplay they support.

- Fulton's *ABC Framework* (*Affect, Behavior, Cognition*) [46] corresponds to what players feel, do, and think while playing a game.

- Ryan's *Breakdowns of Interaction* [138] framework considered implications on the player's experience when they fail to learn strategies as intended by designers, misperceive characteristics of the environment, an action, or decision-making step. The four-part framework includes *perceiving the environment, developing a strategy, taking action*, and *meaning making*.

While these frameworks and models are robust as they can apply to different gaming contexts, and many indeed refer to characteristics of the visual design, they are far too general for the same reason. While the impacts of visual designs are occasionally discussed, these approaches do not address perceptual features associated with game elements congruent with attention research. The goal for this thesis is to develop perception-based guidelines in this manner.

As stated in Chapter 2 Theoretical Foundations, game designers often scaffold theories from different domains to address the visual design of elements or the impacts of game design on the user experience. While insightful, these works suffer from the same limitations as the models and frameworks addressed above. For instance Lazaro's *Four Keys to Fun* are based on positive (flow) psychology [90], and include hard, easy, serious, and people fun. Hard fun supports challenge and mastery, easy fun inspires imagination, exploration, and role play, serious fun changes the player's internal state or makes them do real work, and people fun supports social interaction. Several authors discuss implications of visual information processing in games and yet do not cite a particular theory. Koster's *Theory of Fun in Games* [85], suggests mechanisms behind visual perception and attention as contributions to the fun factor: "the brain is good at cutting out the irrelevant, notices a lot more than we think it does, actively hides the real world from us." Bjork also discussed impacts on the player's visual attention as a consequence of certain patterns of game play, for instance, patterns that influence the player's ability to maintain focus, disrupt focus, or swap the focus of attention between game elements. Lemarchand [92] also discussed "getting" and "holding" attention, "vigilance" or executing tasks under stress, and "attention bottlenecks" in games containing "overwhelming sensory inundation". Finally, Linderoth [93] discussed affordance theory in games supporting a perception–action cycle, and informing several design opportunities in games, for instance to support exploratory actions and dimensions, perforator actions, and tool improvements.

3.1.4. Game Development Processes

Game post-mortems and player reviews are a well known resource to identify best practices in game design. These resources are often aggregated to develop guidelines or heuristics by usability and playability practitioners in the HCI community [30,126,161]. However, analysis of post-mortems and game reviews do not address the research topic in sufficient detail as each game includes scenes with dynamic visual compositions. Alternative and well established practices in game design and development are through design iteration (game prototyping) and playtesting with users [24,45,139]. A combination of both practices is needed in the identification of guidelines for design, followed by testing the impacts of the guideline on the user's experience. Unfortunately, there is little work documenting such a process that includes all of the following steps, development of a guideline voiced by a designer, its implementation into a game, and a formal evaluation. The remainder of this section discusses these arguments in further detail.

Post Mortems and Game Reviews

The term post-mortem refers to a project review and summarizes the project development experience, with a strong emphasis on the positive and negative aspects of the development cycle [123]. This document is often prepared by senior project participants right after project completion. Post-mortems are quite common in the games industry, and serve as an important knowledge base for game developers, with over 1,000 documented on *Gamasutra* alone, a popular game development website. In an analysis of postmortems in 20 popular games, problems in the design phase were found in 13 of the 20 games (65%), behind unrealistic scope, feature creep, and cutting features. Examples of problems in the design phase include "overlooked gaps in the design", "full design was never really laid down on paper", "throwing out design", "too much design", and lack of focus in "designing what is important". This work suggests design thinking in regard to features (i.e., setting constraints, variables, and outcomes of a rule-based system) remains an issue of primary concern.

A similar aggregation of game post-mortems over the past two years [148], spanning 24 games from 2008-2010, found complementing trends. Although 17 of 24 games employed an agile or iterative production methodology, design and production / process issues are the highest ranking issues of what went right (36% process, 23% design) and what went wrong (56% process,16% design). Design is defined as “relating to game design, level design, gameplay and rule designs, and overall game vision external to team. This category covers all situations and decisions that were made that are clearly external to the direct team and development process”. Production / Process is defined as “scheduling, work prioritization, production methodologies, development plans and processes, scope, team morale, team communication, team assignment, and team management.” Clearly design and production are areas of game development that can benefit from guidelines extracted through experimental research.

As a counter-point to development-oriented post-mortems, game reviews are reflections of a game voiced by the players. Game reviews are of interest to developers as this is an opportunity to gauge the way a game is received and perceived by players. The work by Zegal et al. [177] analyzed 120 game reviews, from popular games developed from 2006-2008, and organized them into nine themes. Six of these themes address the design of the game or the user experience in some way. *Personal experience* describes the reviewer's first-person account of the experience, such as emotions felt and actions taken in the game. For *reader advice,* the reviewer advises on how to enjoy a particular game. In *design suggestions*, the reviewer explains the perceived flaws and problems a particular game might have. Reviews for *technology* include implications of that technology in a game's design and on the user's experience. And finally, for *design hypothesis,* the reviewer openly hypothesized (or guessed) about the goals or intentions of the game developers and is an attempt to rationalize or explain certain design decisions in the game. This work supports the notion that design of the game and the user experience are central areas of importance for users.

While the post-mortems are insightful in understanding the design challenges in developing a game, and player reviews highlight the design considerations that influence the user experience, once again these remarks are anecdotal and far too general in regard to the research interest.

Iteration and Playtesting

Many discussed the iterative process of design in games, for instance Fullerton defines iteration as a "process of playtesting, evaluating and revising". Zimmerman [139] defines iterative design as a cyclic process of a combination of methods that include prototyping, testing, and analysis. "The prototype is tested, revisions are made, and the project is tested once more". In other words, the design of the final product is a result of multiple iteration steps. Zimmerman described this process as developing a project "through an ongoing dialogue between the designers, the design, and the testing audience." Keith [24] described this process as consistent with software development practices. Iteration in each cycle consists of a concept, design, coding, asset creation, debugging optimizing, tuning and polishing, followed by evaluation before the next cycle repeats. Iteration is beneficial as it allows developers to focus their efforts on “finding the fun first” and “eliminating waste” in developing a game.

Game development often incorporates iteration with *playtesting*, defined as testing the design of a game with players and not the internal development team. Playtesting extends from HCI traditions in user-centered design and usability testing, discussed further in section 3.2. Fullerton [45] views the designer’s chief role as being an “advocate for the player” (in the chapter on playtesting): "playtesting is something the designer performs throughout the entire design process to gain an insight into how players experience the game. [...] as a designer, your foremost goal is to make sure the game is functioning the way you intended, that it is internally complete, balanced, and fun to play.” In Zimmerman’s chapter on the game design process [139], game designers learn best by directly experiencing and playing the games they make with the intent to enhance enjoyable and meaningful experiences for players. This is accomplished through a process of iteration and playtesting, defined as follows:

> *Iterative design is a play-based design process. Emphasizing playtesting and prototyping, iterative design is a method in which design decisions are made based on the experience of playing a game while it is in development. In an iterative methodology, a rough version of the game is rapidly prototyped as early in the design process as possible. This prototype has none of the aesthetic trappings of the final game, but begins to define its fundamental rules and core mechanics.*

Many authors in the game user research community merge a design iteration processes into a well-structured playtesting schedule [80,120]. The documented approaches thus far are industry oriented and product driven, that prioritize rapid and actionable reporting [57,131]. Difficult design problems require additional time that developers often do not have time to address. Given these previous works, design iteration and playtesting methods of game development are the best avenues to identify, and evaluate perception-based guidelines. These processes are discussed in closer detail in Chapter 4 Methodology.

3.2. Human-Computer Interaction

Design, user experience, and games as an entertainment medium are a large focus in the HCI community. In the area of design, reflection by designers and techniques to support design reflection were addressed, however, very little work included the voice of game designers. Work that focused on user experiences developed game heuristics, studied the player's psychology, and game difficulty as a means to improve design. Many discussed the visual design; however, few did so in regard to perceptual stimuli. Finally, many researchers addressed perceptual features and theories of attention in games; however this work did not address perceptual features of elements in motion.

3.2.1. Design Reflection

Given widespread definitions of design as introduced in Chapter 2, design understanding, reasoning, and reflection are recognized as pillars in the HCI and design community. There exists a need for systematic approaches to support design reflection in the development of interactive products or user experiences [40]. For instance, documentation is needed in how ideas emerge, how design concepts are manifested in different forms, and how interaction between participants and stakeholders unfold [28]. One can argue that game design models and frameworks discussed in section 3.1.3 are processes to support design reflection. However many of these works did not develop instruments for measurement or employ a formal user study with designers or players as a form of evaluation and validation. Nevertheless, some research contributions exist, and these are discussed in this section.

Voices from game designers in this community are infrequent. For instance, practicing designers discussed effective strategies supporting learning by Isbister et al. [72]. This work included discussion and critique from 41 designers and led to eight key concepts. Niedenthal's [115] work in simulated illumination in games and the player's affective states included interviews with an art director and a level designer. Related work by Zupko [181] interviewed 19 lighting design experts in the evaluation of an experimental lighting toolset, whereby the toolset was found valuable as a pre-visualization and storyboarding tool. Finally, our early work in this investigation interviewed five expert game designers and led to the development of design patterns to push and pull player movement in 3D games [106]. An experimental game and toolset is a unique instrument to collect the designer's qualitative feedback.

Game Design Patterns

Some user-centered work developed experimental games as a means to validate patterns of game play and spur design reflection. For example, recent work by Hulett [68] studied design patterns in first-person shooter (FPS) games. The patterns are defined by quantitative variables associated with game elements, such as their physical or functional properties. Validation is based on a user study and quantitative player metrics that support the designer's intentions in applying patterns to modify *pacing*, *tension*, and *challenge* forms of gameplay. Overall, four patterns were validated, including *sniper location, arena, choke point*, and *stronghold*.

A related study by Noor et al. [117] evaluated the gameplay aesthetics of procedurally generated Super Mario Brothers levels (Nintendo 1988), with the dual goal to identify patterns of gameplay and model the player's experience. This work crowdsourced over 1,500 game sessions, defined by content data variables, controllable gameplay data of the player's moment-to-moment interactions, and the player's post-play self-report of engagement, challenge, and frustration. Data mining algorithms and artificial neural networks were applied to model the relationship between gameplay features, controllable features, and self reports. These results identified over 20 empirically based design patterns at an exceptionally fine granularity, in gameplay segments lasting .25-1 second in duration. Although this work was not evaluated by game designers, this feedback may confirm designers' intentions and illuminate unforeseen aspects of the game that players find fun or frustrating. This work is also novel in that adaptation techniques may assist the design process in optimizing game content to suit particular aspects of player experience.

Procedural Toolsets and Games

Procedural toolsets and games are growing in popularity as a means to support creativity in the process of design, for instance through lighting or level designs. Procedural games support the design process by allowing designers to change a combination of parameters of the design at once. Smith's constraint-based 2D platform game, *Tanagra* [151], uses quantitative parameters to define the expressive parameters of the toolset, including *linearity* and *leniency*. These parameters are based on the manipulation of game content data to procedurally change the level design, such as the platform height, number of gaps, and width of platforms or gaps. Playable game levels could be easily generated to meet certain design constraints. However, the toolset and expressive parameters were again not formerly evaluated by expert game designers or users. Similarly, Dormans [32] developed an level design toolset that allowed systematic transformations of the game structure, defined by branches and nodes with different functions. The intention for developing the tool was to allow level designers to focus on the more creative aspects of their task during the iterative process of design. This work led to several game prototypes as artifacts yet was not formerly evaluated in an experimental setting with players.

3.2.2. User Experience

Many usability practitioners, psychologists, and a few designers studied the user's experience in games. Games as entertainment software is a relatively a new field, with earlier traditions in software usability testing. Entertainment aside, usability testing originally applied empirical methods to evaluate whether user interfaces in software programs were intuitive and effective in allowing users to accomplish tasks. In this regard, making software usable required an understanding of the user's cognitive psychology. In recent years, usability and playability has broadened this definition to include the user's positive experiences, such as satisfaction and enjoyment [73]. Understanding positive psychology and cognitive demands of the user are qualities that align with concerns of game designers and developers, particularly as they relate to design iteration and playtesting games with users [73,80,120,168].

Game Heuristics

Usability practitioners developed heuristics concerning the impacts of game designs on the player's experience. Heuristic evaluation is a semi-formal inspection method whereby one or several usability researchers directly evaluate an experience and generate guidelines through a process of expert review [116]. In this case, the usability practitioner formulates guidelines on behalf of the user. One benefit in developing heuristics in this way is that they are a time and cost saving approach in comparison to formal user testing. Another common approach to identify heuristics is through collection of game review data discussed in section 3.1.4. The intentions behind game heuristics are many, for instance to support learning, address common pitfalls in interface or interaction design, and mitigate problems found in specific game genres. Well known game heuristics in these areas are summarized below:

- Malone's heuristics [99] for designing instructional computer games are based on theories in psychology, education, and sociology. They include *challenge*, *fantasy*, and *curiosity*. This work included usability testing in two user studies as a means to formalize a theory for motivating instruction in games.

- Sweetser provided heuristics validating the eight elements of gameflow [162] in approximately 40 heuristics. This work was recently revised to include 165 heuristics in the evaluation of real-time strategy (RTS) games [161]. Both works are based on game reviews of popular RTS games.

- Desurvire's game approachability principles [31] are informed by social and cognitive learning theories, with the intent to make games more friendly, fun, and accessible, particularly for novice or casual players. Their purpose is to help game designers understand why inexperienced players feel satisfaction or frustration in the first moments of play, where breakdowns are likely to occur since players must perceive and attend to specific elements, learn the tools, and feel confident in the possibility of mastering the goals in the game. The heuristics include reinforcement feedback, allowing sufficient practice to scaffold skills, and clear goals.

- Pinelle contributed 10 usability principles for video game design [126] based on a review of 108 games. In summary they include *consistent response to user action, user customization, predictable behavior, unobstructed views, allow skipping repetitive content, provide intuitive mapping, easy controls, ease in determining game status, provide instruction, provide representations that are easy to interpret* “so that users can differentiate important elements from irrelevant elements.”

- Smith [153] presented principles to assist the player’s advancement through a level, based on reviews of several commercial action-adventure games. The principles include *visibility, consistent visual language, feedback, mapping connections between elements, and conceptual modeling of the underlying system*. Visibility is when you can visually see well-positioned elements. Consistent visual language separates what is and is not interactive. Feedback communicates what actions have been done, or not. Mapping connections and conceptual modeling identify element functions in support of the game goal.

Many of the heuristics above refer to the visual representation of elements in the game and their influence on the player’s experience. While heuristics are robust and meant for broad application; their application into a game can be interpreted in many different ways. One reason for this is that heuristics are not expressed in the form of perceptual features associated with elements, and quantifiable outcomes in a rule based system, as defined by game designers in section 3.1.1. Furthermore heuristics are often verified through game reviews and expert introspection, one step removed from the voice of the designer or data collected from a user study. Once again, these limitations are understandable since the intent behind heuristics is robust and practical application to game designers and developers, and not necessarily game researchers. However, the goal for this dissertation is to consider perceptual features associated with elements in an experimental toolset and game, with the goal to identify perception-based guidelines. Guidelines developed in this way incorporate the designer’s tacit knowledge to eliminate options while seeking a preferred state.

Player Psychology

Many psychologists studied the player's enjoyment within the context of games. The measurements described in these works are much more in depth than impacts on the player's cognitive demand and affective states. However these works do not define visual stimuli congruent with perception and attention domains. These are summarized below.

- Csíkszentmihályi's flow psychology [27], described becoming absorbed in an activity and included nine characteristics: the balance of challenge and skill levels, the merging of action and awareness, the existence of clear goals, unambiguous feedback, concentration on the task at hand, a sense of control, the loss of self-consciousness, a transformation of time, and a sense that the activity engaged with is intrinsically rewarding. These characteristics include both positive affective states in regard to a well defined task.

- Games are enjoyable for Loftus et al. [95], due to reinforcement schedules that activate the player's cognitive system, including *sensory stimuli, memory, expectation, motor-performance, strategy, problem solving,* and *learning.*

- For Rigby [132], games are successful and enjoyable when they satisfy the needs of human *competency*, *autonomy*, and *relatedness*. Competence refers to our innate desire to grow our abilities and gain mastery in the face of challenge. Autonomy is the innate desire to take actions out of personal volition. And relatedness refers to our need to have meaningful connections to others.

- Grodal [58] discussed the gratifications in games as linked to the player's active control of the game. For instance, players must perform specific action sequences, make mental maps of the game space, notice important elements, and make causal relationships in a short amount of time. This continuous feedback from the player's active control is what makes the games enjoyable. However, the activation of many mental functions can diminish enjoyment.

- Klimmt [83] outlined the players' internal mental processes such as motivation, expectation, effectance, and self-efficacy. Effectance is defined as the satisfaction of having imposed an effect on the environment, dealing effectively or competently with the environment, and includes feelings of self-efficacy, defined as previous reinforcement of the individual's self-reward system and set of mastery goals. Over time and through repeat exposure with games, a habituation of the experience occurs through reinforcement learning in the face of tasks, challenge, success, and failures. Within a game, this means that experienced players with previous reinforcement expect to master difficult challenges as a measure of success, while novice players accept the possibility of failure and underperformance. Novice players therefore expend more effort and have a greater probability of failing, which underscores the importance of motivational feedback or adapting difficulty as part of the game design.

- Bartle [6] and Canossa et al.'s notion of play-personas [19] based on personas theory [129] are defined as "preferential interactions and attitudes that coalesce around different kinds of inscribed affordances in the artefacts provided by game designers". Early work in this area by Bartle identified four personas in multi-user online role playing games: achievers, explorers, socializers, and killers. Achievement players focus on goals to accumulate rewards to elevate status. Explorers seek out as much as possible in the game world and are not always concerned with the same goals as intended by the designer. Socializers use the game's communicative tools in support of role-playing with other players, while killers use tools to impose themselves upon others.

Game Difficulty and Flow States

Many researchers went one step further to study effects of game difficulty on the player's reporting of enjoyment or satisfaction, informed by the flow theory above. While these works did not evaluate perceptual features associated with elements, nor the player's reporting of cognitive demands, they recognize a need to experimentally evaluate properties of the game design and their impacts on the user's experience. For instance Huniche et al. developed the *Hamlet System* [70] to dynamically adjust difficulty in the popular first-person shooter game *Half-Life 2* (Valve 2005). The system statistically infers the probability of a player death, based on a variety of gameplay metrics. Overall, expert players performed on par with novice players and neither group perceived an adjustment in difficulty. While Huniche referred to inattentional blindness [150] as possibly contributing to the results, concludes that the benefits of difficulty adjustment are best suited for expert players since they already attribute success to their own prowess. Consistent with approachability principles, these benefits are uncertain for novice players as they assume a lower success rate regardless of actual performance.

In a related study, Klimmt [82] evaluated the effects of systematic increases in task difficulty on the players' performance and self-report ratings of satisfaction and enjoyment within the *Unreal Tournament 2* FPS game (Epic Games 2004). This study only recruited expert video game players, and like the study by Huniche, the rules of the game changed without a discussion of perceptual features. Results found effects of the difficulty level (easy, medium, and hard) on the player's performance and self-report rating. Satisfaction rises in the beginning of the game in easy difficulty, due to what the game offers in terms of explicit positive and negative feedback of performance. However, performance and self-report measurements decrease as the level of difficulty increased. Given this decline, the authors observe the smallest difference in the enjoyment reporting. This finding suggests that once players become familiar with the game, they actively manage and focus on other factors of enjoyment, even with diminishing performance and satisfaction. While these results are insightful, perceptual features and cognitive demands associated with the task are needed in a follow-up study, in addition to recruitment of novice and expert players as participants.

Modeling the Player Experience

Several researchers conducted user studies with the intent to formally model the player's experience. Related work in this area was previously discussed as a means to develop patterns of gameplay and support design reflection [117]. The benefit of modeling the player's experience reduces the costly observational analysis and time commitment by a user experience practitioner during playtesting. To reach this goal, researchers incorporated physiological instrumentation to continuously measure the player's affective states, in conjunction with post-play self report questionnaires. For instance, Mandryk [100] collected the player's galvanic skin response (GSR), electrocardiography (EKG), electromyography of the face ($EMG_{smiling}$ and $EMG_{frowning}$) and heart rate. These measurements were transformed into arousal and valence affective states as a proxy to boredom, challenge, excitement, frustration, and fun emotional states. The 24 participants in the study were all male experienced gamers. Similar to the studies in game difficulty discussed in the previous section, the procedure consisted of playing a popular hockey video game, *NHL* (EA Sports 2003), followed by a post-play qualitative self report of the same emotional values. This work presented models of the player's emotion based on objective and quantitative measurements. This approach is beneficial as it pinpoints moments in gameplay when a user begins to get stressed, starts having fun, or becomes bored.

Lennart's [112] work in this area considered many of the same physiological measurements with the goal to understand the affective properties of level designs, once again in the popular *Half Life 2* FPS game. Three level designs were evaluated as experimental conditions, conforming to immersion, flow, and boredom. A number of characteristics describe the configuration of each level, for instance immersion includes an exploratory environment, different opponent types, sensory effects, dynamic lighting, etc. Flow includes combat game mechanics, increasing combat difficulty, and brief cool down spots. Boredom included linear level, degradation of visual quality, weak opponents, ample resources, and no real winning condition. Results of the data analysis found significant impacts of level design conditions on the player responses and many physiological indicators for boring, immersive and flow gameplay experiences.

3.2.3. Perception and Attention Studies

Lighting, Color, and Motion

Although motion is a powerful perceptual channel discussed previously in visual traditions of cinematic arts, motion is often overlooked within the context of games. Research that considered elements in motion only studied effects of motion on the player's navigation [3,65,140,170] performance. For instance, moving elements are frequently used to guide and attract the player's movement along paths in the game. These works found elements in motion are salient visual cues among an otherwise static scene, and thereby function to guide the player's attention. These works were not informed by any principles of perception, nor was a combination of elements in motion considered as is typical in action games. The work by Samarinas [140] studied a combination of features that impact navigation performance, including lighting direction, brightness, color, movement, and texture. This study changed multiple perceptual features associated with wayfinding elements scattered throughout the maze, such as Results found that participants remember following bright and colored elements. However, analysis of the player's behavior is inconclusive, as players sometimes notice and follow, sometimes notice and not follow, and sometimes not notice the visual cues at all. Authors conclude that effects of perceptual features associated with wayfinding elements on navigation performance in a game are small.

There are several examples of work that manipulated perceptual features in lighting, for instance, Seif-El-Nasr's *ELE* (Expressive Lighting Engine) [145] and Zupko's *SAIL*, mentioned previously. These works were informed by theatrical lighting design theory to reach dramatic goals. The ELE system dynamically controlled color, brightness contrast and camera positioning in order to highlight and change the emotional states of virtual characters. Many of these parameters were later exposed as a design toolset in Zupko's work, complete with virtual characters and different settings to test out different lighting design configurations. Another study in game lighting includes Niedenthal's Shadowplay studies [115] that considered the influence of color saturation on the player's experience. In one study, 38 subjects navigated through a video game maze tinted in either warm or cool colors, followed by completing a survey gauging different affective states. Results found that participants in the warm condition completed the maze in less time, felt happier, gladder, more enthusiastic and peppy in comparison to the cool condition.

Gaze Studies

Eye-tracking instrumentation in games has gained industry popularity [4,133,159], to track players' patterns of visual attention in a game. Eye tracking allows for the collection of the user's fixation and scan path data, primarily serving a diagnostic purpose, although it has also been used as control *inputs* into a game [159]. For diagnostic purposes, eye tracking allows researchers to determine where users look on screen, and in some case what elements are being looked at, at a given time. In this effort, a computational model of saliency [75] was developed and utilized in a variety of experiments, such as the work by Sundstedt et al. [158]. In this study, saliency and intentional blindness were evaluated in video animations. A total of 160 participants were shown video walkthroughs of an office space, given a fictitious fire marshal role, and assigned a task to count the number of fire extinguishers. The video was viewed twice, with one video rendered with high quality, and a second that applied saliency maps only to the task relevant fire extinguishers, with lower rendering quality for the rest of the image. The results found that viewers consistently fail to notice the difference between high quality images and the selectively rendered images produced by the saliency maps. Results such as these appear to confirm earlier remarks by Koster that we fail to perceive much irrelevant information when engaged in a task of some kind.

Much work investigated eye tracking in the context of a game. Much effort went into acquisition and logging techniques to integrate gaze information within the game engine at a high temporal resolution (in milliseconds) [111,113]. High resolution is needed to account for rapid changes in fixation points on screen. Gaze tracking in games found many insights, for instance, the player's gaze was found predominantly in the near-center of the screen in first-person shooter games [79], roughly 82% of the time. Seif El-Nasr also considered the saliency theory [144] in consideration of low-level perceptual features, such as color, brightness and contrast, texture, and movement, in relationship to top-down goals. Results found that visual stimuli are more salient when located near objects that fit players' top-down visual search goals. For example, elements in the game tied to goals, such as picking up an important item or finding an exit necessary to advance levels. The authors argue a game design can be enhanced by adjusting the communication effectiveness of both top-down and bottom-up attractors to visual attention.

3.3. Visual Information Processing

There is much work in motion perception, attention, cognition, and affect that come to bear on this topic, yet these works are studied outside the context of a game, as defined in section 3.1.1. Given this limitation, these works experimentally test theories of attention, based on a complete specification of all perceptual features underlining a visual composition or task. Furthermore, they seek to understand the impacts of these compositions on the user’s cognitive workload or affective states.

Motion Perception

Visualization researchers found that motion has many expressive perceptual properties, particularly in the periphery, where other features such as color change are imperceptible [8]. Some research has been devoted to identifying distinguishing features of motion [9,66], for instance, the strong grouping effect, speed, shape (the path a motion follows), direction, phase (harmonic motion), flicker (repeating on/off pattern or flashes), and smoothness. Subtle manipulation of features of motion allows elements to be highlighted or ignored. Of these, shape, particularly circular motions, has been shown to be important, especially where communicating affect is concerned [7,9,94] .

Features of motion also affect the user’s task performance. Kingstone’s study [81] of motion grouping in a visual search task found the manipulation of features inhibit or excite users' visual search efficiency. This was accomplished simply by changing the *density* (amount) of elements and *direction* (phase) that elements move. This test is worth noting in that results are congruent with the similarity theory [34], introduced in Chapter 2, whereby perceptual features assigned with target and non-target elements impacts the user’s task performance. Once again, similarity is defined as the degree to which elements that share a common feature are perceptually similar. Task efficiency (i.e., users’ reaction times) decreases as target elements are perceptually similar with non-target elements. The result of this study produced three perception-based guidelines: 1) search is easier when there are fewer motion groups (i.e., smaller density of elements), 2) target elements are easier to disrupt rather than excite, and 3) search is easier as stimuli move in a group. Although these perceptually based guidelines are perhaps closest to the approach taken in this dissertation, results are difficult to apply into a game. Chapter 4, Methodology discusses these threats to ecological validity in further detail.

Visual Attention

Action games share a set of characteristics of interest to perception and attention researchers. For instance Green et al. [56] identify many of these characteristics as follows:

- Extraordinary speed (both in terms of very transient events and in terms of the velocity of moving objects);
- A high degree of perceptual, cognitive, and motor load (multiple items that need to be tracked and/or kept in memory;
- Multiple action plans that need to be considered and quickly executed typically through precise and timely aiming at a target);
- Unpredictability (both temporal and spatial);
- An emphasis on peripheral processing (with important items often appearing away from the center of the screen).

Although features of motion are not the emphasis of this work, many of the visual tasks outlined above were studied in perceptual and attentional tests [20,54,55,56,67]. These studies recruited experienced gamers and inexperienced non-video game players and found expert gamers have a performance advantage and greater attentional resources. In particular, expert players excel in tasks that require fast reaction times, multiple element tracking, flexible allocation of attentional resources, and spatial attention acuity, such as peripheral and temporal vision. These performance differences diminish when inexperienced users retake the test after several hours' exposure to video games [54]. Given these results, the authors acknowledge that perceptual and attentional tests are *not* games [56]. Users engage in tasks that are "quite boring" as they consist of abstract representations of elements and repetitive tasks consisting of randomized trials. Not only are these tests incompatible with existing game development and evaluation practices, only task performance measurements are collected without consideration of users’ perception of cognitive workload or affective response. These responses are a critical area of concern for game designers and HCI practitioners.

Cognitive Workload

A number of researchers considered effects of task demands on users’ cognitive workload. Instrumentation to measure such effects includes validated self-report questionnaires and physiological instrumentation. Appearing in over a thousand studies, the NASA Task Load Index [60] defines workload as users' subjective feelings, influenced by the skills, behaviors, and perceptions, in relationship to a well defined task. Once again, the six factors of the survey consist of *mental demand, physical demand, temporal demand, effort, success*, and *frustration*. One major limitation with self-report questionnaires is that users’ biases and preconceptions may influence responses, since users may be unaware of actions and decisions that underlie their experience. There are many physiological instruments to empirically measure cognitive load as well, such as heart rate, skin conductance, eye pupillometry (eye pupil size), electroencephalography (EEG), and functional magnetic resonance imaging (fMRI) [53].

Work by Lavie [89] investigated the impacts of cognitive load on selective attention and the user’s ability to ignore task irrelevant distractors. This work found that increasing the cognitive loading of task relevant elements decreases the user’s ability to ignore irrelevant distractors in conditions of high perceptual load. This result is especially true when the user must resolve conflict between targets and salient non-target distractors that strongly competes with the target. This work underscores the importance of considering the type of load involved in a given visual condition or task, including in the processing of goal-relevant target information and distractor non-target processing.

One instrument utilized in this research is pupillometry, previously validated as a proxy for cognitive load in mental addition, multiplication and digital recall tasks [84,166]. Previous work found pupil size dilates (increases in size) in response to greater cognitive demands. However, pupil size may also contract [127] if the cognitive load exceeds capacity. One limitation working with pupillometry and visual stimuli is the pupil’s sensitivity to lighting changes that occur in parallel to cognitive and affective responses.

Therefore, pupillometry research experimentally controlled lighting through the use of used auditory signals or static images, as a replacement to changing visual stimuli.

Affective States

Research also utilized pupillometry instrumentation to study effects of visual or audio stimuli on user's affective states, via positive or negative valence. For instance, the valence of auditory signals [76,122] was found to dilate pupils in arousing positive and negative sounds, for instance laughter or crying. Another study [76] found auditory feedback influenced perceptions of performance in a visual search task masked as a game. Researchers found positive (winning) and negative (losing) reporting of performance *both* increased pupil dilation, but not a neutral reporting. Positive or negative valence is an important dimension to consider in users' experiences within the context of a game, in addition to cognitive workload associated with task demands.

3.4. Discussion and Conclusion

This chapter outlined the intersection of multiple domains that addressed the topic of visual design in the context of games, their implications on the player's experience, and closely related work that considered the perceptual and attentional mechanisms underlining these designs. Given the immense amount of contributions in this area, a number of limitations were found in each domain to address this topic. A need exists to incorporate a perception-based framework into a game design domain as a means to generate perception-based guidelines. The goal for this dissertation therefore engages practitioners from the game design community to participate in a process of developing and reflecting upon visual designs in a game, and their impacts on the player's experience, in consideration of these underlining perceptual and attentional mechanisms. The methodology for accomplishing such a goal is discussed in further detail in the next chapter.

4. Methodology

As elaborated upon in the previous chapters that discussed theoretical foundations and related work, the research goal identified that the visual designs of video games can benefit from a perception and attention based theoretical scaffolding. A need exists to develop guidelines scaffolded by such theories, consider their application into the design of a game, and to evaluate these impacts on the player's experience in a user study. Engaging the game design practitioners in this process in conjunction with a player study is one avenue to reach this goal.

Epistemological and methodological choices to address the research goal are discussed in this chapter. These choices are guided by Dewey's notion of pragmatism [25], which is a practical and applied research philosophical stance. Pragmatism is problem-centred, practice-oriented, and pluralistic in that quantitative and qualitative methods are used in order to address the research questions. Dewey rejects the idea that practice should simply follow theory as this excludes the reflective potential on the part of the practitioner. This stance also rejects a forced choice dichotomy between post positivist and constructivist knowledge, and finds a mixed approach [25], employing both qualitative and qualitative methods of inquiry, are best suited to address this topic.

4.1. Approach

The approach taken to address this topic integrates design research [88] and user research [10,73,143,168] perspectives. This approach includes reflection by game designers respective to the iteration of an experimental game, over the course of two user studies. For Zimmerman [178], new and unexpected questions emerge during the process of iterative design as “there is a blending of designer and user, of creator and player.” Stapleton [155] also identifies a link between design iteration and research whereby designers rely on intuition and tacit knowledge as a means to generate “solutions through synthesis”. This process can benefit by addressing similar “problems through analysis”, “deductive logic”, and scaffolding a scientific theory. Finally, Purpura [130] highlighted the importance of quantitative evaluation of design choices that lead to an artifact. Quantitative methods naturally fit in towards the end of the design cycle, after the conceptual and exploratory phases of design.

Many game researchers apply experimental designs as a means to conduct game user- user research [10,73,143]. For Isbister [73], the benefits of user research are desirable when game developers try to reach a target audience that does not resemble the developers themselves, supports development in large development projects where design intuition is difficult to manage, and where rigorous experiments are needed to fine-tune designs. As Isbister discusses, the opportunities for user research are numerous in games as 1) the iterative development cycle of games is well adapted to user research, 2) most developers and designers are dedicated to providing a great user experience, however often only functional needs are met, and 3) there are excellent frameworks for considering how user research can contribute to games.

There are many additional methodological questions to unpack with this approach. As a starting point, in what way does one develop an experimental game congruent with principles of perception and theories of attention? One must address threats to ecological validity early in this inquiry and explore this problem in more depth before progressing forward. Furthermore, the structure and constraints of such a toolset and game are unknown and thus require some iteration. Once created, in what way do game designers interact with the toolset as a means to manipulate perceptual features, since previous work has not engaged the game design community in this way? Finally, in what way are design intentions expressed through the manipulation of perceptual features as a basis to formulate guidelines? These sub-questions must be addressed before the effects of perception-based guidelines are considered.

Based on these questions, the research approach is divided into three parts, shown in Figure 5. The first part includes an exploratory method [26] and study that applies a perception-based framework into a game, and informs the development of an experimental toolset and game. The second part is the actual development of the experimental toolset and game in Chapter 6 called *EMOS (Expressive MOtion Shooter).* This step is informed by iterative design and agile software development methods [24,45,139] and includes instruments to collect data based on the two user studies that follow. In Chapter 8, the toolset is revisited after study 2, the designer study whereby design intentions are synthesized into perception-based guidelines. This step applies guidelines into new iterations of the EMOS game as experimental conditions, suitable for the Chapter 9 Study 3: Player Study. The third part consists of mixed and triangulation methods [25] employed in both the Chapter 7 Designer and Chapter 9 Player Studies, studies 2 and 3, respectively. This method is used to first identify perceptual guidelines based on designers' intents, and second, to validate their effects on the player's experience. The next sub-sections address each method in further detail.

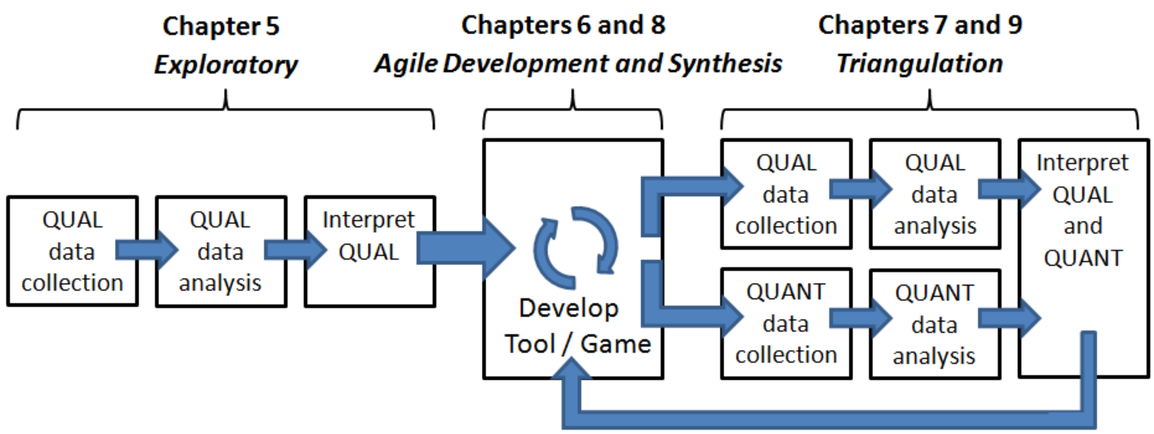


Figure 5: Methodology Diagram per Chapter

4.1.1. Exploratory

Exploratory methods [25] are based on the premise that exploration of a problem is needed, and that measures or instruments are currently unavailable. An exploratory design typically occurs in two steps, first consisting of a qualitative exploration of a problem, followed by development of a research instrument to collect quantitative data. Examples of exploratory designs come from social psychology and social psychiatry [25]. Chapter 5 considers threats to ecological validity and explores a perception-based framework within the context of six commercial video games, as a means to understand the cognitive effects on users. The data collection includes video recordings of popular commercial games that contain dynamic and complex visual designs, and a qualitative process of video coding clips by features of motion in association with game elements. The coding process went through an inter-coder agreement step [25], based on raters' associations of features to elements in the game. This exploratory study supported the application of a perception-based framework into a game, identified qualitative guidelines, and informed the structure and constraints of the experimental instrument, documented in Chapter 6.

4.1.2. Design Iteration

An iterative and agile development method [24,45,139] was used in the design and refinement of the EMOS experimental toolset and game. An agile approach includes multiple steps in the development of a game prototype, including concept, design, coding, asset creation, debugging, optimizing, tuning, and polishing. Steps are revisited through a series of game prototypes and therefore the final outcome is not defined initially. For this reason, agile approaches typically do not rely on formal design documentation before development. This process includes short intervals of time in frequent iterations of the game. The outcome of one design iteration contains a functioning game prototype and informal evaluation. Results from this step refine the design goals of future iterations.

Chapter 6 documents this method in developing the EMOS experimental toolset and game. The outcome of this chapter led to the selection of three features, *speed*, *size*, and *density*, instanced 11 times in association with two target and four non-target elements in continuous motion. Additional fixed features in the game include the *circular*, *expansion*, and *linear* trajectories of motion that elements follow. The structure of the game allows features to independently change across an ordered sequence of 15 levels, corresponding to one game session. This chapter includes instruments to collect data in the Chapter 7 Study 2 Designer Study and Chapter 9 Study 3 Player study. The EMOS toolset is revisited in Chapter 8 in the application of perception-based guidelines, based on formulae of intended perceptual effects found in Chapter 7. New versions of the EMOS game are created suitable for a formal player study, discussed in Chapter 9.

4.1.3. Triangulation

The two user studies in Chapters 7 and 9 consist of mixed and triangulation methods [25]. Game user research often employ a mixed methodological approach [80,120,121] consisting of the collection and analysis of both quantitative and qualitative data. The benefit of a mixed approach offsets the weaknesses associated with one method alone. For example, closed-ended quantitative approaches often lack important contextual information and exclude the voices of experts or users embedded in the field. Conversely, an open-ended qualitative approach is subject to bias, interpretation, and difficult to generalize findings outside the issue in question.

There are many quantitative and qualitative methods of data collection and analysis in game user research. Examples of quantitative data include metrics of players' performance in the game [33,168], such as time on task, task success, errors, and learnability, defined as the performance change over time. As discussed in the previous work section, the player's physiological performance is another form of quantitative data [4,112], such as heart rate, skin conductance, or electromyography. Qualitative data includes introspection via participant talk aloud [64] and self report of perceptions in the game through questionnaires. Some questionnaires are encompassing, such as the validated seven factor game experience questionnaire [71] while other questionnaires survey a specific quality or seek to classify users, such as affective valence [70,82], or the gaming expertise of players [36].

Common in the games industry is a triangulation methodology [25,143], whereby results are based on quantitative and qualitative data collection and analysis. This approach is used to analyze different but complementing data collected. For instance, this design is appropriate when the research wants to compare and contrast quantitative statistical results with qualitative findings, or to validate quantitative results with qualitative data. The triangulation of different data sources allow analysts to pinpoint where problems occur in the game, based on what players see, feel, and think while playing. Corrective steps can be taken by developers based on these kinds of results. A mixed and triangulation approach is widely used in the game industry to support rapid and actionable reporting [57,131] to help designers and usability practitioners make informed decisions, quickly.

In Chapter 7 Study 2 quantitative data is collected from expert game designers' interactions with the EMOS toolset, followed by statistical analysis of this dataset. Eight designers verified the accuracy of their selections and provided additional qualitative feedback based on their experience interacting with the toolset. The qualitative feedback went through a textual analysis phase [26] that identified several themes, and again went through a process of inter-coder agreement. Designers' comments are then organized in relationship to the quantitative results found. The output of Chapter 7 is a summary of designers' experience working with the toolset and their intentions to manipulate difficulty in the game via perceptual features. These results are then condensed and restated into perception-based guidelines in Chapter 8.

The Chapter 9 Study 3 Player Study also employs mixed and triangulation methods to evaluate the effects of the perception-based guidelines on the player's experience. The 105 participant study evaluated three experimental conditions of the EMOS game. Quantitative and qualitative data is collected during play, including game play and physiological performance measurements, specifically pupillometry, and qualitative self-reports of cognitive workload, satisfaction, and expertise. Analysis is once again informed through a formal interview with three expert designers, followed by textual analysis and inter-rater agreement. The output of this chapter seeks to verify the effects of the guidelines on the player's experience.

Triangulation in Chapter 9 also includes pupillometry instrumentation as a physiological proxy of the player's cognitive workload. Although pupillometry is cited in games research [4], very few publications exist within the context of games [104]. This is due to the methodological constraints of working with pupillometry in games containing dynamic visual stimuli. Previous work discussed in Chapter 3 acknowledged confounding effects of brightness that occur in parallel with cognitive and affective responses and resolved this problem in many ways. Yet few considered pupillometry in the context of games. The few cases that work with dynamic visual stimuli [84] employ sophisticated averaging techniques and employ noise reduction algorithms, for instance to remove eye blinks. In this case, a high repetition of trials for a given task are collected and then broken down into discrete periods of time for further analysis. The pupillometry methods used and success of these methods are discussed in Chapter 9.

4.2. Threats to Ecological Validity

One must acknowledge a threat to ecological validity given the inherent complexity in game designs verses the experimental control found in theories of attention. The experimental setup and tasks evaluated in attention tests are concerned with understanding human vision and not game design problems meant for entertainment purposes. These threats can be illustrated through example, for instance Kingstone's motion coherence experiment [81]. In this study moving patterns of dots and letters represent abstract target and non-target elements. Task difficulty is randomized where the user must visually search for targets and click a button if a target is visible or not. This test is inconsistent with the structure of a game in four ways. First, games do not randomize task difficulty as they consider training and learning as an integral part of the experience. Second, games include target elements in association with a goal and reward, so it is arbitrary to measure task performance in relationship to invisible targets. Third, the interaction modality is more sophisticated in games, via standardized control interfaces and devices, such as a mouse or game controller. And finally, games introduce visual stimuli as a result of the player's interaction with the control device. These issues must be addressed in the context of a game.

These threats can be alleviated in two ways; first through the development of instrumentation integrating a perception based framework as a means to manipulate visual elements. This instrument must be easy to use by a game designer. Second, that outputs are empirically measurable as a means to consider a theory of attention. The following describes minimum criteria for ecological validity in each study. The degree to which these are achieved are revisited in Chapter 10.

4.2.1. Study 1: Commercial Game Analysis

Given multiple game design frameworks in existence, a perception based framework must offer new insight toward the problem of complex visual designs. Does this framework define visual designs and their impacts on the users experience in a way that existing frameworks cannot? These insights should be found in the context of commercial games that contain complex scenes. Analysis using this framework is a crucial first step in the addressing principles of perception and theories of attention.

4.2.2. Experimental Game and Toolset (EMOS)

An experimental game to investigate this topic must exist in a well known genre. Congruent with previous work in attention, we need a clear definition of the game structure, task, perceptual features associated with elements, and how they change over time. The toolset should fit seamlessly into the game and allow a researcher to manipulate perceptual features over time. The researcher must be able to preview these changes and correct if necessary as a means to produce games. Finally, the toolset must be instrumented in such a way to record the change in perceptual features as a first step to consider theories of visual attention.

4.2.3. Study 2: Designer Study

Game designers as expert practitioners can easily use the tool and manipulate perceptual features to author games. Furthermore they must be able to describe the intended impacts of their selections for a target player. Perception based guidelines must be derived from an analysis of these manipulations and whether or not they show evidence of a theory of visual attention. Guidelines must be robust in allowing different perceptual features to change.

4.2.4. Study 3: Player Study

There are several considerations of the ecological validity of the guidelines. First, application of guidelines into experimental conditions must reflect common manipulations found in the previous study. Second, designers have an opportunity to interpret results in regard to specific perceptual compositions and impacts for specific target audiences. These remarks should demonstrate new insights concerning the study of visual design guidelines in a game.

4.3. Limitations with this Approach

There are several limitations to address with a pragmatic philosophical stance; mainly this stance does not epistemologically distinguish between theory and practice. This point draws into question the relationship between truths found in science, verified by scientific theory, and common sense. Dewey suggested that scientific knowledge is not simply a truth to follow but a possibility that practitioners can use in solving everyday problems. Given this limitation, great care should be made to distinguish between and integrate theoretical and practical perspectives.

Further limitations are found with respect to each approach to address this topic. Limitations of the exploratory approach in Chapter 5 include the guidelines found, as these are not empirically validated. Furthermore, reliance on this method alone is limited to the commercial games and video clips selected. Exploratory methods are best when the purpose of research is to gain familiarity with a phenomenon or acquire new insight into it in order to formulate a more precise problem or develop hypothesis. The purpose for this approach is viewed as a first step to consider a perception based framework before commencement of the EMOS game or user studies discussed later.

Limitations of the iteration development approach include the lack of feedback from expert game designers in the process of developing the EMOS game. They could only respond to the decisions made afterwards, as discussed in Chapters 7 and 9 limitations sections. Furthermore, imposing a perception-based framing in the development of a game may be suitable as internal prototype or Gray box prototype, not meant for a commercial release. Experts within the game design community may reject a theory-based approach and prefer an alternate design philosophy without such constraints. More qualitative data of designers' reflections could be collected in the development process, or for Chapter 8, allowing designers to comment on the application of perception-based guidelines back in to the context of a game.

Many of the same limitations of expert designer feedback are also found in the mixed and triangulation approaches in the Chapter 7 and 9 user studies. This research is conducted external to a game development studio, so eight designers graciously contributed their time and expertise. In total, 1 hour for 9 designers in Chapter 7 and two hours for three designers in Chapter 9. For example, a follow-up interview with each designer could benefit from a review of their individual selections, rather aggregating their selections as a group. This merging step may exclude individual design choices, particularly in regard to differences between the fixed feature trajectories of motion.

5. Study 1: Commercial Game Analysis

This chapter applies a perception-based framework to explore effects of visual load in commercial games on participants' ranking of cognitive load. The goal for this chapter is to identify links between perceptual features of motion and qualitative self-reports of cognitive load. Once again, the motivation for this exploration is that games containing high cognitive load due to visual stimuli may negatively impact the player's performance or perception of performance. Therefore one assumption in the study is that a relation exists between perceptual features and the perceived cognitive load. This chapter addresses three questions:

1. **RQ1:** To what extent can a perception-based framework apply to elements in motion within the context of commercial action adventure games?

2. **RQ2:** In application of this framework, what is the organization of features motion in scenes ranked with high or low cognitive load?

3. **RQ3**: What are guidelines for elements in motion within the context of these games?

The next sections introduce the methods including participants, data collection, and analysis. Results evaluate features of motion in relationship to the cognitive load rankings between games. As a result, the discussion section includes three guidelines in for organizing elements in motion in games.

5.1. Method

5.1.1. Data Collection and Participants

Data collection occurred in three steps including 1) selecting a total of 12 gameplay video clips from six action-adventure commercial games (two per game), 2) video coding each clip according to a perception-based framework, and 3) self-report rankings of cognitive load for each game. For step 1, two video clips from six games are collected, shown in Table 1. The selection of games is based on the following criteria: (a) recently produced (2009 or later), (b) received high sales, and (c) span the 3rd person action adventure genres. All games selected received aggregated metacritic reviews between 70-100, which are generally favorable and received universal acclaim. The clip selection criteria is that multiple expressive features of motion are represented in association with a combination of game elements. Given this criteria, many of the clips contain gameplay associated with a challenging task, such as a boss fight. Excluded are clips with few features of motion since previous research found that players easily identify moving elements as targets among otherwise static scenes [3,65]. To constrain the amount of features coded as the visual content on screen continuously changes, the clip duration is limited to 20 seconds. All clip selections occur within the first hour of play.

Table 1: Data collection from six games

Game Name	Developer	year
Assassin's Creed Brotherhood (ACB)	Ubisoft	2010
God of War III (GOD)	Sony	2010
Prototype (PRO)	Radical	2009
Ratchet & Clank Future: A Crack in Time (RATCH)	Sony	2009
Fable III (FAB)	Lionhead Studios	2011
Prince of Persia: The Forgotten Sands (POP)	Ubisoft	2010

In step two, two researchers watched the video clips and coded features of motion, discussed further in the next section. The researchers were graduate students in the expressive motion research group and experienced gamers who had played each game previously. In step 3, a total of five researchers provided self-report rankings of cognitive load for each game, based on a 5-point scale (1 = lowest and 5 = highest). The additional three participants also belong to the research group and were familiar with encoding features of motion from the scientific visualization and human movement analysis domains. Two of these participants had not played the games previously.

5.1.2. Data Analysis (Coding)

In step 2, video coding each clip is informed by a perception-based framework. The framework includes the classification of features of motion in association with target or non-target element types. In total four elements types are defined as games typically include a combination of elements functions. These types are defined next:

- **Target** elements contain a core game function in relationship to a goal or task in the game. For example boss enemies or resources to collect are targets associated with game goals, such as advancement or collection.

- **Non-Targets** elements contain relevant or irrelevant visual stimuli. Irrelevant stimuli can be purely atmospheric, such as visual effects, while visual feedback of players' interactions using a control device is relevant stimuli associated with core game functions. For instance, visual feedback is relevant in association with controllable actions or events in the game, such as attacks or explosions

- **User Interface (UI)** Targets are similar to targets as they communicate core game functions. UI targets are frequently arranged in a dashboard configuration on the screen display, often on the bottom of the screen or screen periphery. UI targets are typically fixed in place as they are attached to the camera element. UI targets may also be attached to targets and detached from the camera.

- The **camera** element is a dynamic game object and can therefore influence the presentation of target and non-target elements on the screen. Action adventure games typically allow the player to control the camera view with certain position and viewpoint constraints, controlled by the player or game designer. Therefore the presentation of elements results from constraints of a dynamic camera and perceptual features associated with game elements. In this study, movement of the camera is coded three ways:

- *A stationary* camera locks the position and point of view.
- *A tracking* or *dolly* camera constrains movement along a track, yet the point of view remains locked. This camera type appears to trail in front of, behind, or alongside important elements in focus.
- *A free* camera unlocks both constraints, thereby allowing the player to freely move and reposition the point of view at will.

The four features of motion evaluated in this study include *flicker* (flashing), *trajectory* (shape of motion), *speed*, and *repetition*. The selection of these features is based on previous literature in visual perception [8,66] and discussed further in Chapter 3. Depending on their function in the game, human avatars are treated as any other target or non-target element in the game. Given this set of features, each feature contains different coded attributes, shown in Table 2. The flicker attributes includes flashing once or repeating. Trajectory (shape of motion) attributes include linear, circular, expansion, and expansion with contraction. Speed attributes include slow and fast. Finally, the repetition attribute refers to harmonic motion, or motion that contains a clear looping cycle and is frequently coded in combination with the speed or trajectory features. Based on a total of 151 coded features associated with elements, Cohen's kappa coefficient is used as a measure of statistical inter-rater reliability. Almost perfect agreement in all motion features are found for flicker, trajectory (shape), speed, and repetition, with a kappa value of 0.898, 0.847, 0.9, and 0.967, respectively.

Table 2: Motion features and coding attributes

Feature	Coding Attribute
Flicker (flashing)	once, repeating
Trajectory (shape)	linear, circular, expand, expand-contact
Speed	slow, fast
Repetition	has repetition

Error! Reference source not found. illustrates a coding example for ACB clip 1[2]. This example includes a definition of element types, including the camera type, and features of motion defined by attributes. Each clip contains multiple elements as stated previously, and each element may be coded with more than one feature. ACB clip 1 uses a stationary camera and four elements (labeled in Figure 1) that include 1) user-interface targets, 2) visual feedback non-target explosions, 3) ambient non-target distractions of debris falling, and 4) target elements. The user interface targets flash *repeatedly* in 1), the visual feedback explosion trajectory *expands* in 2), and is *linear* in relationship to the ambient non-targets in 3). The target elements (labeled as 4) are only distinguishable by a difference in brightness in relationship to the background terrain. In this screenshot all elements *except* targets are coded with features, so *ignoring* these distractions is part of accomplishing the goal presented to players: “destroy the enemy cannons”.

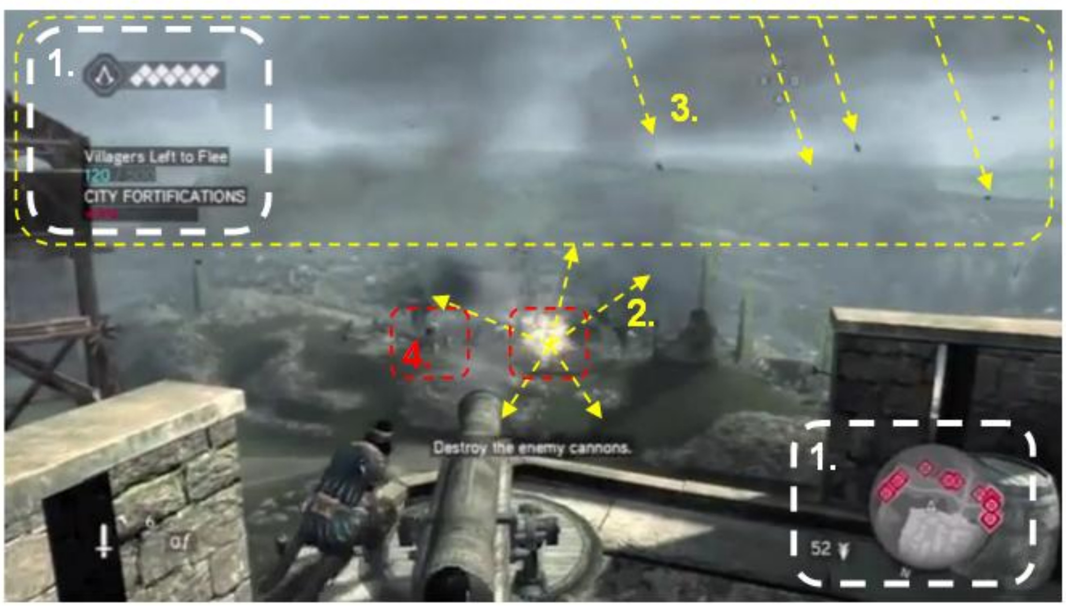


Figure 6: ACB clip 1 coding examples

[2] http://youtu.be/rYyUkW-sbLA

5.2. Results

Results include the cognitive load rankings for each game first, followed by a summary of the coded element types, camera constraints, and features. Figure 7 shows the average, minimum, and maximum rankings, with the vertical axis corresponding to lowest = 1 and highest = 5 load. Prince of Persia (POP) is ranked lowest while Prototype (PRO) is ranked highest. Fable (FAB) and Assassin's Creed (ACB) are rated neutral or below while Ratchet and Clank (RATCH) and God of War (GOD) are rated neutral or above.

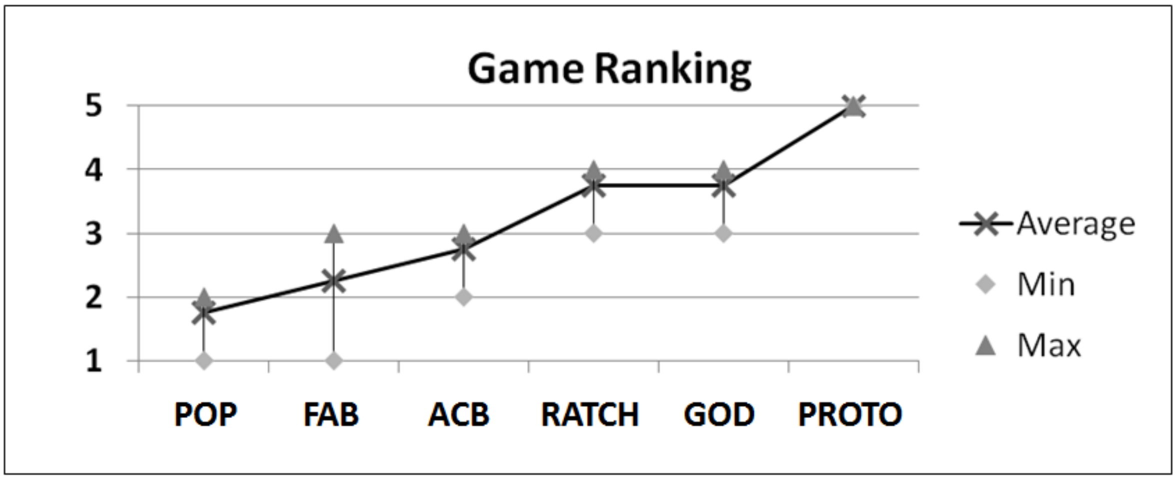


Figure 7: Ranking of cognitive load per game

A data collection overview is shown for target and non-target element types in Figure 8, and user interface target element types in Figure 9. In total, target or non-target elements received 124 coded features, and user interface targets received the remaining 27 features. The x-axis in Figures 8 and 9 arrange clips by the coded camera constraint. A stationary camera is used for ACB clip 1, both FAB clips, and POP clip 2. A tracking or dolly camera is used in both GOD and RATCH clips, and POP clip 1. A free camera is used in both PRO clips and ACB clip 2. The y-axis in both figures shows the amount of unique target and non-target elements per clip and the amount of feature attributes coded in association with these elements. In Figure 8, clips generally contain no more than one target and 2-8 non-target elements. The general trend is that each coded element received two feature attributes, and this 2:1 ratio is similar for user interface targets in Figure 9. However, in half of all clips, attributes were only coded in association with non-target elements. In other words the target elements did not receive any coded attribute of motion. The clips without coded target elements include both ACB and POP clips, and clip 1 of GOD and RATCH. In regard to user interface targets in figure 4, five of 12 clips received no attributes, including both POP and RATCH clips, and PRO clip 2.

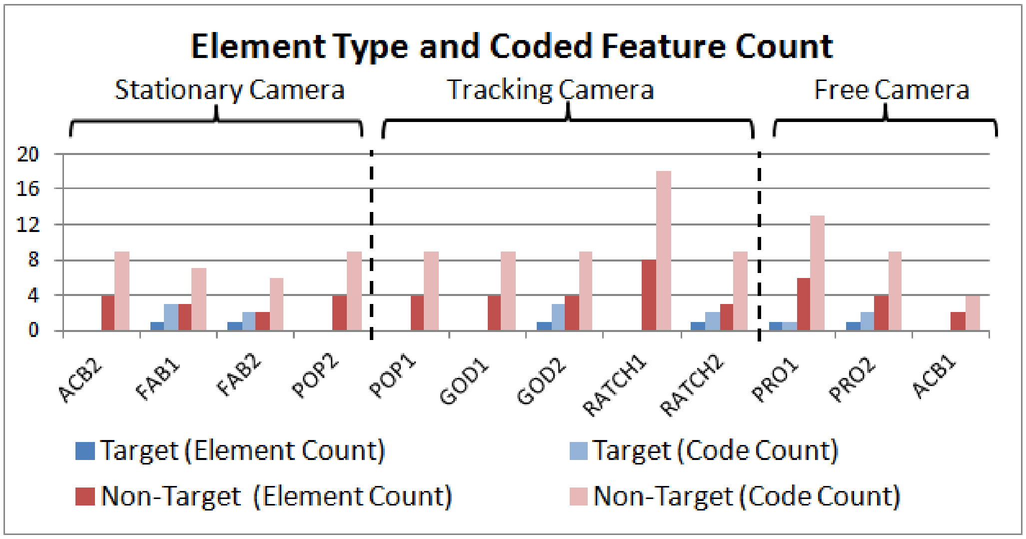


Figure 8: Target and non-target element and coded feature count

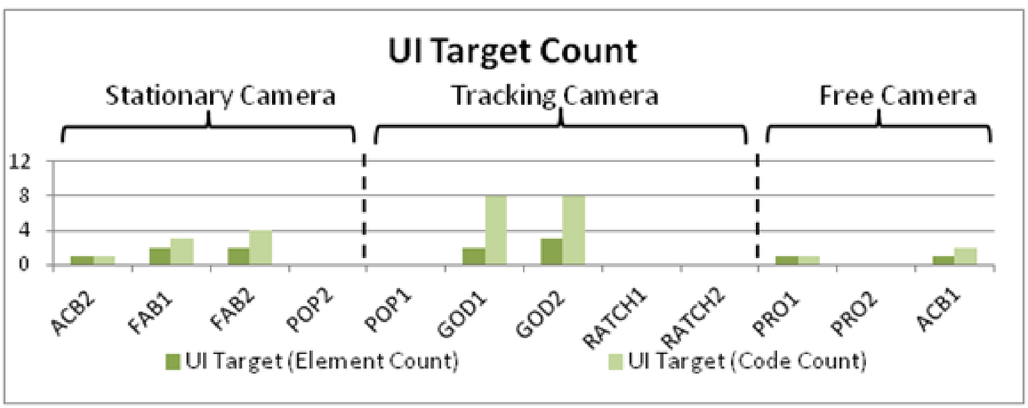


Figure 9: UI target count

From this overview, attributes associated with non-target elements are by far coded most frequently. Clip 1 from PRO and RATCH contains a high amount of non-targets, 6-8, coded with 12-16 attributes of motion found, respectively. Clips from ACB and FAB contain fewer coded attributes. Attributes associated with target elements are much less frequent, with no more than one target element per clip. Although all clips contain at least the player avatar as a target element, and in many cases additional non-player player characters (NPC), the character animation sequences did not fit with the feature attributes in the coding framework. FAB clip 1 and GOD clip 2 are the only exceptions as both clips contain NPC enemy targets moving in a circular trajectory. Both clips in PRO, and clip 2 in RATCH and FAB also contain attributes associated with target elements, however these are collectable (static) elements, rather than NPCs.

Given the rankings and overview, it is easy to determine PRO has the highest load due to the unconstrained free camera. However, ACB clip 1 also used the free camera and was ranked lower than games that constrained the camera. Additionally, PRO received a similar amount of features associated with elements and fewer user interface targets, in comparison to clips that used a constrained camera. For example, RATCH and GOD have just as many non-target elements, while GOD has the most UI target elements, yet load for these games are ranked lower than PRO. Therefore the cognitive load rankings depend on the type of camera constraint and features of motion. These are discussed further in the next sections.

5.2.1. Influence of Camera Constraint on Features

The camera constraint played an organizing role in establishing a visual hierarchy for elements in motion. The ACB, FAB, and POP clips that use a stationary camera are ranked lower in cognitive load since the camera position and viewpoint are locked. Given this constraint, target elements often act as a *focal point* to anchor a combination of feature attributes associated with non-target elements, such as fast speed and different trajectories. Another reason for the lower ranking is that *focal points* persist on screen for a longer period of time in comparison to the tracking and free camera. Figure 10 contains illustrations of a focal point in the FA3 clip, containing circular trajectory movements of the non-player character target enemies, expansion-contraction and linear trajectory of the player’s magic particles, and visual feedback explosions anchored to the target (player avatar). The figure includes diagrams containing yellow lines and gray shading to illustrate the focal point.

Figure 10: Focal Point in FA3 clip 1

Unlike the stationary camera, the tracking and free cameras move with constraint. Therefore, an alternate approach to establish a visual hierarchy is to organize features into distinct visual regions on the screen. Figure 11 contains multiple examples of visual regions from POP clip 1, RATCH and GOD clips. These diagrams include shaded regions in gray depicting a visual region on the screen. In POP clip 1, dozens of non-target army soldiers with slow speed are located in the background and a fireball non-target element with a fast speed and a linear trajectory moves across the screen. The effect is very dramatic as the fireball element stands out as it moves towards the player's avatar, over a background of slow activity. Application of both focal points and visual regions are used in clips from RATCH and GOD, also shown in Figure 11. In these clips, the repetition of speed and trajectory features distinguishes between active and inactive regions of the screen. For RATCH, the top part of the screen contains non-target distraction elements moving in a linear and circular trajectory, with slow speed. For GOD clip 1, non-target elements in the background move in a linear trajectory with fast speed and repetition, while the focal point contains a circular trajectory with fast speed, also in repetition. Although fast speed and repetition are found in both cases, elements are distinguishable by the linear or circular trajectory.

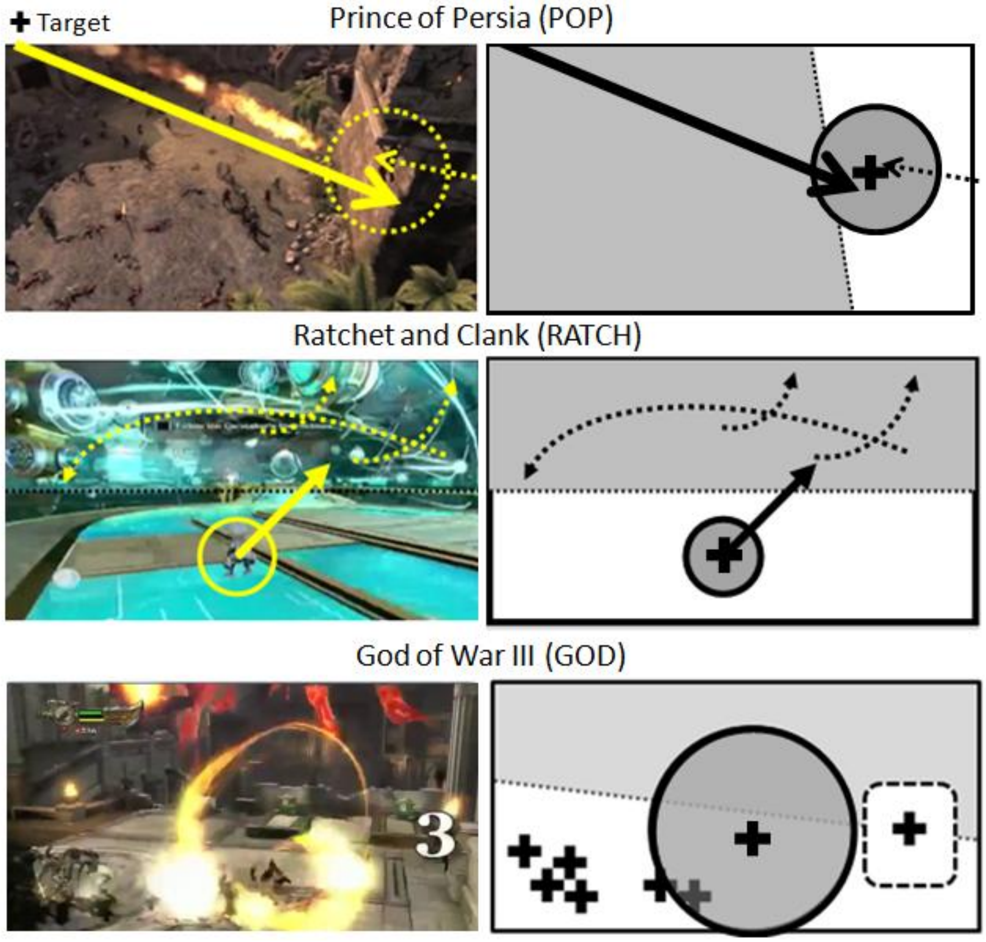


Figure 11: Visual Region and Focal Points in POP, RATCH, and GOD

The free orienting camera, unlike the stationary and tracking cameras, is without a sustained focal point or visual region. ACB clip 1 and PRO use a free camera and are ranked higher in cognitive load in comparison to games that use a stationary camera. This is due to the viewpoint and position change of the camera moment to moment, which changes the presentation of elements on screen, regardless of features associated with these elements. As shown in Figure 12, PRO includes linear trajectories, originating from multiple targets on screen. While these features signify enemy target fire, no dominant focal point is visible other than the player avatar. Furthermore, focal points are diminished in PRO since non-target distractions also contain attributes coded with fast speed and expand-contract trajectories. Clip 1 from ACB did not encounter this problem since flashing is a feature associated with only target elements.

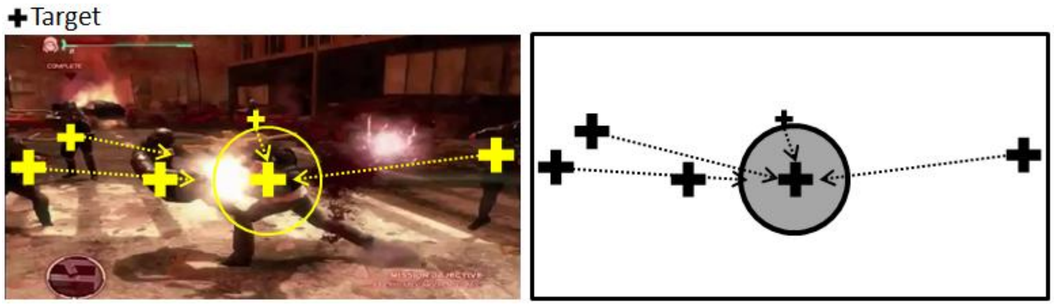


Figure 12: Free Camera in Prototype (PRO)

5.2.2. Motion Features

The relationship between combinations of feature attributes also contributed to the cognitive load rankings. These relationships are through attributes of speed and features associated with the user interface targets. Figure 13 shows the coding for slow and fast speed in each clip, with the amount coded shown on the y-axis. From the figure, multiple elements with only fast speed and a free orienting camera have a high cognitive load ranking. Both clips of PRO have five elements coded with fast speed while ACB only contained one fast element. Use of a stationary camera, even with fast moving elements, has low load, found in the FAB and POP clips. Games that use a tracking camera, RATCH and GOD, contain fast and slow moving elements as a means to highlight focal points and visual regions. The high amount of coded speed features in RATCH and GOD, with the tracking camera, explains the higher load ranking.

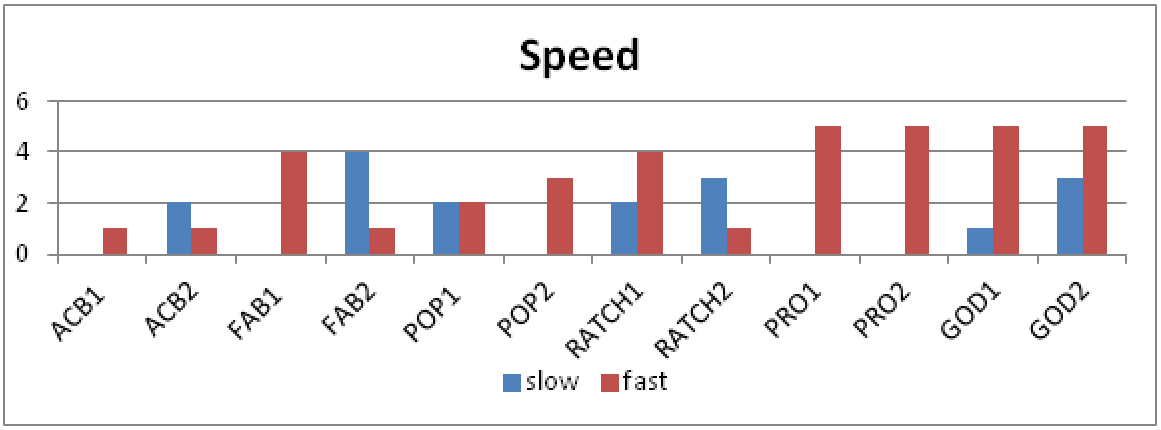


Figure 13: Speed attributes per clip

Games are also different in features associated with the UI target elements, shown in Figure 14. Typically, the UI elements flash to grab attention. However, FAB and GOD introduce a combination of features such as trajectory, speed, and periodic repetition associated with these elements. For example, clips from GOD contain the most features and greatest variety in attributes, which explains the higher cognitive load ranking. Clips from FAB also contain many features; however these clips apply a stationary camera.

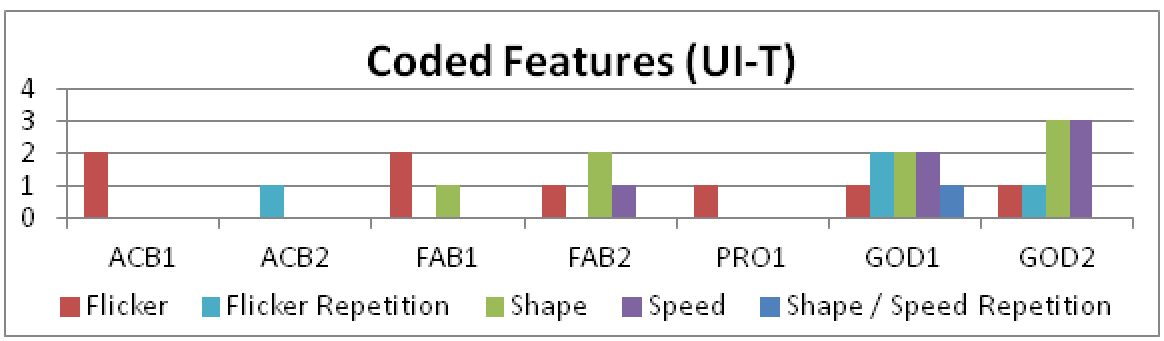


Figure 14: Number of coded features for UI-Targets per clip

The flicker, trajectory, and repetition features do not appear to contribute to the cognitive load rankings. It is still useful to point out different combinations in their usage between clips. For flicker, 11 of 17 instances were located on the user interface as a notification, and were thus localized to a small point on the screen. FAB, GOD, ACB are unique in flashing both the user interface target and target elements in the game, corresponding to the same action or event. By contrast, multiple elements in PRO flash, yet in relationship to different actions, which further supports the higher load ranking. In regard to the trajectory feature, the RATCH and GOD clips are unique in that multiple trajectory attributes received coding for fast and slow speed, with repetition.

5.3. Discussion

This chapter applied a perception-based framework to understand the relationships between elements in motion and cognitive load rankings of six commercial games. In accordance with the framework, nine attributes associated with four features of motion were coded in association with target and non-target element types. The results found the camera constraint and a combination of features contributed to the cognitive load rankings. Research questions 1 and 2 are discussed followed by guidelines.

In regard to research question 1 that considered the ecological validity of applying a perception based organizational framework, the distinction between target and non-target elements in association with features easily transfers into the context of a game. However, additional elements were added to this framework within the context of a game. Additional element types are needed due to their unique functions in the game. These elements include the user-interface targets, different types of non-targets based on relevant (i.e., visual feedback from control input) and irrelevant distractors, and the camera as a dynamic element that can globally influence the presentation of elements. The definition of these additional element types and inclusion into the analysis were necessary to understand the cognitive load rankings in research question 2.

In consideration of the applicability of this organizational framework, results surprisingly found most features coded in association with non-target elements in the game, rather than targets. As a means to establish a visual hierarchy, these features are often anchored in relationship to the target elements as distinct focal points, or spread across visual regions of the scene. While target elements are typically present in scenes, these were least frequently associated with the expressive features in question. As discussed in the coding example, one reason why targets were not coded more frequently is they were discernible by a different perceptual feature such as color, rather than motion. Another reason is due to their human-centric movement that did not fit within the organizational framework. Therefore the perception-based framework is most successful in evaluating environmental motion based on an abstraction of discrete elements, rather than human-centric motion.

Given application of the organizational framework into the context of a game, research question 2 found many relationships between the cognitive load rankings and perceptual features in association with game elements. Although coding found almost perfect agreement for features of motion, results found only one case where a combination of features affects the rankings. Video clips that contain multiple instances of fast speed, without any slow speed, supported the high load ranking results. Additional results depend on the stationary, tracking, or free camera constraint utilized. For example, fast speed associated with a combination of features is still perceived as low load given a stationary camera and a focal point. In another example, fast and slow speed with a tracking camera has lower load in comparison to a free camera with multiple elements with fast speed. This is due to distinct visual regions associated with the tracking camera that establish a visual hierarchy in the composition. This stability is easily lost in the free camera since the presentation of elements on screen changes moment to moment.

5.3.1. Guidelines

Based on the success of the perception-based organisational framework in six commercial games, the following three guidelines identify approaches to control the cognitive load.

1. Establish a visual hierarchy using focal points and visual regions. This is accomplished by organizing non-target features in relationship to target elements or into distinct visual regions of the screen. Establish a visual hierarchy in conjunction with a stationary or constrained camera to control the cognitive load. The organization of features persists on screen for a longer duration in time in comparison to a free camera. Although players have more freedom with the free

orienting camera, they demand additional cognitive load in their control as elements in focus can easily become lost with the wrong point of view.

2. Perceptual features are most frequently coded in association with non-target visual feedback or irrelevant distractions. Use contrasting features of motion to ignore or easily distinguish between these features and elements. For instance, consider a combination of select features, such as trajectory, speed, and rhythmic repetition, to establish a visual hierarchy.

3. Games look stale if too many elements are static and can easily overwhelm when all elements move at once. Since our visual system is wired to detect visual patterns, prioritize repeating, harmonic, and rhythmic motion when establishing a visual hierarchy.

5.3.2. Limitations

Limitations of the exploratory approach include the coding framework, cognitive load rankings, and difficulty controlling for confounding stimuli in commercial games. There are three limitations with the coding framework. The first is that many results depend on the camera constraint and few results found a relationship between combinations of features. Therefore, control of the camera constraint is necessary in order to study relationships between features in closer detail. Second, the framework does not account for additional perceptual features in the clips, which also may influence rankings. For instance, brightness and contrast, color, and camera lens effects, such as shaking or blurring, are excluded in the analysis. To this extent the impacts of game audio may also contribute to the rankings and should be controlled in a future investigation. Third, the manual process of coding features as categorical attributes is time consuming and this constraint limited the clip duration to 20 seconds. Typical game sessions last from a few minutes to several hours and therefore this approach is not scalable. These limitations can be addressed through the use of an experimental game.

Limitations of the cognitive load rankings include the brief clip duration evaluated. This constraint removed the period of play before or after the clip that may provide additional contextual or instructional information. The rankings are also limited since participants only viewed clips and did not interact with the games themselves. In other words participants did not have a measure of control in changing actions and events in the game in the pursuit of goals supporting their rankings. Future work can address these threats to validity by including self-reports of participants who played through a complete game session.

Evaluation of perceptual features is also challenging within the context of commercial games for several reasons. Each game contains a different set of elements, task rules and reward structures, and stylistic representations of elements. Evaluation is difficult as the player can execute multiple action plans in rapid succession, causing the system to dynamically change visual content on screen. These changes are hard to account for based on human observation on a moment-to-moment basis. Finally, it is also important to recognize stylistic differences between the games in this study. For example, games such as ACB and PRO present photorealistic renditions of elements, actions, and events while games RATCH and GOD exaggerate these effects. These stylistic differences evolve over time in support of training and habituating players' behaviors in the game in association with the rules and rewards. Once again, these changes could not be evaluated given the short clip duration.

Future work may consider an experimental game to address the topic in further detail. Experimental games allow a degree of control in the aforementioned confounding stimuli. For instance, features can easily be defined as scalar values rather than categorical attributes as this approach allows quantitative analysis. Given the success of the perception-based framework and in recognition of stylistic differences inherent in commercial games, formal guidelines should consider more abstract representations of elements.

5.4. Conclusions

This exploratory study applied a perception-based framework to investigate features of motion in association with game elements, in six commercial action adventure games. In application of this framework, additional elements were defined, including user interface targets, non-target irrelevant distractions, non-target visual feedback from players' interactions, and the camera element that can globally alter the presentation of game elements. Inter-rater agreement found almost perfect agreement in identifying the features of motion: flicker, trajectory (shape), speed, and repetition, in association with elements. However, investigation of cognitive load rankings required consideration of the camera constraint utilized. This perception-based analysis is a new approach to understand the visual design of games and results presented three guidelines to control the cognitive load. The results and limitations with this approach guided the development of the Chapter 6 EMOS experimental game.

6. *EMOS* Experimental Toolset and Game

This chapter discusses development of the EMOS experimental game, which stands for *Expressive MOtion Shooter*. The Chapter 5 Commercial Game Analysis found evidence that perceptual features influence participants' rankings of cognitive load. However, the guidelines are not empirically based and analysis within commercial games introduced a number of confounding factors besides features of motion that may contribute to this ranking. Most notably, the games differed in the use of camera constraints, rules, reward structures and interfaces supporting a range of tasks, thus limiting the analysis. Controlling these factors motivated application of a perceptual framework within the context of an experimental game. This chapter addresses the following two research questions in the development of the EMOS game:

1. **RQ1:** What kind of game and constraints are necessary in application of a perceptual framework in the development of an experimental game?

2. **RQ2:** What are the perceptual features of motion in the EMOS game and in what way can they change over time?

The following sections include a description of the EMOS game according to agile development methods.

6.1. Method

Agile software development methods [24] are used in developing the EMOS game. This method includes the following steps: concept, design, coding, asset creation, debugging, optimizing, tuning and polishing. Iteration of the EMOS toolset and game are discussed in line with these steps. All development occurred using the Unity 3D engine and a standard mouse control device. Development was completed in 2-3 months.

6.2. Results

6.2.1. Concept and Design

Development started by acquiring already completed Unity 3D first-person shooter games as a foundation for iteration. This approach appeared desirable since gameplay and polished art assets were already developed, including textured and well-lit 3D environments, animated characters, visual and atmospheric effects. The initial intent was to emulate the same genre of games found in the Chapter 5 Commercial Game Analysis, with the introduction of a new camera restraint. This inspiration came from the railed-shooter action game and genre. Railed shooters are well known in games such as *Virtual Cop* (Sega, 1994), *Rez* (Sega 2001), and *DeadSpace Extraction* (Electronic Arts 2009). As the name implies, the genre is well known for constraining the player's progress through the game along an imaginary rail. A large part of the game design in this genre consists of controlling the presentation of elements on screen. In other words, the player has no control of the camera so that the presentation of elements on screen remains the same.

The primary task and goal in railed-shooter games is to identify and click on enemy target elements in order to advance levels. The player advances through the game by successfully clicking on targets and ignoring any irrelevant distractions to reach this goal. This genre often includes secondary goals, for instance to collect ammunition, health, or points as an additional reward. This genre and goals therefore reinforce achievement and skill mastery as levels increase in task difficulty. In other words, the point and click task becomes more difficult over time as levels progress.

In the very first design iteration of the railed shooter version of the game, it quickly became clear the presentation of elements on screen was more difficult to control than expected. This is due to the changes in color, brightness and contrast, and motion that occur at once, in association with target and non-target elements. Given this complexity, theses games were essentially scrapped, and the EMOS railed-shooter prototype was built from scratch. A total of four design decisions guided the subsequent steps in development in regard to integrating a toolset into EMOS. The design decisions address the many possible approaches to apply a perceptual framework in association with a combination of game elements.

1. All visual features in the game are controllable using the toolset. Since this is a railed-shooter game, particular emphasis is on perceptual features associated with both target and non-target elements. Subsequently, the user interface targets do not link to any feature of motion as a means to constrain the amount of controllable features in the toolset.

2. Target and non-target elements share many of the same perceptual features. The features chosen during this step include *speed*, *size*, and *density* of elements in motion. Speed and density of elements (amount on screen) were discussed in the Chapter 5 Commercial Game Analysis. Speed is chosen since the speed elements move affects the task difficulty in this genre of game. The density of elements on screen is another aspect to consider as clips contained different amounts of elements in Chapter 5. Since this is a target shooting game, element size is included as a new feature.

3. Target and non-target elements move in a common group, coinciding with the Gestalt principle of common fate [173]. The trajectories of motion that elements follow were informed by the trajectories and shape in Chapter 5, the constrained trajectories that elements follow include *circular*, *expansion*, and *linear* motion, shown in Figure 15.

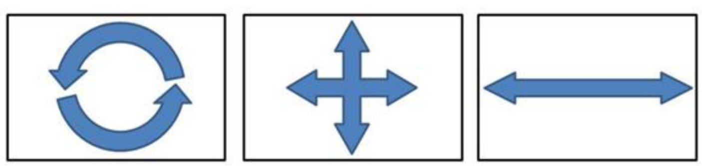


Figure 15: Circle, expansion, and linear trajectories of motion

4. The rules associated with the task and goals of the game remain fixed. For example new game functions like shooting weapons or enemy defenses are excluded. This design choice introduced undesirable task repetition and monotony to the game. Commercial games mask task repetition by allowing

multiple tasks to be executed at once through multiple control inputs. This complexity far exceeded the scope of the EMOS game, so providing rest breaks and alternating the trajectories of motion was found to be a good remedy.

6.2.2. Coding

This section defines the game structure, elements associated with features in the game, and the toolset to manipulate features within this structure. The general structure of the game consists of the simple targeting task as outlined above, in association with two goals. The targeting task consists of two mouse control inputs. The first is to accurately position the mouse cursor on top of moving targets and the second is to mouse-click while the cursor is positioned on top of moving targets. The goals in the game include a level advancement and point acquisition goal. To accomplish the level advancement goal; users must click on two boss target elements *twice* in order to advance to the next level. Players can optionally pursue a secondary point acquisition goal and increase the score by clicking on minion target elements *once*. The game contains a simple interface located on the bottom of the screen, shown in Figure 17. The interface displays a stop button, the number of targets shot, the number of points, and a countdown level timer.

As stated previously, all features associated with the game elements can be manipulated in the toolset. The elements include the boss and minion targets discussed previously, and four non-target elements. Two of the non-target elements correspond to visual stimuli as feedback of players' interactions in support of the task and goal. The feedback identifies when a shot is fired, and when a boss or minion target is shot. The remaining two non-target elements are irrelevant ambient and ring distractors. These six elements are associated with up to three perceptual features, shown in Table 3. Boss targets (T-B), minion targets (T-M), and ambient non-targets (NT-A) are adjustable by *speed*, *size*, and *density* features, respectively. Once again, these three elements always move in a group along the same trajectory of motion. The game contains no background environment geometry as discussed in more detail in the asset creation section. The background is replaced by non-target geometric rings, controlled by *speed*.

The movement of rings abstracted a sense of movement through an environment. *Size* is the only feature associated with the non-target visual feedback spark (NT-S) and explosion (NT-E) elements.

Table 3: Element Variable Key

Element		Name	Feature
(T) Target	T-B	Boss	speed, size, density
	T-M	Minion	speed, size, density
(NT) Non-Target	NT-A	Ambient	speed, size, density
	NT-R	Ring	speed
	NT-E NT-S	Visual Feedback Explosion Visual Feedback Sparks	size

A diagram of the game structure is shown in Figure 16. In order to mask the task repetition, one complete game session includes 15 levels in three fixed trajectories of motion. Levels 1-5, 6-10, and 11-15 correspond to block 1 circular, block 2 expansion, and block 3 linear trajectories of motion, respectively. The trajectory ordering is fixed within the game structure to preserve the same beginning, middle, and end sequence of levels. As trajectories switch in levels 5-6 and 10-11, the game includes a two-second cut-scene that allows a break in the rapid clicking targeting task. All trajectories are periodic as elements are in continuous movement and loop indefinitely. The circular trajectory moves elements along the screen-periphery in a counter-clockwise circular rotation. In the expansion trajectory, elements are positioned in the centre of the screen and move outwards, towards the screen periphery. These elements also move along the Z-axis towards the camera to enhance the expansion effect. Once these elements move off-screen, they re-position back in the screen centre. Finally, the linear trajectory is the circular trajectory viewed from the side. In this case, elements move horizontally on screen in a linear direction, from the left to right screen edges. The expansion and linear trajectories are unique in that elements move into the foreground and background of the scene, thus target speed and size also change relative to the camera position. A screenshot from each trajectory is shown in Figures 17-19.

cut scene

EMOS Level Structure														
Block 1 *Circle*					Block 2 *Expansion*					Block 3 *Linear*				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Figure 16: Diagram of EMOS Game Structure

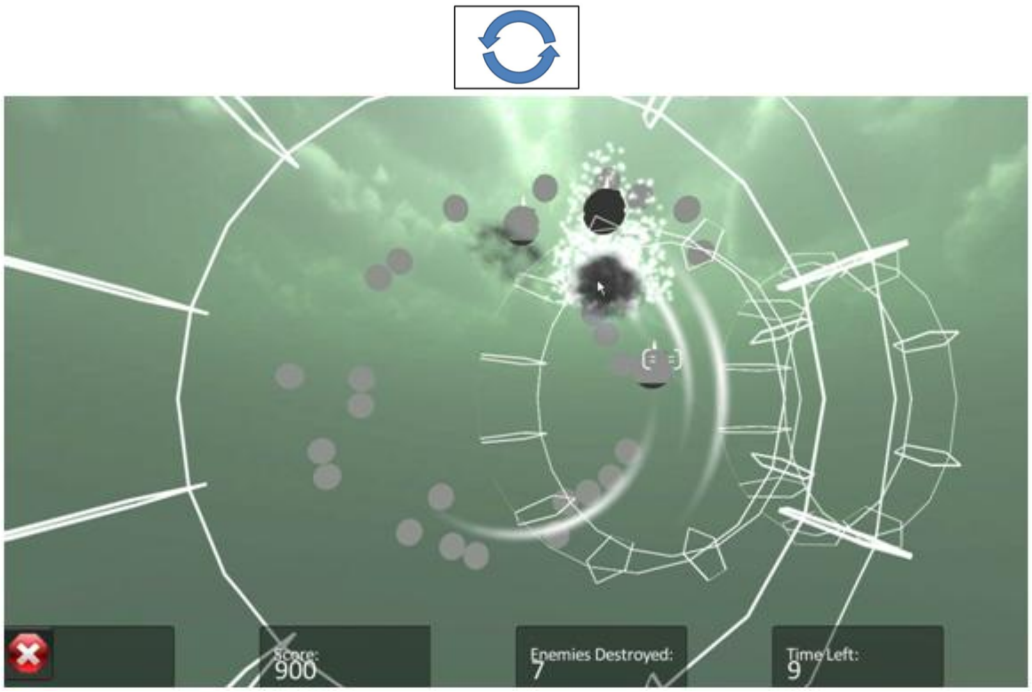


Figure 17: Circular trajectory

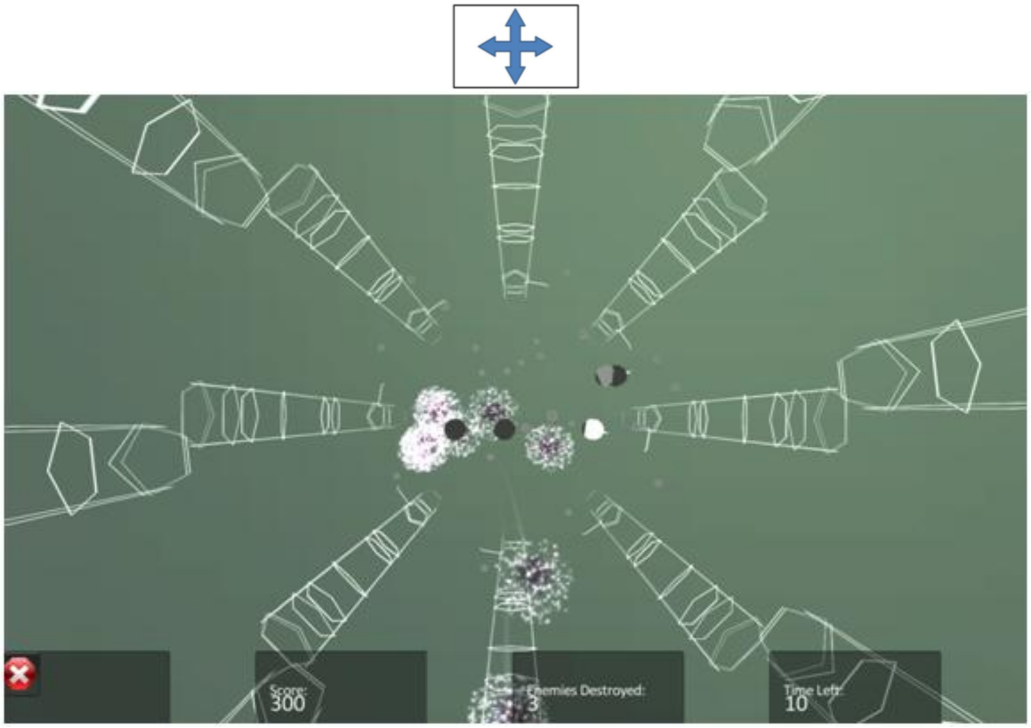


Figure 18: Expansion trajectory

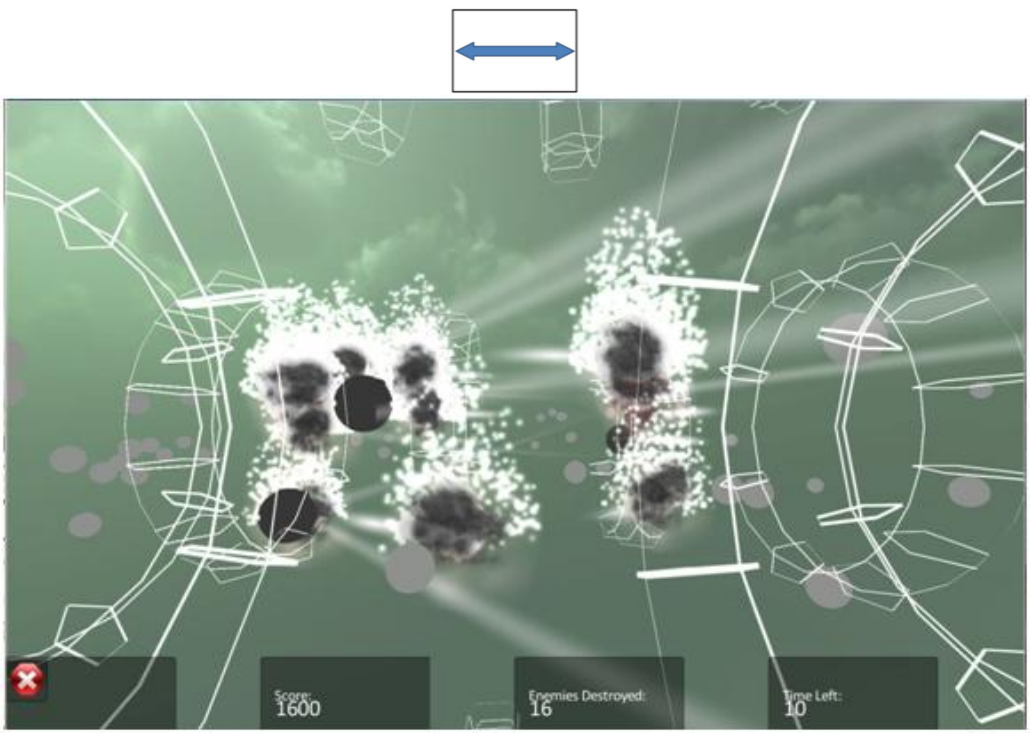


Figure 19: Linear trajectory

The toolset consists of a pop-up user interface that exposes speed, size, and density features in association with all six elements, for each level of the game. In total, 11 features can independently change for all elements. In other words, each level may contain a unique appearance of game elements, yet the level order is always the same. A screenshot of the toolset is shown in Figure 20. The 15 tabs on top of the interface correspond to each level. Within each tab, horizontal sliders allow the user to independently manipulate each feature. Screenshots of how game elements visibly change using the toolset are shown in Figure 21. The left image shows small element size and the image on the right shows a large size, including large explosion size.

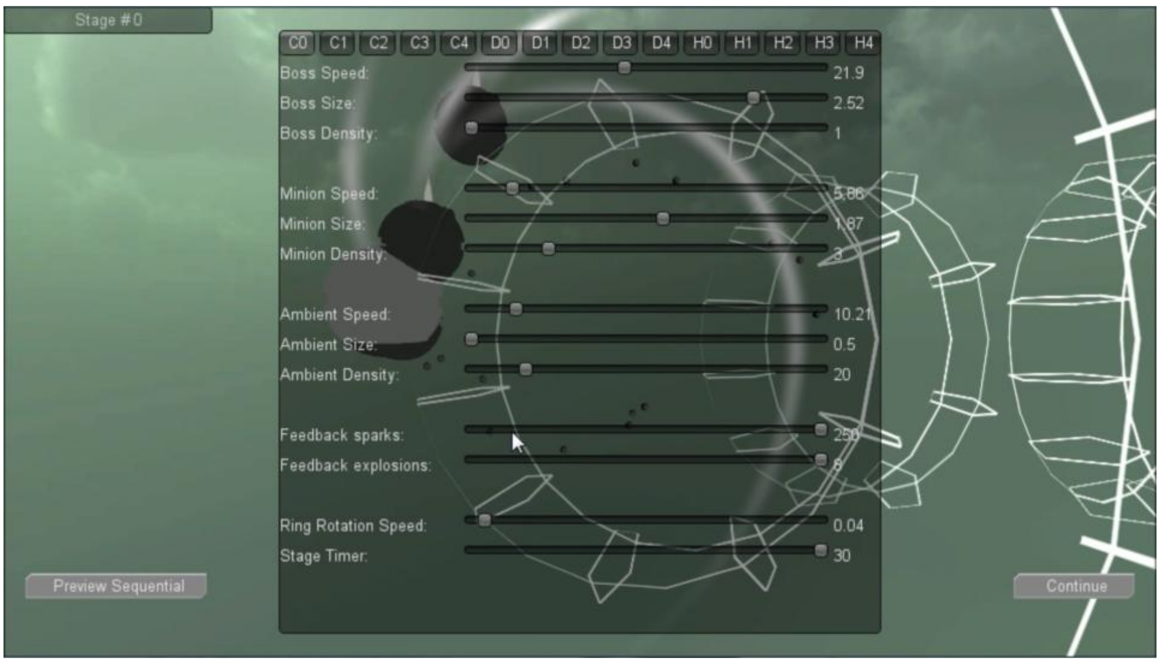


Figure 20: EMOS Toolset Interface

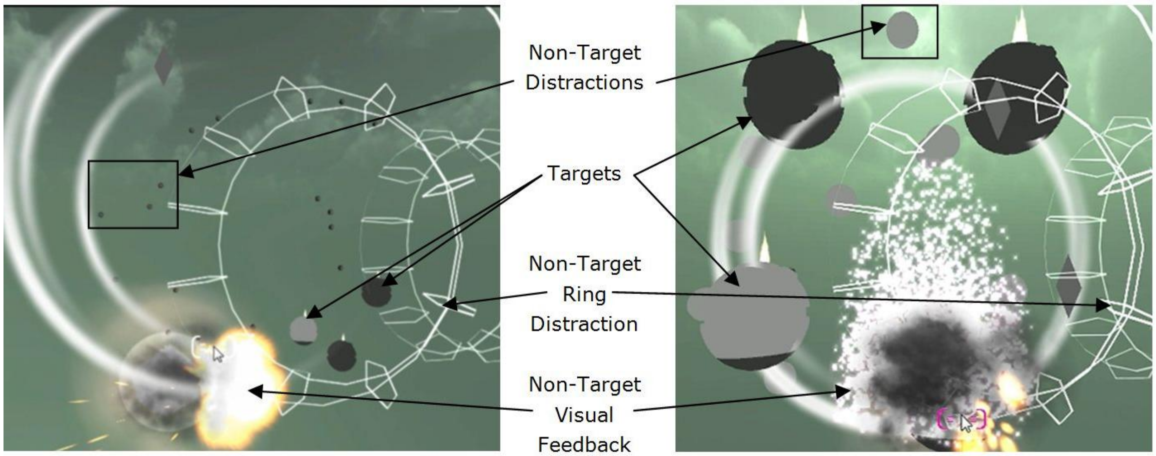


Figure 21: Toolset adaptation of game elements

Early versions of the EMOS game included a dual targeting task, where boss targets shoot missiles for additional reward. However, this task and associated elements were later removed since features associated with the boss missile elements were not exposed and controllable via the toolset. At this point in development, the toolset already contained 11 changeable features per level, so no additional features were included to keep the scope of manipulating perceptual features simple and manageable.

6.2.3. Asset Creation

As stated initially, the early EMOS prototypes included a rich set of game assets, such as the player avatar, navigation obstacles, level geometry containing non-photorealistic built environments, and terrain. Many of these assets are activated by core game play, actions and events, such as multiple weapon types with different targeting capabilities (e.g., accuracy, range, ammunition, reload, etc.) or different types of enemy defences. The early prototypes identified too many perceptual artifacts associated with these elements that needed to be controlled by a more advanced toolset. These assets were removed in order to focus on a greater variety of changes in fewer features and elements, in association with one targeting task and ordered sequence of levels.

To maximize the utility of a perception-based framework the target and non-target elements in the final game were replaced by simple geometric shapes. These elements were monochromatic in color and shaded without shadow. The decision to work with only primitive shapes, with features of motion the most expressive quality, gave the game an abstract appearance. This style is reminiscent of a Space Invaders art style. Basic sound effects were added to support this style, including ambient, laser (on mouse click), explosion on enemy death, and a cut-scene transition sound.

6.2.4. Optimizing, Tuning, and Debugging

The optimization step includes setting up instrumentation to collect data, toolset modalities to support the process of iterative design, and additional simplification of the game structure. Instrumentation in the game includes automatic saving of the feature values, for each level, as users interact with the tool. Users can independently manipulate each feature for any level in any order; the EMOS continuously saves these settings as a data file associated with each game session.

Two additional modalities were included to support the iterative process of design. The first includes a copy/snapshot button that allows independent manipulations of 11 features from one level to be copied to a different level. The ability to copy multiple features at once allows the user to quickly propagate selections across levels, while still allowing individual changes to specific features if necessary. The second modality is a play mode to preview the game selections. In play mode, the toolset is hidden from view and the complete game can be played. Switching between the toolset and play mode supports the iterative design process as users can quickly playtest creations and refine selections in the toolset mode if necessary.

Additional game structures were removed in the game for simplicity since the focus is on the manipulation of perceptual features in relationship to a targeting task. For instance, players do not have health or ammunition resources to collect or manage in the game. In other words, players cannot restart the game due to poor performance as they have unlimited shooting and health. Similarly, there is no additional positive reward or punishment in the game associated with the task or goal that can influence the player’s perceptions in the game. The levels automatically advance after a preset period of time if the boss targets are not shot fast enough.

6.3. Discussion

This chapter documented the development of the EMOS experimental toolset and game within the context of a well-known game genre. Design iteration and agile methods are used in application of a perception-based framework to a game, and exposing multiple features via a toolset. In regard to the first research question, EMOS is a railed shooter action game that required several constraints in order to focus on features of motion. This genre is well known for constraining the camera, yet addition steps were taken to focus on a simple targeting task, and a game structure that requires few elements. Additional constraints were needed for the purposes of an experimental game such as the removal of art assets and common game play elements found in this genre. This removal was necessary to minimize the amount of perceptual features that could be manipulated. To this extent, many elements are removed unrelated to the task, such as resource management, and additional penalty or reward in the game. The intent behind these constraints allows a user to manipulate features associated with the target task, with many shared features with non-target elements. The removals of these elements are limiting factors and acknowledged further in the limitations section.

In response to research question 2 regarding the exposed features in the game; the EMOS toolset allows *speed, size*, and *density* features to change for six elements in continuous motion. The toolset is embedded into the game structure comprised of 15 levels, which allows 11 instances of these features to independently change over time, on a per level basis. This approach allows a wide range in possible manipulations of features in association with target and non-target elements over time, for each game session. Three additional features are fixed to add visual variety to the task, including *circular, expansion,* and *linear* motion. The trajectories break the task monotony, as they change in five-level increments, by varying the movement of elements on screen, without altering the rules of the game.

Additional instrumentation and optimizations of the toolset were necessary during development. Any manipulation of features by the user is automatically saved as an external file for later quantitative analysis. Optimizations to the toolset were needed to support the iterative process of design by the user, including a copy and paste feature from one level to another to streamline the process of manipulating only specific features, and a play mode to preview the final game.

6.3.1. Limitations

Limitations in developing the EMOS game include a lack of feedback with expert designers and abstract art style in the game. During the iterative process, the researcher made several design choices to constrain and control the visual stimuli on screen with the intention of running experiments. These choices did not receive feedback from expert designers regarding the selection of features, game task and structure, or consequences of removing elements from the game. Future work discussed in Chapter 10 can incorporate experts into this decision-making process, for instance to assist in the selection of different features of motion. Unfortunately, the designer's ability to contribute time was very limited and could not be involved in this development step.

The EMOS game took additional steps to remove polished art assets and common game structures also found in the genre that were not part of the toolset and core game mechanics. This choice may degrade the quality of the player's experience. Over the course of multiple iterations, the game became more abstract in appearance as characters and environments were replaced by primitive geometric shapes and monochromatic colors. Game development dedicates enormous time and resources to polishing these visual assets during testing and in the final product. Development of EMOS reversed this process by proactively stripping away polish and removing stylistic or thematic elements as a means to focus on features of motion associated with a small set of elements found in this genre. This approach is best suited to an early prototype in a game development setting, for instance as a gray box prototype.

6.4. Conclusions

This chapter documented the development of the EMOS experimental toolset and game. The goal behind development is threefold; first to select a simple and well-known railed shooter genre that can benefit from perceptual guidelines for elements in motion; second, to embed a toolset into this game structure that allows manipulation of common perceptual features found in this genre; and third, to set up instrumentation allowing features to be manipulated, previewed, and saved for later quantitative analysis. The features selected include *speed, size*, and *density*, in association with six game elements that can independently change across 15 levels. The game also includes three fixed trajectories of motion that elements follow, including *circular, expansion*, and *linear* motion. For experimental purposes in preparations for chapters 7 and 9, controlling the visual stimuli on screen became an important issue. Therefore many art assets, game structures, and reinforcement feedback disconnected from the task itself are removed.

7. Study 2: Designer Study

As discussed in Chapter 4, the research interest is to identify guidelines for elements in motion within the context of a game, informed by a theory of visual perception. In order to address this question, a tool was developed based on exploratory and agile software methodologies, as described in Chapter 6. The tool includes instruments to collect designers' choices on how perceptual features of game elements change over time. Designers intended effects on the player's experience is a necessary first step in identifying perception-based guidelines, defined in Chapter 8, and formally evaluated in the Chapter 9 Player Study. The focus of this chapter is to understand designers' insights, based on quantitative and qualitative analysis of the results, formulated in the following research question:

1. **RQ1:** In what way do designers change perceptual features over time using the EMOS toolset?

Two assumptions are bound with this question. Since the genre of the game and goal reinforce achievement and skill mastery, the first assumption is that perceptual features change to increase difficulty over time. The second assumption is that designers use some tacit knowledge to manipulate features as these changes affect the perception of elements. However, which features change and their direction of change are unknown. The following sections outline the methods, including recruitment, study design, data collection and analysis.

7.1. Method

7.1.1. Apparatus and Experiment Setup

The apparatus includes the EMOS toolset and game discussed in detail in Chapter 6. In summary, the game includes one targeting task associated with two goals. The primary goal is to advance levels by shooting two boss targets twice. The secondary goal is to acquire points to increase score by shooting a minion target once. In total there are 15 levels per game. The structure of each game is divided into three 5-level blocks, separated by two cut scenes. Blocks 1-3 change the trajectories of motion that elements follow (i.e. these elements move as a group) that coincide with the circular, expansion, and linear trajectories of motion, respectively. Designers could not manipulate these fixed features. The cut scenes allow a two second break in the targeting task. The game includes additional constraints and fixed features in order to investigate elements in motion. The most obvious fixed constraints are the monochromatic coloring of elements, static illumination without shadow, and abstract appearance as elements, represented as simple geometric shapes. The player avatar is also removed due to element occlusion, and replaced with a user-interface cursor.

The experimental setup consists of designers interacting with an online version the EMOS toolset. They could independently manipulate 11 instances of the speed, size and density features, in association with six game elements, shown in Table 4. From the table, three instances of speed, size, and density features independently change for the boss and minion targets (TB and TM) and ambient non-targets (NTA) elements. The non-target ring, visual feedback sparks, and explosions are adjustable by speed and size, respectively. The choice of these features was already discussed in Chapter 6.

Table 4: Features associated with Game Elements

Element		Name	feature
(T) Target	T-B	Boss	speed, size, density
	T-M	Minion	speed, size, density
(NT) Non-Target	NT-A	Ambient	speed, size, density
	NT-R	Ring	speed

	NT-E	Visual Feedback Explosion	size
	NT-S	Visual Feedback Sparks	

7.1.2. Task

The task given to designers was to interact with the online tool and manipulate features over time to produce two games: one suitable for a novice and the other for an expert player. This task took approximately one hour. The structure of the game 1 and 2 are shown in Figure 22. This goal required designers to consider what features change or remain fixed over time, suitable for inexperienced or experienced players. As previously stated one assumption with the goal given to designers is that difficulty increases from novice to expert levels of difficulty.

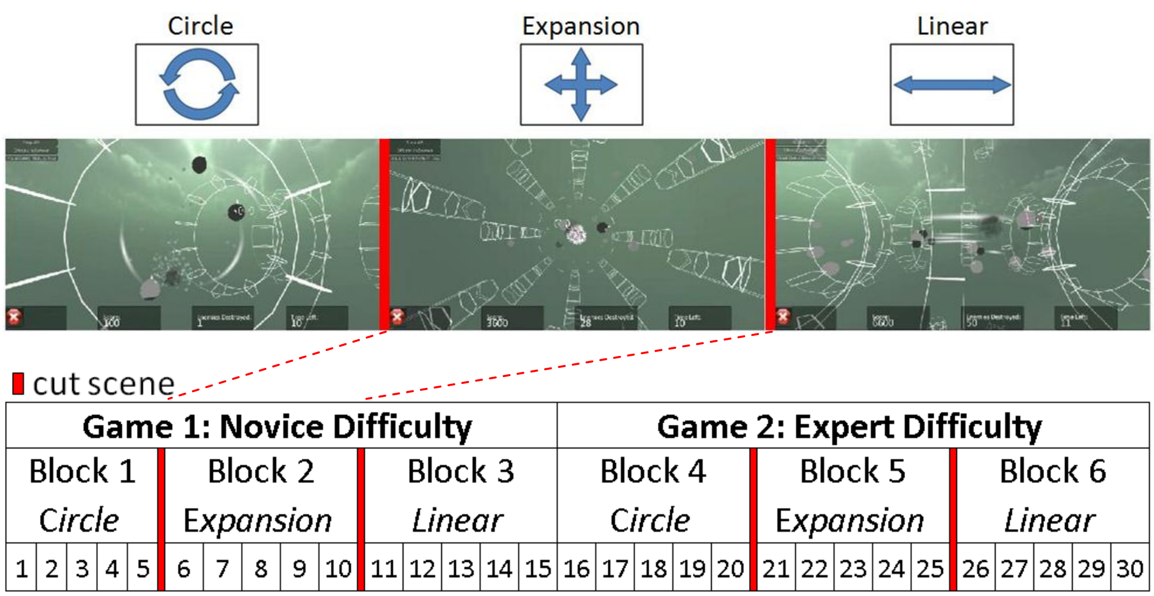


Figure 22: Study procedure and structure of game 1 and 2

7.1.3. Recruitment and Participants

Experts were recruited through a network of game user researchers and related professional groups in the game design industry. Recruitment occurred through the game user research e-mail announcements. Over the span of five weeks, 110 experts were contacted, and eight participated in the study. Recruitment included a web link to a three minute video introduction[3] to the problem of visual overload in games and includes several examples in commercial games. The video also introduces the EMOS toolset and process of manipulating features to change the appearance of game elements, discussed in detail in Chapter 6.

The backgrounds of the eight designers that participated are shown in Table 5. The researcher screened each designer to make sure each had published at least one game online, with most working in the game industry for several years. The table shows the title / role for each participant and years of experience. The experience includes a range of expertise in game development in addition to design, such as art direction, programming, technical design, visual effects, and user experience. It is important to note that all members of a development team contribute to the game design, and not just the game designer. Additionally, each company defines a design role differently. Four IDs develop games independently and the rest were employed in large companies such as Bungie, Valve, Ubisoft, or Warner Brothers Games. ID 7 was interviewed in person during the data collection and compensated given a background in user experience (psychology) and games for companies such as Electronic Arts and Disney.

Table 5: Expert background

ID	Title / Role	Experience (years)
01	Associate Artist	5
02	Programmer	1
03	Technical Design	3
04	Technical Artist	10
05	Game Design	10
06	Visual Effects Producer	20
07	UX / Game Design	17
08	Animator	5

[3] Video introduction: http://www.youtube.com/watch?v=lVsG26_0wfQ

7.1.4. Study Design

The study design consists of a within-subject design for the eight designers that manipulated features using the toolset in two game sessions. Included in the study design is qualitative expert review by expert game designers.

7.1.5. Data Collection

Data collection includes four phases that employ mixed methods. The first phase includes an e-mail submission to the researcher of the quantitative data of designers' manipulations using the toolset. Phases 2-4 include qualitative feedback at three points in time, phase 2 is at the same time as the phase 1 data submission, phase 3 is a verification step upon reviewing a personalized summary of designers' selections, and phase 4 is during the player study discussed in Chapter 9. With the exception of ID 7 that interacted with the tool in person, all communication with designers in phases 1-3 occurred remotely through e-mail conversation. The three designers that participated in phase 4 were interviewed in person. Each phase is introduced in more detail next.

In phase 1, the designers manipulated features on a per level basis or per block basis. As designers interacted with the toolset, their selections were saved automatically. Features left untouched preserve the default value and are included into the final data submission. Once finished, designers e-mailed two data configuration files back to the researcher. Each file contained 165 data points (11 variables as changeable features across 15 levels).

Qualitative feedback was collected from this point forward, in phases 2-4. During the time of data submission at the end of phase 1, designers responded to two open-ended questions in phase 2 to better understand the insights behind their choices.

1. What are important preferences or trends in manipulating features using the toolset?
2. What are limitations of the toolset?

Phase 3 is a verification step and started after all responses to phase 2 were received. In other words, five weeks passed before the summary was returned to ID 1, and one week passed for ID 8. In phase 3, the researcher emailed a one-page visualization summary of the designer's selections. The visualization consists of 11 line charts; each chart traces the value of one feature across 30 levels, coinciding with the two games produced. Each chart includes two measurements, the first is the individual designer's manipulation of each feature and the second is a group average from all designers. Included with the visualization summary, the researcher highlighted features that appear to change over time and whether a similar pattern of change is found for a combination of features. An example of the verification step is shown in Appendix A. In e-mail form, all designers verified the accuracy of their selections based from the visualization summary.

All designers that participated in phases 1-3 were invited to participate in phase 4. This phase took place approximately 2-3 months later, during the Chapter 9 Player Study data analysis step. Three designers participated in this phase (ID 1, 4, and 7) and were interviewed in person. Each conversation lasted two hours and the verbal recording was transcribed in preparation for qualitative textual analysis. The goal of this interview addressed changing features over time and their effects on the player's experience; however, designers also expanded upon earlier remarks to the phase 2 open-ended questions, so these remarks are included in this chapter.

7.1.6. Data Analysis

The quantitative data collected in phase 1 was organized in two ways:

1. **15 Level Analysis** that constitutes one complete game submission.
2. **30 Level Analysis** that combines two complete games. This analysis is necessary since designers did not change all features within one game submission.

The data collected from each designer is merged into a single data set and then analyzed using a two-way between-subject bivariate correlation. This analysis method finds the strongest and most frequent manipulation of features over time across all IDs. This method produces two outputs: Pearson’s correlation coefficient and significance result of the strength of the relationship. Pearson’s coefficient is a measure of linear association between two features in the game. Positive coefficients identify a relationship between features that either increase or decrease as a group over time. A negative correlation identifies a relationship where one feature increases as the other decreases over time. Given each correlation found, the number of designers that manipulated both features can be determined.

Qualitative data collected in phases 2-4 went through textual and inter-rater agreement analysis for seven designers. ID 6 is excluded since this ID only verified selections without additional qualitative remarks. Designers’ comments collected from phase 2 question 1 went through an inter-rater step. This step identified important phrases and passages in the conversation with designers along five common themes. The most frequently occurring themes address implications of changing *individual* features or *multiple combinations* of features in association with specific game elements. Organization of the remaining themes are then associated to one of these two themes. Changing individual features includes designers’ comments to balance the visual or game difficulty. Changing a combination of features includes designers’ comments to support training and learning and ramping difficulty (increasing and decreasing a combination of features simultaneously). The phase 1 quantitative analysis is included with the theme regarding changes to a combination of features. The phase 3 verification step corresponds with both organizing themes.

A total of 205 codes were found for the five themes. Cohen's kappa statistic is used as a measure of inter-rater reliability and found almost perfect agreement in these codes (kappa = .856). Open-ended feedback regarding the limitations of the study, phase 2 question 2, is included in the limitations section.

7.2. Results

7.2.1. Effects of Individual Motion Features

Change in Individual Features

According to designers, an increase or decrease in speed, size, and density features in question has multiple intended perceptual effects. These effects depend on whether features change in association with target or non-target elements, thereby influencing the ease of the targeting task (perceiving, moving and clicking the mouse) or ignoring distractions, respectively. In regard to the target elements, increasing speed or decreasing size makes targets *harder* to shoot and the level advancement goal therefore becomes harder, as discussed by seven designers. The opposite is also true, where decreasing target speed or increasing size makes the targeting task easier. The density feature is more complex as the rules associated with boss and minion target elements are different. Although increasing boss target density makes targeting easier, as there are more bosses to shoot on screen, the level advancement goal is *harder* as the rules dictate the same boss target must be shot *twice* in order to advance levels. In this case the level advancement goal is harder as density increases for boss targets since these elements are in continuous motion. This requires the player to visually track, precisely position the mouse cursor, and rapidly fire at the right time to successfully hit the boss targets. Six of the eight designers address increasing boss density as a method to increase difficulty in this way.

By contrast, minion targets only require one shot, so increasing minion density makes the targeting task and the goal to acquire points *easier*. The one-shot rule requires less tracking and precision, and enhances the player's efficiency in shoot targets as greater amounts appear on screen. However, increasing density for minion targets is nevertheless a *distraction* as this makes the boss targeting task and level advancement goal *harder*. This subtle difference in boss and minion game function was only clarified by ID 3 and not addressed by IDs 1 and 8. The remaining four IDs (2, 4, 5, and 7) did not distinguish between boss and minion targets and did not address the point acquisition goal during phase 2-4. Consistent with designers' earlier remarks, increasing minion density is viewed as making the boss targeting task and level advancement goal *harder*.

In regard to non-target elements, designers were unanimous in that increasing speed, size, or density makes ignoring distractions harder as this adds irrelevant noise into the scene. As a consequence of this, the targeting task also becomes harder. An obvious example of this in ID 1 and 7, is the possibility of “motion sickness” or “vertigo” in reference to the speed of non-target rings. Consistent with designers’ views in balancing visual and game difficulty, ID 1, 2, 3 and 5 preferred the least intrusive and infrequently changing features associated with ambient and visual feedback non-target elements. As stated previously, the intent is to enhance the visibility of targets in support of targeting, and to make the non-targets easy to ignore. To this extent, these designers described the non-targets as “negligible”, “ancillary”, and should be “filtered out”.

Although trajectory is a fixed feature in the game, four designers (ID 1, 2, 4, and 7) discussed the manipulation of features and difficulty in relationship to trajectory. ID 1 and 2, discussed changing targeting and ignoring distraction strategies as players must “compensate” for changing “predictability” and “patterns” of element movement in each trajectory. In the circle and linear trajectories, ID 1 described the movement of non-target rings as “fighting for the player’s attention”, “in conflict with the movement of targets”, and “difficult to ignore” as rings visually overlap targets as they move from the foreground to the background of the scene. ID1 and 4 viewed these visual patterns of movement as a “puzzle” in what elements to ignore, and identified strategies to improve targeting efficiency. For instance, ID 1 stated “I may track an element around the circle attempting to click on it”, however, would switch strategies in high physical demand to retain control of one segment of the target’s circular path. This response is similar to ID 4, “as a player, I want to play as efficiently as possible [...] I kept the mouse cursor stationary and waited for the targets to come around (back to the same point). I waited in my little window…wait and click. I would not really follow them around. You had enough time left where it was inconsequential if you missed one.”

In the expansion trajectory by contrast, the ring non-targets are located on the screen periphery and remain in the background. The rings appear less distracting in this trajectory for ID 1 since they do not overlap targets, and because targets appear in the centre of the screen. For these reasons, ID 1 perceived this trajectory to be “aesthetically pleasing”, with rings that are “visually complementing“, “never in your face” as they “frame the targets”, and “communicate to players that the center of the screen is the most important”. However, designer ID 2, 4 and 7 commented on difficulty shooting due to the recycling (i.e., re-spawning) target position and parallax effects as elements move towards the camera. With regard to elements recycling position from the screen centre to the edge, ID 4 found this undesirable: “you can stay fixated on a target when it is just moving in a circle or side to side […] however the further the target is from the center of the screen, the more difficult it is to track”. ID 4 discussed compensating to more efficiently accomplish the targeting task: “what I was doing when I was playing, is to keep my mouse closer towards the center of the screen and then click on every element that I could reach quickly enough, instead of tracking them all the way out.” With regard to parallax effects of elements moving towards the camera, ID 2 and 7 commented that size and speed of elements change, even when locking these features in the toolset. ID 7 considered these perceptual changes as an additional burden since players are “not quite as accustomed to elements coming right at you”. As a remedy, ID 7 suggested moving targets further away from the camera, which makes them appear to move slower, to allow players more time and chances for success in the targeting task.

Features that appear to change in the linear trajectory were again addressed by ID 2 and 4. Even with a fixed target speed and size in the toolset, the angular speed and size change as elements move closer to the camera and further from the screen centre. This gives the appearance of elements changing size, slowing down and speeding up. ID 2 perceived this to be a burden on players as they must again compensate in targeting. Since the trajectory and pattern of movement is predictable, ID 4 considered the path with slowest speed (towards the screen edge) as a more efficient targeting strategy, given the precise positioning of the mouse cursor, and timing of mouse clicks.

Balancing Difficulty

Designers discussed the visual design as an extension to the game design. All designers articulated the need for clearly visible targets since EMOS is a target shooting game, among non-targets that could easily be ignored. ID 7 succinctly described this relationship as a mental decision-making process that “players have to identify and distinguish between target and non-target elements”. For ID 7 this required “focusing more” on targets and “working harder” to maintain this focus as distractions increase over time. Distinguishing between elements is really *two* visual tasks that occur in parallel, first is to visually track and shoot at the boss or minion targets as these are linked to the level advancement or point acquisition goals, referred to as *targeting*, while the second task is to *ignore irrelevant distractions*. The ability for designers to conceptually distinguish and prioritize between element types often came before a more exhaustive discussion of perceptual features associated with elements, or how features change over time. For instance, ID 1 stated “once you know what these elements are in level 1 [referring to the target elements], these elements are all you look out for and the rest of the stuff is just stuff, they don’t really matter anymore [referring to non-target irrelevant distractions to ignore]”. Consistent with this reasoning, ID 3 agreed non-targets “may technically make things more difficult”, however preferred that they appear “least distracting“, “never change”, and are “easy to ignore” as players would “want these constant”. ID 2 did not want to “confuse players” with an additional challenge to ignore irrelevant non-targets as it “may hide important gameplay objects”.

7.2.2. Change in a Combination of Motion Features

The correlation results allow further insight into changes between a combination features in relationship to elements. Qualitative analysis is included in this analysis where appropriate and general qualitative remarks included at the end of this section. Figures 23-24 summarize the correlation results in the form of correlation matrices, which contain the 15, or 30 level analyses. Each matrix represents a combination of only two features in relationship to the elements in the game that allow manipulation of that feature. For instance in figure 3, the top 3 X 3 matrix is for density, and the 4 X 4 matrix below is for speed, since these features can be manipulated by three and four elements, respectively. Annotations for each cell in the matrix correspond to the element: boss (B) or minion (M) targets, ambient (A), ring (R), explosion (E) or spark (S) non-target elements. The blue and red color-coding of each matrix cell represents the positive or negative correlation coefficient, respectively. Dark blue or red signify high significance ($p < .01$) while light blue or red are significant ($p < .05$). White cells represent the same variable or no correlation.

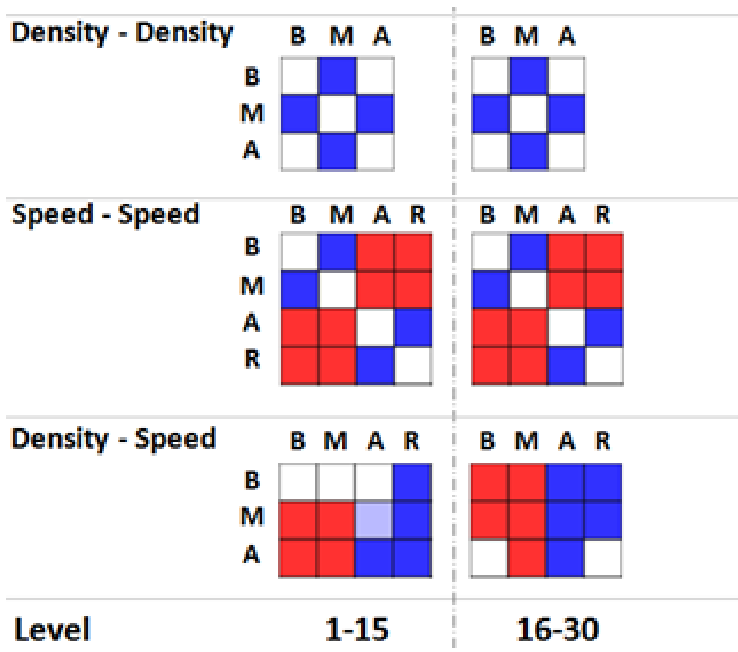


Figure 23: Correlation Matrix 1: 15 level analysis

The following is a summary of the 23 correlations found, based on a total of 141 individual correlations. Organization of the correlations is by feature and results identify the positive or negative correlation (+corr or –corr), along with elements and features in subscript. Positive correlations signify a constant delta, whereby both features either increase or decrease over time. Negative correlation results include an increasing delta (↑Δ); that is one feature decreases while the other increases (i.e., increase in similarity or dissimilarity). Each result includes the intended perceptual effect to make the goal easier or harder and the number of contributing IDs in at least one case for levels 1-30.

The following is a summary of the 23 correlations found, organized by feature, based on a total of 141 individual correlations. Each result found includes the contributing IDs, in at least one case, in levels 1-30. General results identify the positive or negative correlation (+corr or –corr), along with elements and features in subscript. The delta measure is used to clarify the direction of change between the two features in question. Positive correlations signify a constant delta where two features change together with no increasing or decreasing gap between their values. Negative correlations identify situations where one feature decreases as the other increases. A negative correlation can either signify a decreasing (↓Δ) delta (features become more similar) or an increasing (↑Δ) delta (features become more dissimilar).

Density-Density

1. **+Corr (T-B$_{DEN}$, T-M$_{DEN}$)** constant Δ: *Increasing* for 4 IDs (1,2,4,5) making the level advancement goal *harder*.

2. **+Corr (T-M$_{DEN}$, NT-A$_{DEN}$)** constant Δ: *Increasing* for 2 IDs (4 and 6) making the level advancement goal *harder.*

The first correlation asserts that density increases for boss and minion targets. This implicates how many targets the participant sees, and as noted previously, makes level advancement harder as the amount increases. This process was described by ID 5 as "introducing more enemies, beginning with minions and occasional boss number increases." The second correlation is for density between minion targets and ambient non-targets (NT-A). This result was found for ID 4 and 6 only. As mentioned previously, ID 6 did not provide additional qualitative feedback to support this finding and ID 4 did not distinguish between boss and minion target density in relationship to ambient non-target density. Based on the previous section, the intention is to make the level advancement goal harder by increasing distractions.

Speed-Speed

3. **+Corr (T-B$_{SPD}$, T-M$_{SPD}$) constant Δ**↓: *Decreasing* for 7 of 8 IDs, except ID 8. This makes the level advancement and point acquisition goals *easier.* ID 8 *increased* speed.

4. **+Corr (NT-A$_{SPD}$, NT-R$_{SPD}$) constant Δ**↑: *Increasing* for 2 IDs (7 and 8) and making the level advancement goal *harder.*

5. **-Corr ($T\text{-}B_{SPD}$, $NT\text{-}A_{SPD}$) $\Delta\downarrow$**: *Decreasing* delta for 3 IDs (2, 4, 7, and 8). This makes the level advancement goal *easier* as distractions make the same task *harder*.

6. **-Corr ($T\text{-}B_{SPD}$, $NT\text{-}R_{SPD}$) $\Delta\downarrow$**: *Decreasing* delta for 4 IDs (1, 4, 6, and 7). This makes the level advancement goal *easier* as distractions make the same task *harder*.

7. **-Corr ($T\text{-}M_{SPD}$, $NT\text{-}A_{SPD}$) $\Delta\downarrow$**: *Decreasing* delta for 3 IDs (2, 4, and 7) and makes the level advancement goal *harder.*

8. **-Corr ($T\text{-}M_{SPD}$, $NT\text{-}R_{SPD}$) $\Delta\downarrow$**: *Decreasing* delta for 5 IDs (1, 2, 4, 6, and 7) and makes the level advancement goal *harder.*

The six correlations show increasing and decreasing speed over time. Although the correlation coefficients are both positive and colored blue in Figure 23, speed for boss and minion targets *decreases* over time, while speed for ambient and ring non-targets *increases* over time. In regard to the targets, a decrease in speed makes the level advancement and point acquisition goals easier. ID 4 discussed boss and minion target speed as a key feature in balancing the game difficulty. “I was able to properly identify targets, but had trouble hitting them [...] the speed of the enemies is a huge factor in the difficulty, not just for visual tracking but for response time in clicking on them. It's one thing to perceive the enemies, but another to have the skill in hand-eye coordination to target them accurately.” At the same time, speed for ambient and ring non-targets increases, thereby increasing distraction. ID2 and 5 commented on speed shared by a combination of elements. ID 2 stated that “core difficulty comes from a mix of speed from enemies, ambience, and rings”. ID 5 stated that “speed plays a massive factor in separating elements.”

Size-Size

Due to the fact that changes in size are more pronounced in the 30 level analyses, only the 30-level analyses are shown in Figure 24. As discussed previously, size is one of the features designers changed less frequently, or left a constant value. Only from novice to expert difficulty, did all size features change.

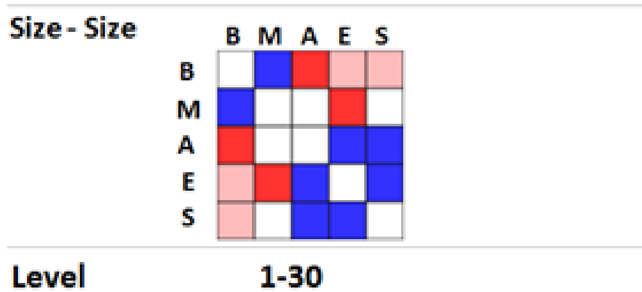


Figure 24: Correlation Matrix 1: 30 level analysis

9. **+Corr (T-B_{SZE}, T-M_{SZE})**, constant Δ: *Decreasing* for 5 IDs (IDs 3-7). This makes the level advancement and point acquisition goals *harder.* A negative correlation was found for ID 8 who decreased boss size and increased minion size. The effect is the same as it makes the level advancement goal *harder.*

10. **-Corr (T-B_{SZE}, NT-A_{SZE}) Δ↓**: *Decreasing* delta for 3 IDs (4, 6 and 8) and makes the level advancement goal *harder.*

11. **-Corr (T-B_{SZE}, NT-E_{SZE}) Δ↓**: *Decreasing* delta for 3 IDs (4, 6 and 8) and makes the level advancement goal *harder.*

12. **-Corr (T-B_{SZE}, NT-S_{SZE}) Δ↓**: *Decreasing* delta for 3 IDs (4, 6, and 8) and makes the level advancement goal *harder.*

13. **-Corr (T-M_{SZE}, NT-E_{SZE}) Δ↓**: *Decreasing* delta for 4 IDs (3, 4, 6, and 8) and makes the point acquisition goal *harder.* Increasing explosion size also makes the level advancement goal harder.

14. **+Corr (NT-A_{SZE}, NT-E_{SZE}) constant Δ**: *Increasing* for 5 IDs (2, 4, 6, 7, and 8) and makes the level advancement goal *harder.*

15. **+Corr (NT-A_{SZE}, NT-S_{SZE}) constant Δ**: *Increasing* for 5 IDs (2, 4, 6, 7, and 8) and makes the level advancement goal *harder.*

16. **+Corr ($NT\text{-}E_{SZE}$, $NT\text{-}S_{SZE}$) constant Δ**: *Increasing* for 5 IDs (2, 4, 6, 7, and 8) and makes the level advancement goal *harder.*

These eight correlations also show increasing and decreasing size over time. In the first correlation result, size for boss and minion targets is positively correlated and decrease over time, thereby making the targeting task and level advancement goal harder. Even though ID 1 and 2 did not manipulate target size, ID 1 stated that a “reduction in target size critically affects the player’s success rate”. ID 2 stated “having smaller enemies gives a bit more umph to the challenge”. In the last three correlation results, size for ambient, explosion, and spark non-targets are also positively correlated, and increase over time. Once again, increasing distraction makes the targeting and thus advancing levels advancement harder. The remaining four correlations are all negative correlations, where size for boss and minion targets decreases as size for ambient, explosion, and spark non-targets increase. Again, these correlations make targeting harder. ID 3 commented on this approach to increase difficulty in relationship to size for non-target explosions and sparks: “I didn't add distraction via the explosion/sparks to be a particularly "fair" (or interesting or whatever) way to increase difficulty. It feels cheap and not something I'd do in a game I'm personally designing and not something I'd generally advocate doing”. In phase 3, designers ID 1, 4, and 7 agreed that increasing size for the non-target elements can be ignored to a certain extent, until they obscure the visibility of targets.

The eight negative correlations with decreasing deltas, for speed and size, between target and non-target elements (Δ↓ correlations 5-8 and 10-13), are examples of stimuli similarity. Once again, the similarity theory of attention [34] is defined as the degree to which elements that share a common feature are perceptually similar. A visual search task decreases in efficiency and increases in reaction time as non-targets become similar in appearance to targets, and as the degree of dissimilarity between non-targets increases (in other words, as the non-targets become increasingly different from each other). These correlations show that speed and size decrease for boss and minion target elements as the same features increased for non-target ambient and ring elements. In phase 3, designers ID 1, 4, and 7 agreed that the ability to differentiate between elements is one avenue to increase difficulty. In reference to size for target and ambient non-targets, ID 5 stated that "you are now forced to pay attention to them as your enemies are now hidden in the forest of huge distracting particles."

Using this method of analysis, designers also manipulated different combinations of features at once, rather than the same features. One of the most frequent combinations is density and speed. While comparison of the deltas is not possible with different features, increasing or decreasing trends may still be observed.

Density-Speed

17. **-Corr (T-B_{SPD}↓) (T-M_{DEN}↑)**, Speed *decreases* for boss targets and density *increases* for minion targets for 3 IDs (1, 2, and 6). This makes the level advancement and point acquisition goals *easier.* However, the goals conflict with each other as an increase in minion density makes the level advancement goal *harder*.

18. **-Corr (T-M_{SPD}↓) (T-M_{DEN}↑)**, Speed *decreases* and density *increases* for minion targets, for 3 IDs (1, 2, and 6). This makes the point acquisition goal *easier,* and the level advancement goal is *harder*.

19. **-Corr (T-M_{SPD}↓) (NT-A_{DEN}↑)**, Speed *decreases* for minion targets and density *increases* for ambient non-targets for 3 IDs (4, 6, and 7). This makes the point acquisition goal *easier. H*owever*,* increasing ambient density also makes this goal harder. Either way, this makes the level advancement goal *harder*.

20. **+Corr (NT-A_{SPD}, T-M_{DEN})** ↑, Speed and density *increase* for ambient non-targets and minion targets for ID 2. This makes the level advancement goal *harder*.

21. **+Corr (NT-A_{SPD}, NT-A_{DEN})** ↑, Speed and density *increase* for ambient non-targets for 2 IDs (6 and 7). This makes the level advancement goal *harder*.

22. **+Corr (NT-R_{SPD}, T-M_{DEN})** ↑, Speed and density *increase* for ring non-targets and minion targets for 6 IDs (ID 1-6). This makes the level advancement goal *harder*.

23. **+Corr (NT-R_{SPD}, T-B_{DEN})** ↑, Speed and density *increase* for ring non-targets and boss target density for 4 IDs (ID 1, 2, 4, and 5). This makes the level advancement goal *harder*.

The seven correlations between speed and density show different effects with respect to the level advancement and point acquisition goals. In all cases, the net effect makes the level advancement goal *harder* as features associated with the minion target, or a combination of non-targets increase distraction. While this result is consistent with designers' views that difficulty increases over time as this is characteristic of the genre, five designers (2, 3, 4, 5, and 8) *increase and decrease* difficulty with respect to density for boss or minion targets, and speed for ambient and ring non-targets. These *ramping difficulty* manipulations occur within the 5-level fixed trajectories of motion, in sync with the two cut-scene rest-breaks per game. Figure 25 contains a visualization of these manipulations. The vertical axis represents the feature value and the horizontal axis represents 6 5-level blocks that span 30 levels. Levels 1-15 and 16-30 are annotated as E and H for easy and hard versions of the game. The top row represents density of the boss and minion targets shown in red and green colors, respectively. The bottom row represents speed for the ambient and ring non targets on the bottom, shown in blue and orange, respectively. The figure shows density and speed features increasing and decreasing over time, with increasing intensity in the expert difficulty setting. ID 8 applied ramping difficulty for speed in association with the non-target ring and ambient elements.

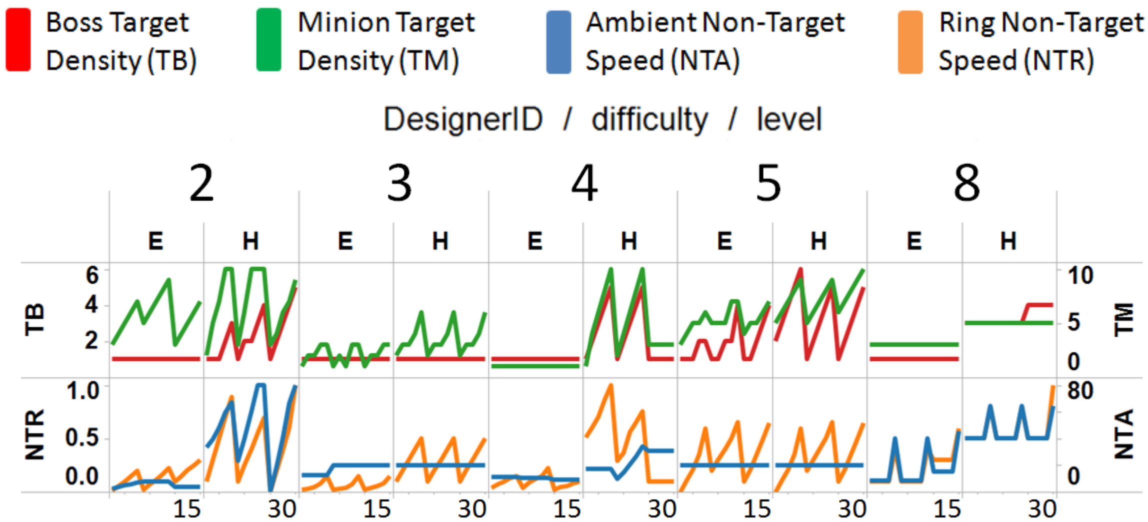


Figure 25: Ramping difficulty in 30-level analysis

In phase 3, ID 4 addressed ramping difficulty as "a process designers are not aware they do", that is, a common approach in game design to "train novice players to become experts, as quickly as possible. So you make it easy in the beginning and ramp up the difficulty as quick as your players can handle." In phase 2 and 3, ID 7 expressed caution with this approach, and preferred only gradual and linear increases in difficulty as inexperienced players may perceive these levels as too difficult or distracting. As ID 7 stated:

> *"...they [designers] are thinking more about the game play and not the trajectory of the first-time experience.[…]. I would apply ramps after the first 5-10 minutes of play, so my selections were based on accessibility rather than regular game playtime. I do more predictable in the first five minutes of play, even for experts, so they can have success-then ramping can be applied for excitement. […] When the designers ramp things up the way they did like in yours, I was not surprised. That's typical because I think they are concerned more with the gameplay and less about the trajectory of the first-time experience."*

The 23 correlations above are summarized in table 4. The table shows that designers manipulated a combination of features at once in association with different game elements. In total, between 4 and 18 correlations are found per ID. The table also includes the intended effects, predominantly to make the level advancement harder. The exception to this trend, annotated as “mix” in the table, includes a reduction in boss target speed (correlations #3, 5 and 6) to make the targeting task and level advancement goal easier. The intended effect is to balance difficulty, that is, to make the targeting task easier as the non-target distractions are more difficult to ignore.

Table 6: Correlation summary per ID

feature	#	correlation	intended effect	ID 1	2	3	4	5	6	7	8
DEN	1	+Corr ($T\text{-}B_{DEN}T\text{-}M_{DEN}$)	harder	1	1		1	1			
	2	+Corr ($T\text{-}M_{DEN}$ $NT\text{-}A_{DEN}$)	harder				1		1		
SPD	3	+Corr ($T\text{-}B_{SPD}$ $T\text{-}M_{SPD}$)	easier	1	1	1	1	1	1	1	
	4	+Corr ($NT\text{-}A_{SPD}$ $NT\text{-}R_{SPD}$)	harder							1	1
	5	-Corr ($T\text{-}B_{SPD}$ $NT\text{-}A_{SPD}$) $\Delta\downarrow$	mix		1		1			1	
	6	-Corr ($T\text{-}B_{SPD}$ $NT\text{-}R_{SPD}$) $\Delta\downarrow$	mix	1			1		1	1	
	7	-Corr ($T\text{-}M_{SPD}$ $NT\text{-}A_{SP}D$) $\Delta\downarrow$	harder		1		1		1		
	8	-Corr ($T\text{-}M_{SPD}$ $NT\text{-}R_{SPD}$) $\Delta\downarrow$	harder	1	1		1		1	1	
SZE	9	+Corr ($T\text{-}B_{SZE}$ $T\text{-}M_{SZE}$)	harder			1	1	1	1	1	
	10	-Corr ($T\text{-}B_{SZE}$ $NT\text{-}A_{SZE}$) $\Delta\downarrow$	harder				1		1		1
	11	-Corr ($T\text{-}B_{SZE}$ $NT\text{-}E_{SZE}$) $\Delta\downarrow$	harder				1		1		1
	12	-Corr ($T\text{-}B_{SZE}$ $NT\text{-}S_{SZE}$) $\Delta\downarrow$	harder				1		1		1
	13	-Corr ($T\text{-}M_{SZE}$ $NT\text{-}E_{SZE}$) $\Delta\downarrow$	harder			1	1		1		1
	14	+Corr ($NT\text{-}A_{SZE}$ $NT\text{-}E_{SZE}$) const Δ	harder		1		1		1	1	1
	15	+Corr ($NT\text{-}A_{SZE}$ $NT\text{-}S_{SZE}$) const Δ	harder		1		1		1	1	1
	16	+Corr ($NT\text{-}E_{SZE}$ $NT\text{-}S_{SZE}$) const Δ	harder		1		1		1	1	1
SPD / DEN	17	-Corr ($T\text{-}B_{SPD}\downarrow$) ($T\text{-}M_{DEN}\uparrow$)	mix	1	1				1		
	18	-Corr ($T\text{-}M_{SPD}\downarrow$)($T\text{-}M_{DEN}\uparrow$)	harder	1	1				1		
	19	-Corr ($T\text{-}M_{SPD}\downarrow$)($NT\text{-}A_{DEN}\uparrow$)	harder				1		1	1	
	20	+Corr ($NT\text{-}A_{SPD}$ $T\text{-}M_{DEN}$) $\uparrow$	harder		1						
	21	+Corr ($NT\text{-}A_{SPD}$ $NT\text{-}A_{DEN}$) $\uparrow$	harder						1	1	
	22	+Corr ($NT\text{-}R_{SPD}$ $T\text{-}M_{DEN}$) $\uparrow$	harder	1	1	1	1	1	1		
	23	+Corr ($NT\text{-}R_{SPD}$ $T\text{-}B_{DEN}$) $\uparrow$	harder	1	1		1	1			

		TOTAL	**8**	**13**	**4**	**18**	**5**	**18**	**11**	**8**

The phase 2 question was open ended, and therefore designers did not methodically comment on each pairing of features and their isolated change over time. Instead, they recalled important manipulations between features and elements, supported by their earlier remarks to balance or increase the game difficulty. The following selections include what designers considered to be important manipulations in a combination of features, organized per ID. Where appropriate, designers' remarks are associated with the correlation number, shown in table 4.

1. ID 1 considered the changing relationship between elements to include "keeping the density and speed of the minions in relation to the boss", and "having minions at a higher speed and smaller size than the boss" (correlation # 17, 18, and 3). In regard to non-targets, preferred "least distracting" explosion and sparks size, and found the ambient non-targets "most negligible, even at their largest and densest [...] as they fade into the background so seamlessly that they didn't interfere with the gameplay" (no correlation # 16 or correlations with NT-A).

2. ID2 stated a reduction in target speed is necessary to compensate for increasing distraction, for instance explosion size (correlation # 3, 14-16). Furthermore, to "increase enemy (boss and minion) density, ambient noise and ring speed linearly for each skill level" (correlation # 1, 20, 22, 23). "Additionally, I often went for more (explosion) effects rather than higher speeds of the enemies [...] just to create a perceived difficulty when it actually isn't that difficult at all" (correlation # 3 and 14).

3. The "biggest factors" for ID 3 include the manipulation of target size and speed (correlation # 3, and 9). In regard to non-targets, "I didn't experiment much with the ambients, as they just seemed a bit too ancillary to make a large enough difference" (no correlations with NT-A).

4. ID 4 stated, "I'm not surprised that the overall speed of the targets went down in expert difficulty, since their size also decreased, making them harder to target" (correlation # 3 and 9). "I'd wager the designers wanted more density while not

going insane with the difficulty" (correlation # 1). "In my 'expert' version, the ambients are the same size as the targets" (correlation # 10). "In my easy mode, I reduced the number of distractions considerably to begin with (only three, I believe, and they're very small) and increased gradually them as the stages progressed" (correlation # 14, 15, 16).

5. For ID 5, "speed and size of the target (minions/bosses) are proportionally related" (correlation # 3 and 9). "Hitting targets is really hard on the default settings [...] I attempted to adjust for this on novice difficulty by increasing size, and reducing speed" (correlation # 3 and 9).

6. ID 6 only verified selections and did not provide additional qualitative feedback.

7. ID 7 described the manipulation of features in the novice setting, "Ok, so we want to make the targets way bigger and I want the speed to be really slow. They are moving way too fast" (correlation # 9 and 3). "I want to reduce the amount of targets to 1. I want the least amount. I want to really keep things at a minimum" (no correlations for density). In regard to distraction, stated, "I don't mind the explosions and sparks too much for the hardcore players in the beginning" (correlation # 16).

8. For ID 8, "size and speed of targets were the big two.[...] smaller and faster meant more of a challenge (correlation # 3 and 9) [...] Add in ambient size, speed and density to mask the boss, and suddenly a full fledged encounter began to take shape" (correlation # 5 and 10).

Five designers discussed training and learning associated with their manipulation of the visual or game difficulty. For instance, ID 1-4 and 7 discussed "growing challenge", "challenge curves", and "linear increases" via the manipulation of features. The designer's intent in the novice difficulty setting is for difficulty to be low and increase over time in steeper and larger increments in the expert difficulty setting. For instance, ID 1 stated, "you want the game to ramp up and increase difficulty as the player grows accustomed to the game. [...] and provide an increasingly harder challenge for the player". This is a delicate process where "you push hard enough that the audience feels engaged, but not overwhelmed". At the same time, "you don't want players to feel completely calm", and therefore "risk and hard work" are necessary as this is what makes the experience "fulfilling". ID3 and 7 stated similar intents; to "create a feeling of increasing difficulty", "tension", and "pace". ID 7 continued to say "there is probably a lot of learning going on in the first level to first just get acclimated to the game". ID 4 discussed learning in regard to ignoring the irrelevant distractions task, with the goal "to turn a novice player into a more expert player...[by] training them to ignore the distractions". In the expert difficulty setting, ID 1 felt the design must include "stress tests", since "players must work to maintain their engagement".

7.3. Discussion

This study investigated designers' insights behind the manipulation of perceptual features for elements in motion within the context of the EMOS experimental game. The approach taken is consistent with perception research since analysis considered changes in features in regard to a fixed task. The research question considered in what way designers change features and results found that designers manipulate features individually and in combination with other features, with the intention to manipulate difficulty in the game. Designers revealed their tacit knowledge behind these manipulations, for instance to balance the visual and game difficulty and to support learning and training in the game. These are discussed further below.

Multiple intended effects were found for changes in individual features associated with elements. For instance, any manipulation of features associated with boss or minion targets influence the targeting efficiency (physical ease in shooting targets), and thus the level advancement or point acquisition goals. Increasing density, speed, and reducing size for boss targets makes the level advancement goal harder. Increasing density for minion targets, or any feature associated with non-targets elements, also makes the level advancement goal harder as these are all distractions in relationship to the level advancement goal. Designers' comments regarding *balancing the visual game difficulty* are consistent with this interpretation, such that players must continuously distinguish between target and non-target elements in order to progress through the game. Many designers saw a negative impact of distractions in relationship to the player's targeting and goal-seeking behavior, and therefore manipulated features in such a way to make these elements appear as minimally intrusive as possible. Many designers also discussed the influence of the fixed trajectories, specifically in regard to the predictability and patterns of movement, and compensating when the trajectories changed.

Multiple intended effects were found for changes in a combination of features associated with elements. Of the 23 combinations found, more than half changed features in association with target and non-target elements. This shows a strong relationship with the target and less relevant distractors elements, rather than one element type alone. The remaining 11 correlations are split between either targets or non-target elements. The three most frequent correlations found, applied by six of eight designers (correlation # 3, 9, and 22), exemplify efforts by designers to *balance the visual game difficulty.* These correlations include a decreasing speed and size for boss and minion targets, and increasing minion target density and non-target ring speed. The reduction in speed for target elements makes targeting easier in pursuit of the level advancement goal, while a reduction in size makes the same task and goal harder. In regard to the minion target density and non-target ring speed, these features increase and decrease over time, referred to as *ramping difficulty.* Designers' intents here are to *train* players to be more efficient in targeting and ignoring distractions in pursuit of the level advancement goal. ID 7 cautioned using this approach as a means to enhance excitement in the game as this may deter less experienced players from becoming accustomed to the game. Otherwise designers commented on a more gradual approach to change a combination of features in support of the same *learning* and *training* goal.

One additional observation in designers' manipulations of perceptual features is in regard to similarity in perceptual features. As defined by similarity theory of attention [34], task difficulty increases and reaction time decreases when perceptual features become similar (contain an increasing delta), in association with target and non-target elements. Similarity was found in 8 of the 23 correlations found, specifically in relationship to the speed and size features. In regard to speed, the intended perceptual effect is to make the targeting task easier and ignoring distractions harder. In regard to size, the intended perceptual effect is to make both harder. The theory also discussed non-target dissimilarity, and this was not found in the correlation analysis, as these features always positively correlated and increase together. Further investigation into non-target dissimilarity should consider the underlining feature values in order to determine increasing or decreasing differences in features. Nevertheless, increasing similarity is present in designers' selections, and is another avenue to explain designers' intents to change the visual design to become more challenging, through differentiating between target and non-target elements. These results are novel in that evidence of a perceptual principle and attentional theory are found in the context of a game, and can be used to explain changes to the visual design, and implications on task difficulty.

7.3.1. Limitations

Limitations include the designers' comments in phases 1-4 regarding their interaction with the tool. Limitations can be summarized as designers learning and working with the tool constraints, concerns regarding the abstract appearance of game elements, and usability concerns of the toolset in the manipulation of features. Designers had to learn and work with the constraints of the tool to formulate selections. The perception-based motivation for the EMOS game was a foreign concept to communicate initially. The constraints of the EMOS game did not allow color, trajectory, or rules associated with elements to change, so asking designers to work with a constrained subset of select visual features initially felt arbitrary, as designers are accustomed to iteration across all aspects of the visual and game design process. For instance, ID 4 suggested enhancing the player's targeting ability by changing the rules of the game as distractions increase in the game. Alternatively, ID 5 did not agree that the same explosion feedback should apply to different element types (boss and minion), or that the different element types move as a group with the same uniform spacing. Many also commented on the abstract presentation and movement of elements. ID 5 stated, "I had difficulty creating a sense of the space […] I couldn't figure out the logic of the space. Ordering of sequence is unusual but still workable". Similarly, ID 3 stated "...the abstract quality of motion was one drawback, as the grouping of targets and distractions looked artificial and not like a typical casual game."

In particular, seven designers cited element color when discussing the appearance of elements in the game. For instance, ID 5 stated “color plays a massive role in separating elements” and found this feature difficult to ignore in combination with motion. Designer ID 1, 3, and 4 also commented on element coloring in this way. For ID 4, “It's possible that even with a lot of visual noise, if the targets contrast enough with the overall environment, even a novice would be able to identify them correctly and without experiencing fatigue.” The monotone choice of coloring elements was not clear for ID 7 and ID 8 as most commercial games include color as a distinguishing feature of the visual design. ID 1 was the only one to comment the coloring of specific elements, for instance, the ambient non-targets appear to “fade into the background, the minions are really contrasting black elements that really stick out for me, and you can’t ignore the white color non-target rings.” ID 1 stated that selections would be totally different had the element coloring been different. Future work should consider the integration of features of brightness, colour, and motion. Although the EMOS game is abstract in visual presentation and developed outside a commercial game in production, designer ID 1 saw application into commercial games in production: “when you strip down the fancy textures and graphics, commercial games still consist of elements moving around, large and small, fast and slow targets, medium size targets, small targets, slow targets, etc.”

Along with learning the tool and working with a constrained set of visual features, ID 1, 4, and 7 commented on usability issues in the manipulation of a combination features. They suggested a control panel to globally visualize changing features across all 15 levels in one display, instead of sliders on a per level basis. Although the copy feature allowed a high degree of control, this method of manipulation became repetitive since each difficulty setting is sampled 15 times for 11 features. Designers commented that they needed to remember settings and switch back and forth between difficulty settings while modifying selections. In summary, designers recommended embedding a visualization summary, like the one used in phase 3, into the toolset. This would allow the relationships between elements to be more obvious to designers sooner in the design process.

7.4. Conclusions

This study investigated eight designers' manipulations of perceptual features *speed*, *size*, and *density* for elements in motion, within the EMOS experimental railed shooter game. Only features could change over time while the rules remained fixed, in association with two targets and four non-target elements. Several intended effects were found based on designers' verified selections using the EMOS toolset, qualitative expert review, and correlation analysis between combinations of features. Results found designers manipulate individual and combinations of features with different intended effects, depending on the ease in shooting targets in relationship to goals, and the ability for players to ignore distractions. The correlation results found increasing density and reducing size for targets, and increasing any feature associated with non-target elements makes the targeting task harder. Interestingly, as distraction increased, designers chose to balance the visual and game difficulty by reducing target speed as a means to make the targeting easier. Designers further discussed the intent behind their choices to train players to become experts. In accordance with the similarity theory of visual attention, 8 of the 23 correlation results in speed and size are found between target and non-target elements. These results support the claim that the domain of games are a viable avenue to conduct perception and attention research, for instance in a discussion regarding the visual design.

8. Perception - based Guidelines

The Chapter 7 results show how designers manipulated speed, size, and density features of elements in motion using the EMOS toolset. These manipulations received additional qualitative feedback as to their intended effect on task difficulty in the game. This chapter documents the process of consolidating these effects into EMOS perception-based guidelines, and the process of applying guidelines back into the EMOS game in preparation for the Chapter 9 Player Study. Three research questions are addressed:

1. **RQ1:** What are guidelines, stated as formulae of intended perceptual effects?

2. **RQ2:** What are important design considerations in the application of guidelines on the player's experience?

3. **RQ3:** In what way are guidelines applied within the EMOS experimental game?

The designer's intended effects discussed in the previous chapter contrast with existing guidelines, or heuristics in games [31,126,153]. Game heuristics are stated as rules of thumb and are based on a usability practitioner's introspection complemented with game reviews. They are perceptually unspecific to allow broad application to a variety of different games. The results from the Chapter 7 designer study are specific, in that the manipulation of features can be empirically expressed given a well-defined task and game structure. In this regard, perception-based guidelines can be defined through simple mathematic statements, whereby each statement identifies what feature changes in association to what element type, with the intended effect to increase or decrease task difficultly. For the purposes of consolidating the 23 correlations found in Chapter 7, the next sections outline the guidelines for elements in motion. They are named appropriately as *targeting task, interference,* and *accessibility* in pursuit of the level advancement game goal. These are discussed next.

8.1.1. *Guideline 1: Targeting Task*

Targeting difficulty refers to engaging in the targeting task, using the control device to click on targets, in pursuit of the level advancement goal. Task success requires the ability to differentiate between elements and ignore distractions. Difficulty (d) associated with the boss targeting task and level advancement goal (g_1) becomes *harder* as density and speed increase (↑) and size decrease (↓). This is due to the fact that bosses are in continuous motion and the game rules dictate that two bosses require two shots each in order advance to the next level. By the same rationale, the boss targeting task is easier as target density and speed decrease, and size increases.

- **$\uparrow dg_1 = (\uparrow T_{DEN}, \uparrow T_{SPD}, \downarrow T_{SZE})$**

It is important to note the difference in element color and game function between the boss and minion targets (T-M). Minion targets are darker in color in comparison to boss targets, and although the targeting task is the same, targeting minion supports the point acquisition goal (g_2) (i.e., additional reward to increase score). This is due to the difference in game rules that dictate minion elements require *one* shot, while boss targets require *two* shots. Given an increase in minion target density, the minion targeting task becomes easier (↓d). However, an increase in minion density also increases distraction in relationship to the boss targeting task, and thereby makes the boss targeting task *harder*.

- **$\downarrow dg_2 = (\uparrow T\text{-}M_{DEN})$**
- **$\uparrow dg_1 = (\uparrow T\text{-}M_{DEN})$**

8.1.2. *Guideline 2: Interference*

There are multiple approaches to increase interference respective to the task. As found in the multiple positive correlations with the non-target elements, any increase in these features makes them more difficult to ignore. By the same rationale, ignoring distractions become easier when these features both decrease.

- **$\uparrow dg_1 = (\uparrow NT_{DEN}, \uparrow NT_{SPD}, \uparrow NT_{SZE})$**

The user's ability to differentiate between target and non-target elements in the game also interferes with the targeting task and therefore impacts game difficulty. This is based on the eight correlations found, T-NT similarity for speed and size, supporting the similarity theory of attention [34]. We assume initially in the game that the target speed and size are faster and larger than the non-target speed and size.

Assumptions: ($T_{SPD} > NT_{SPD}$) and ($T_{SZE} > NT_{SZE}$)

Given this assumption, two formulae outline the impacts of increasing similarity on game difficulty:

- **$\uparrow dg_1 = \downarrow\Delta\ (T_{SPD}, NT_{SPD})$** Game difficulty increases in relationship to the level advancement goal when target and non-target (T-NT) speed become more similar ($\downarrow\Delta$), and therefore more difficult to differentiate.

- **$\uparrow dg_1 = \downarrow\Delta\ (T_{SZE}, NT_{SZE})$** Game difficulty increases when target and non-target size become more similar and therefore more difficult to differentiate

One must not forget the similarity theory also considered effects of non-target dissimilarity on task performance. In other words, task performance is diminished as a combination of features associated with non-target elements become more dissimilar over time (e.g., increasing delta $\uparrow\boldsymbol{\Delta}$). The correlation analysis in Chapter 7 did not find evidence of dissimilarity in non-target features as this method of analysis only evaluated whether a combination of features increases or decreases, not by *how much* these features change. Therefore, the interference guideline should consider both target similarity (T-NT) and non-target dissimilarity (NT-NT) as a scaling factors contributing to overall task interference, as a means to increase in game difficulty:

- **$\uparrow dg_1 = \uparrow\Delta\ (NT_{SPD}, NT_{SPD})$** Game difficulty increases when the difference between non-target speed increases, thereby interfering with the targeting task.

- **$\uparrow dg_1 = \uparrow\Delta$ (NT_{SZE}, NT_{SZE})** Game difficulty increases when the difference between non-target size increases, thereby interfering with the targeting task.

8.1.3. Guideline 3: Accessibility

Given an empirical measure of game difficulty, it is important to anticipate expertise effects on the players' performance and perceptions of performance as an additional guideline. The previous guidelines only define game difficulty in terms of easier or harder tasks with more or less interference, yet this approach must incorporate previous work that found expertise effects on performance, and implications on the player's perceptions of performance. For instance previous work in visual attention [54,55] found expert players have a performance advantage in a variety of attentional tasks (e.g., faster reaction time). Furthermore, game approachability principles [31] found novice players respond differently in comparison to experts when faced with challenge. These impacts may be difficult for the game designer to intuit, since they are often expert players or closely familiarized with the game in development. The accessibility guideline is therefore needed for broad target audiences in order to observe whether the visual design poses a problem for all players, or just specific players. Much game research controlled for these effects by recruiting only experienced players [68,82,100,112] and these results are limited to only these audiences.

The player's expertise was not addressed in detail in the Chapter 7 Designer Study, yet designers factored in the player's ability into their designs, since the goal was to manipulate features in a game suitable for novice and expert difficulty. Designers' comments to *balance the visual and game difficulty* and support *learning and training* intuitively reflect this awareness. Therefore, in evaluating guidelines with increasing game difficulty, we acknowledge expertise effects on the player's performance (P) and perceived difficulty (d). We can restate this assumption as an additional accessibility (A) guideline, such that performance and perceived difficulty are specific to a novice or expert player, identified by N or E subscripts ($_N$ or $_E$).

Given: $\uparrow dg_1 = (P_N, d_N)$ and (P_E, d_E)

Increasing game difficulty ($\uparrow dg_1$) as formulated in guidelines 1-3 has effects on the player's performance (P) and perceived difficulty (d) for novice (P_N, d_N) and expert players (P_E, d_E).

- **A = (P_N, d_N) = (P_E, d_E):** No difference in performance and perceived difficulty between novice and expert players. This suggests novice players learned the game, performed, and perceived their performance comparable to an expert player. This indicates changes to the perceptual features associated with the visual design are accessible (A) by a general audience.

- **if (P_N, d_N) ≠ (P_E, d_E):** A difference is found in performance and perceived difficulty between novice or expert players. This suggests an accessibility problem with the visual design for one group of players in relationship to the other.

8.2. Application of Guidelines to EMOS

In Chapter 7, designers applied guidelines to increase and decrease difficulty, however the net effect is that difficulty increases over time as this is characteristic of the genre. The expectation is that learning and training are present as levels repeat, whereby players seek to optimize their targeting task efficiency and ability to ignore interference. Guidelines were applied to new versions of the EMOS game described in Chapter 6, consistent with this understanding to increase difficulty. This step was simple as the manipulation of features could easily be hardcoded into the game. The look and feel of each new version of the game is different given application of these guidelines in relationship to different features. Informed by designers feedback in Chapter 7, new versions are appropriately named to match this feel, including *Target Assault, Hidden Target Scavenge,* and *Particle Mayhem,* defined and discussed further in Chapter 9.

An agreed upon baseline version of the game is needed in the player study, since designers' baseline settings and rates of change are different. In the Chapter 7 Designer Study phase 3 verification step, the researcher included a *baseline intermediate difficulty* version of the game, based on the level to level average for each feature, across all eight designers. In this step, designers received a web link to this playable version of the game and were asked whether this version increased the targeting and ignoring distraction difficulty in a way that did not appear too easy or difficult. All designers verified the accuracy of the baseline intermediate difficulty version as meeting this goal. Given this starting point, the second game played is based on one of the three versions that increase difficulty.

8.3. Discussion and Conclusion

This chapter consolidated the formulae of intended perceptual effects documented in Chapter 7 into three perception-based guidelines for elements in motion. The guidelines include *targeting task, interference,* and *accessibility*. The targeting task and interference guidelines are empirical in expressing which feature changes, in association to what element, and how this change affects task difficulty. It is important to note that the interference guideline encapsulates the similarity theory of visual attention as target similarity in relationship to non-targets (T-NT), and non-target dissimilarity (NT-NT). The accessibility guideline factors in expertise effects based on previous work that found performance and perception of performance differences between novice and expert players. This guideline is needed along with an objective measure of task difficulty so that designers and user experience practitioners can pinpoint whether specific users encounter a problem with the visual design. The targeting task and interference guidelines were applied to the EMOS toolset, described in Chapter 6, with the intent to increase difficulty over time. Three versions of the EMOS game were created in preparation for the Chapter 9 Player Study.

9. Study 3: Player Study

As discussed in Chapter 4, we need to evaluate the perception-based guidelines in a formal user study. Chapter 8 only discussed the formulation of guidelines and their application into the EMOS experimental game. The *targeting task* and *interference* guidelines are each defined by the manipulation of perceptual features in association with element types, with the intent to increase game difficulty. One additional *accessibility* guideline anticipates variances caused by increasing game difficulty on the players' experience, due to expertise effects. Given this goal, we need to set up a formal user study, consistent with triangulation and game user research methodologies [73,120,143]. To run the study, we need to define instruments for measuring the player's experience and the methods to collect and analyze the data given experimental conditions, thus addressing the impact of guidelines on the player's experience. The research questions for this chapter ask:

1. **RQ1:** What are the impacts of perception-based guidelines on the player's experience, in three experimental conditions? The player's experience is defined by game play performance data and self-reports of cognitive workload, satisfaction, and expertise.

2. **RQ2:** Since pupillometry as a physiological proxy of cognitive load is a new instrument in game user research:

    a. What are the impacts of perception-based guidelines on the player's pupillometry?

    b. What trends exist between pupil size, self-report of cognitive load, and satisfaction?

The methods section includes the apparatus and setup, task, conditions, and hypothesis. This is followed by the recruitment of participants, study design, data collection, and analysis. Results and discussion speak to the validity of the guidelines and use of pupillometry instrumentation in the context of a game.

9.1. Method

In two phases, a mixed method approach is used. The first phase includes an empirical task where participants played the EMOS game in which game performance and pupillometry metrics were collected and qualitative questionnaires for self-reports of player experience and expertise. In phase 2, task results were qualitatively reviewed by three expert game designers.

9.1.1. Apparatus and Experimental Setup

The apparatus consists of the EMOS railed shooter game running the Unity 3D™ game engine discussed in Chapter 6. The railed-shooter game genre constrains the player's control of the camera, and therefore the presentation of elements is identical. The primary level advancement goal requires two boss targets to be shot twice. The secondary goal is to collect points by shooting minion targets once. These goals remain fixed across 15 levels, whereby only *speed*, *size*, and *density* features change, in association with six game elements (two targets and four non-targets). Game elements move in three fixed trajectories of motion: *circular* in block 1 (levels 1-5), *expansion* from the screen centre to periphery in block 2 (levels 6-10), and *linear* (i.e. side to side) in block 3 (levels 10-15). Blocks are separated by a two-second cut scene that allows players a rest break. A user interface is located on the bottom of the screen and displays a countdown level timer, amount of points collected, and the number of targets shot. The interface also contains a button to stop the game at any time.

Games of course include more than one task and a variety of positive and negative reinforcements that needed to be constrained in this study. Additional control of the visual content was needed with intent to neutralize any positive or negative reward associated with task success or failure. In other words, features only affect the targeting task or amount of interference. In regard to the targeting task, levels automatically advance after a fixed period of time, even if the primary level advancement goal is not satisfied, as negative feedback will influence the player's perceived difficulty. In the same regard at the end of the game, only the player's task performance (score and amount of targets shot) is presented on the user interface, without any further reward.

The experimental setup took place in a lighting controlled laboratory free from distraction. Participants used a gaming PC with a standard keyboard and mouse to play the game, as well as answer survey questions. The PC is a quad core 3GHz processor with 6 gigabytes of RAM, connected to a 22" monitor, and equipped with a Tobii X60 eye-tracker to collect pupillometry data. The Tobii tracker is robust in that very little data is lost, regardless of a subject's ethnic background, age, use of glasses, contact lenses or mascara, or so-called "droopy" eyelids. Additionally, head movement compensation algorithms ensure accuracy and precision, even when subjects move relative to the eye tracker. Participants sat in a fixed position, in a chair with no wheels, so that subjects' eyes remained within tracking range. Slight movement of the participant head is within the tolerance of the tracker, however some participants moved outside of the tracking range. A snapshot of the apparatus and experimental setup is shown in Figure 26.

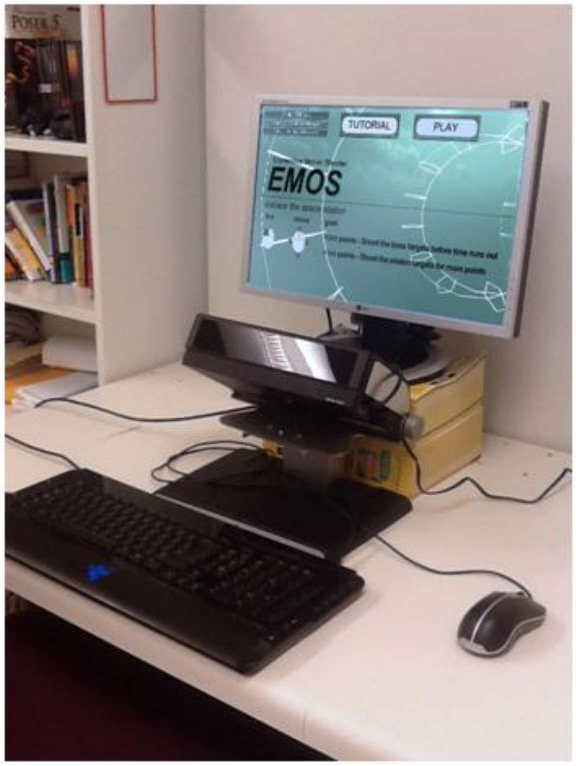


Figure 26: Experimental Setup with the Tobii Eye Tracker

The study procedure is as follows and shown in Figure 27. Prior to the task participants were introduced to the basic goal of the game both verbally and visually, using a web page containing text and game screenshots. Participants were instructed to work to the following goals:

1. Shoot boss targets to advance (and collect points)

2. Shoot minion targets for more points

3. Ignore the swarms as these are distractions

After this step, the Tobii eye tracker was calibrated. Participants were then asked to play a three-level tutorial of the game to become familiar with the mouse controls (moving and clicking). Once the setup was complete, the researcher moved to an adjacent room so as to not bias or distract the player in completing the task.

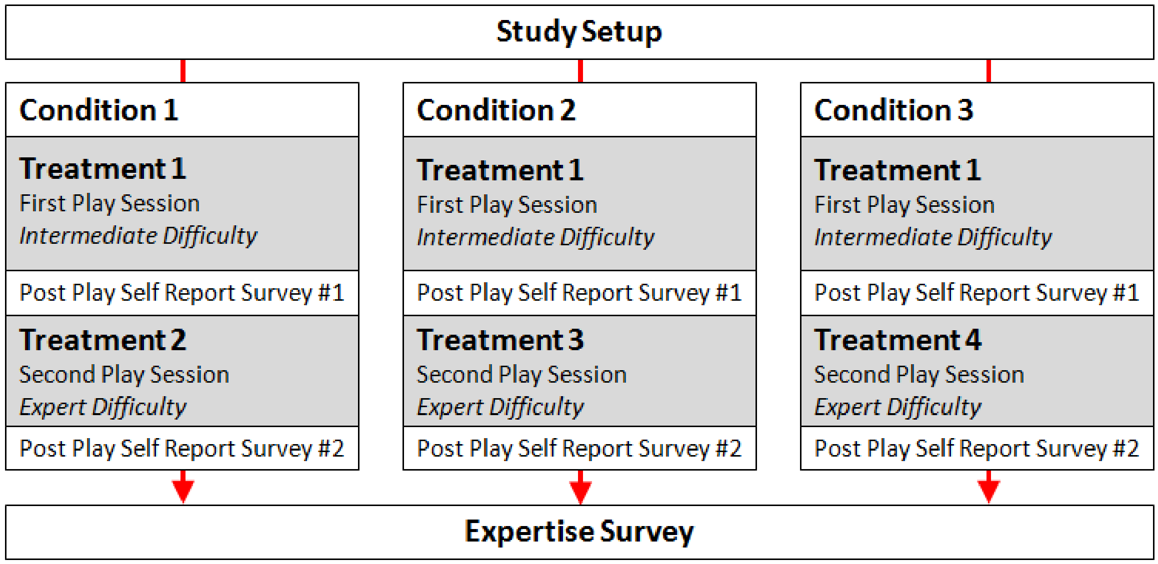


Figure 27: Study Procedure

9.1.2. Task

A participant played the game in one of three experimental conditions, described in the next section and Figure 27. All players started with the same control set of trials, referred to as treatment 1. This was followed by a self-report survey on cognitive workload and satisfaction. Once complete, a player was then randomly assigned a second set of trials, referred to as treatments 2-4, followed by a second workload and satisfaction survey. Upon finishing the second post play survey, the player completed the expertise survey. This was set last in order to not bias the sample [15]. Once finished with the task, participants were thanked for their participation.

9.1.3. Stimuli / Conditions

Conditions 1-3 refer to treatments 1-2, 1-3, and 1-4, respectively. As discussed in Chapter 8, treatment 1 manipulates a combination of features suitable for intermediate difficulty, previously verified by eight game designers, and is considered a baseline treatment to compare the more difficult treatments against. Each condition applies guidelines (i.e., manipulates a combination of perceptual features) to increase game difficulty over time. The guidelines are defined once again:

1. **Targeting Task** refers to engaging in the targeting task while using the control device to click on targets in pursuit of the level advancement goal. The targeting task in pursuit of the level advancement goal becomes harder as the target density and speed increase and size decrease.

2. **Interference:** refers to the presence of non-target elements in the scene. Any increase in features associated with non-targets makes non-targets more difficult to ignore and reduces the visibility of targets. More specifically, and as discussed by the similarity theory of attention [34], interference increases task difficulty in two ways. The first is when target and non-target speed or size features become more similar (increasing T-NT similarity), and therefore more difficult to differentiate between these elements. The second is when features associated with non-target elements become more different (increasing NT-NT dissimilarity).

Each condition is defined by the change in features (e.g., the delta, Δ) between the first and second treatments played. As discussed in the task description, the change in features is needed in order to evaluate the change in self-report, collected only after playing each treatment. Changes in features are shown per condition in the first three columns in Table 7. Each row in the table corresponds to one feature in association with target (T) or non-target (NT) elements that manipulate this feature. The first three columns consist of the average difference (in percentage) between the first and second treatment played. Cells shaded in pink indicate a negative difference for the second treatment played, where features *decrease* over time. The table shows all conditions reduce targeting task difficulty for boss and minion speed (TB and TM in the figure), as these values decrease on average 9% and 5%, respectively. However, this reduction in speed is offset by a reduction in target size, from 4-37%, which makes the targeting task difficulty *harder*. The changes in the remaining features alter the look and feel for each condition, which are named for simplicity and illustrated in Figure 28. Conditions 1-3 are named *Target Assault, Hidden Target Challenge,* and *Particle Mayhem,* respectively. The guidelines are discussed in more detail within these three conditions next, as well as the difference between conditions.

Table 7: Feature percent difference (left) and ratio of the difference (right) in conditions 1-3

Feature / Elements		C1	C2	C3	C1	C2	C3
Δ Speed	TB	91%	91%	91%	1	1	1
	TM	95%	95%	95%	1	1	1
	NTA	120%	120%	120%	1	1	1
	NTR	180%	124%	124%	1.5	1	1
Δ Density	TB	183%	160%	160%	1.1	1	1
	TM	136%	76%	76%	1.8	1	1
Δ Size	TB	82%	63%	82%	1	1.3	1
	TM	96%	73%	96%	1	1.3	1
	NTA	119%	273%	119%	1	2.3	1
	NTE	100%	100%	200%	1	1	2
	NTS	125%	125%	161%	1	1	1.3

Negative (decreasing) value over time

C1-C3 Ratio of the difference per feature

Increasing non-target dissimilarity

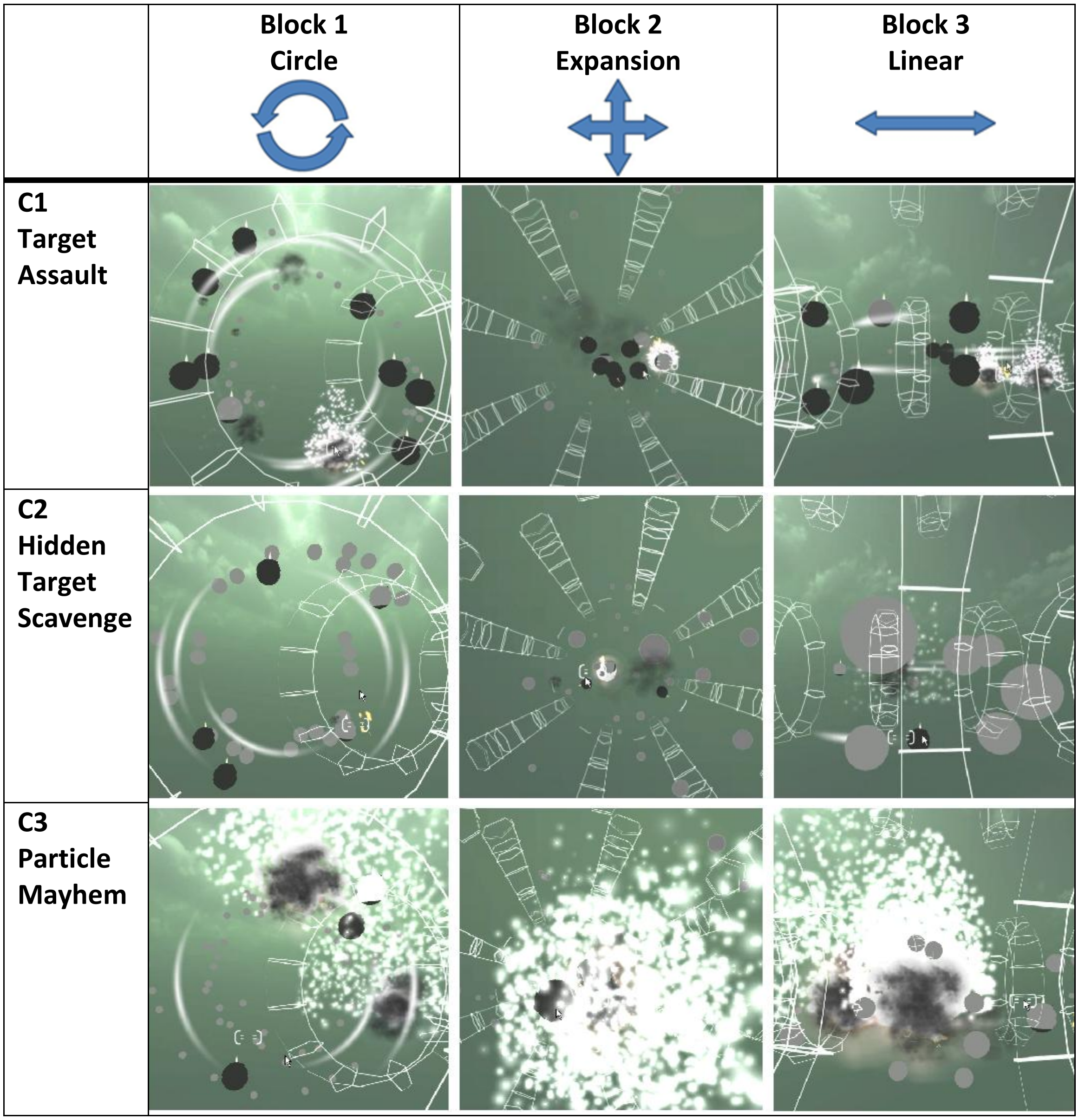


Figure 28: Visual design screenshots of Conditions 1-3 in blocks 1-3

Condition 1: Target Assault

- **Targeting Task:** The boss-targeting task becomes harder as the density for the boss and minion targets (i.e. number of targets on screen) increases 83% and 36%, respectively (an increase of two bosses and two minions per level). In Figure 28, this is noticeable by the higher amount of minion target (TM) elements on screen (darker in color). As discussed in Chapter 7 and 8, increasing minion density makes the point acquisition goal easier, however, it also increases the amount of distraction in pursuit of boss target elements and the level advancement goal. The targeting task is also harder by decreasing size for boss and minion targets 18% and 4%, respectively.

- **Interference:** Ambient non-targets and visual feedback spark size increase distraction 19% and 25%, respectively. Non-target ring speed increases 80% and is thus more dissimilar in speed in comparison to the ambient non-target speed, which only increased 20%.

Conditions are unique as the names suggest and illustrated in Figure 28. The far right three columns in Table 7 are a ratio of the difference for each feature between conditions 1-3. Cells shaded in blue represent the highest or lowest ratio as some features change more than others in each condition. Many cells are also outlined in an orange color, and these cells identify instances of increasing non-target dissimilarity. From the table, the ratio of the difference is constant for boss and minion speed, and ambient non-target speed, as these elements change by the same amount in all conditions. In comparison to conditions 2 and 3, condition 1 increases level advancement difficulty through:

- **Targeting Task:** Boss and minion density increase 10% and 80%, respectively.

  Interference: Non-target dissimilarity, via a 50% increase non-target ring speed.

Condition 2: Hidden Target Scavenge

- **Targeting Task:** The boss targeting task becomes *harder* by increasing density of the boss targets 60% (an increase of 1 boss) and reducing boss size 37%. However, the boss targeting task is *easier* by decreasing minion density (a decrease of one minion) and size 24% and 27%, respectively.

- **Interference:** Non-target ambient size increases 273% and is thus more dissimilar in size in comparison to the non-target visual feedback sparks, and explosion size. Explosion size remains constant and spark size increases only 25%. In Figure 28, the ambient non-targets (NTA) are most noticeable due to their large size. These elements are colored the same as boss targets. Non-target ring speed increases by 24%.

In comparison to conditions 1 and 3, condition 2 increases level advancement difficulty through:

- **Targeting Task:** A reduction in boss and minion target size 30%.

- **Interference:** The ambient non-target size increases 230%. This increase in size increases similarity in size in relationship to the boss and minion target size. The same increase also increases non-target dissimilarity in relationship to the visual feedback sparks and explosion size.

Condition 3: Particle Mayhem

- **Targeting:** The boss-targeting task becomes *harder* by increasing density of the boss targets 60% (an increase of one boss) and reducing boss size 18%. However, the boss-targeting task is *easier* by decreasing minion density (a decrease of one minion) and size 24% and 4%, respectively.

- **Interference:** Non-target explosion size increases 200% and is thus more dissimilar in size in comparison to the non-target ambient and visual feedback sparks size. The ambient and spark size remains constant, and increases 61%, respectively. In Figure 28, the explosions particles are most noticeable due to their large size, making the targets less visible. Additional interference is due to a 24% increase in speed for non-target rings, 19% and 61% increase in size for ambient and visual feedback spark non-targets, respectively.

Unlike conditions 1 and 2, condition 3 only increases level advancement difficulty through task interference.

- **Interference:** Non-target explosion size increases 200% and is thus more dissimilar in size in comparison to the non-target visual feedback sparks size, that only increase 30%.

9.1.4. Hypotheses

Research question 1 includes three hypotheses, regarding effects of the *targeting task* and *interference* perception-based guidelines on the player's experience. The first hypothesis is informed by Chapter 5 results and Klimmit's study of player performance and satisfaction in a game [82], discussed in Chapter 3.

Hypothesis 1: An increase in game difficulty through application of *perception-based* guidelines has the effect of decreasing the player's game play performance, increasing reports of cognitive demand, and decreasing reports of satisfaction. Given a different application of guidelines in each condition, shown in the Table 7 ratio of the difference, only specific guidelines and features are evaluated in each experimental condition.

- Condition 1 Target Assault evaluates both guidelines in hypothesis 1, in reference to increasing target density and non-target ring speed.
- Condition 2 Hidden Target Scavenge evaluates both guidelines in hypothesis 1 in regard to decreasing target size and increasing ambient non-target size.
- Condition 3 Particle Mayhem evaluates only the task interference guideline in hypothesis 1, in regard to increasing visual feedback size of non-target explosions.

The second hypothesis for research question 1 evaluates a combinatorial effect of perception-based guidelines on game difficulty.

Hypothesis 2: Condition 3 Particle Mayhem has smaller effects on the player's game performance, reports of cognitive demand, and satisfaction, in comparison to conditions 2 and 3. This is due to a change in features corresponding to only the interference guideline, whereas conditions 1 and 2 apply both guidelines.

The third hypothesis for research question 1 evaluates the accessibility guideline in conditions 1-3, respectively. This hypothesis is informed by attention studies [55,67] and approachability guidelines [31], as games are performed and perceived differently depending on the player's expertise.

Hypothesis 3: Given an increase in game difficulty through perception-based guidelines, expert players demonstrate a performance advantage and report lower cognitive demands in comparison to novice players. Novice players report lower satisfaction in comparison to expert players.

Research question 2 includes two hypotheses regarding the player's pupillometry measurements as a proxy to cognitive workload, self-report of cognitive workload, and affect. The hypothesis are based on previous research [76,84,127] discussed in Chapter 3. Both hypotheses are evaluated in conditions 1-3, respectively.

Hypothesis 4: Application of guideline(s) to increase game difficulty has the effect of increasing pupil size as an index of cognitive workload.

Hypothesis 5: A relationship exists between the player's pupillometry measurements, self-reports of cognitive workload, and satisfaction.

9.1.5. Participants and Recruitment

The player study includes 105 participants and an expert review with three game designers. The study includes a total of 48 females and 57 males with an average age of 21-22 years for each condition. All participants have normal vision or corrected to normal vision. Recruitment occurred from the author's university campus and participants received a $5 gift card to a campus coffee shop. Participants were tasked to sign up for the session to play a game that explores different visual designs, created by game designers, and that the game is playable by everyone. During recruitment, the player's expertise was not solicited nor was the genre disclosed, as to not bias our sample [15].

As participants came into the session they were seated at the experimental setup. Each session lasted approximately 15 minutes with a total play duration of 2-4 minutes.

9.1.6. Study Design

The study design consists of two phases that utilize quantitative and qualitative methods of data collection and analysis. The first phase, referred to as the *Player Study*, includes a between-subject design for 35 participants that played each experimental condition. The second phase consists of qualitative expert review by expert game designers that reviewed phase 1 results.

9.1.7. Data Collection

Phase 1: Player Study

A total of thirteen measurements are collected in phase 1. This includes four continuous *gameplay* measurements, one continuous *physiological* measurement, seven post-play *cognitive workload* and *satisfaction* self-report measurements, and one *expertise* measurement. Consistent with the change in features associated with conditions discussed previously, all data collected is transformed based on the difference in measurements, calculated by subtracting the baseline treatment 1 values from the same values in treatments 2-4, respectively.

Gameplay Measurements

The gameplay performance measurements are collected for each level and then averaged across each 5-level block. Averaging across 5-levels corresponds to the three fixed trajectories in the game. The average is a marker of performance efficiency and includes compensation and learning respective to the task. These measurements were:

- Level time (seconds)
- Shots fired (count)
- Enemy death (count) including boss and minion targets

- Accuracy (shots fired / enemies hit)

Physiological Measurements

The player's physiological measurements include pupil size (millimetres) via the Tobii X60 instrumentation. Pupil size for the left and right eye are logged every two milliseconds. Raw pupil size data went through two transformation steps consistent with previous work [84]. The first is that raw data collected is transformed into a normalized pupil size average, comprised of left and right eye, and these values are transformed into a *pupil size baseline ratio.* The baseline ratio divides the pupil size during the play activity with a resting state pupil size. The resting state consists of five seconds before the game, during each two second non-interactive cut-scene (four total), and five seconds after completion of the first and second treatments played. Application of pupillometry within the context of a game is complex since the visual content changes moment to moment as players interact with elements in the game. While integration of eye gaze with game logs can achieve high temporal resolution [111,113], the pupil size metric is based on the same averaging technique as the above gameplay performance measurements. This decision was made to maximize the utility of the results. In other words, the baseline pupil size ratio is extracted level-to-level and then averaged for each five-level block. This approach allows a constant comparison with the gameplay performance metrics in each condition.

Cognitive Workload and Satisfaction Measurements

Cognitive workload [60] and satisfaction (positive affective valence) [71] are collected through self report questionnaires. The validated cognitive workload survey contains six questions measuring perceptions of task performance. Satisfaction is included as a seventh measure of positive valence, counter to frustration as negative valence, since the game is intended for entertainment purposes. Each question is rated on a seven-point Likert scale (1=lowest and 7=highest). In addition to the ratings, the original TLX survey posed the same questions to be ranked in order of importance. This elaborate scoring procedure based on ratings and rankings takes time away from the play experience, so only the ratings are collected in the user study. Collection without rankings is consistent with the most common modification to the NASA-TLX survey, in at least 40 publications [59]. The ordering of the cognitive workload and satisfaction questions are randomized in the survey. The scales are defined as follows when presented to participants:

- **Mental Demand:** How mentally demanding was the task (following targets and ignoring distractions)?
- **Physical Demand:** How physically demanding was the task (moving and clicking the mouse)?
- **Temporal Demand:** How hurried or rushed was the pace of the task?
- **Success:** How successful were you in accomplishing what you were asked to do?
- **Effort:** How hard did you have to work to accomplish your level of performance?
- **Frustration:** How insecure, discouraged, irritated, stressed, and annoyed were you?
- **Satisfaction:** How happy, content, good, sense of enjoyment, or amount of fun did you experience?

Expertise Measurements

Expertise is based from a gaming habits survey [36]. This measurement is a categorical variable based on *novice* or *expert* player expertise. The method for determining expertise is based on responses to eight gaming habits questions, shown below. In summary, a player is categorized as novice if they prefer casual, non-3D games, play less than the average, and do not have a gamer ID account associated with 3D console games. The best and favorite games reflect these responses.

1. If you have any Xbox Live (XBL) gamer tag, PSN ID, or Steam ID please name it.
2. During an average week, how many hours do you spend playing video games? (days/week * hours/session = hours/week)

3. Please rank the different game genres. If you have more than one preference write them in order of preference for playing (genres include: strategy, FPS, action, casual, role-playing, sports, music, others, no preference)

4. What platform do you use (PC, Console, Portable, Mobile)?

5. How much time with a new game do you need before you feel that you are mastering the controls? (On a scale from 1 = ‘I basically struggle all the way through’ to 5 = ‘It works for me from the beginning’)?

6. Do you normally feel overwhelmed by the challenges during the first couple of hours of playtime with a new game?

7. What is the best game you ever played and why?

8. Please list your five favourite video games.

Phase 2: Expert Review

In phase 2 all eight designers that participated in Chapter 7 were contacted by e-mail to review and discuss the player study results. Three experts from the Chapter 7 study (ID 1, 4, and 7) agreed to participate in this step and were met individually for a two-hour interview. Once again, ID 1 and 4 have 6 and 11 years experience in the games industry and work in large game development studios, Bungie and Valve. ID 7 has 18 years experience, is an independent play test and usability consultant, and has consulted with game designers at companies such as Electronic Arts and Disney. The interview conversation with experts was recorded and transcribed by the researcher. Designers commented on the following three questions:

1. What is the impact of increasing task difficulty on the user’s experience?

2. Are these impacts specific to a novice or expert player?

3. What are limitations of the experimental game?

9.1.8. *Data Analyses*

Phase 1: Player Study

Three methods of quantitative analysis are used. Both methods 1 and 2 employ a between subject t-test for the 13 measurements collected to identify significant differences in performance and self-report. Method 1 investigates effects of targeting and interference guidelines on game play performance, cognitive workload, satisfaction ratings, and pupillometry measurements. Method 2 investigates the accessibility guideline as expertise effects on game play performance, cognitive workload, and satisfaction ratings. In both methods, analysis of self-report also includes the most frequent responses (i.e. the mode). Based on participants' self-reports of expertise, the study includes a total of 55 expert and 50 novices. Condition 1 includes 20 experts and 15 novices, condition 2 includes 19 experts and 16 novices, and condition 3 includes 16 experts and 19 novices.

Method 3 investigates trends between the pupillometry measurements, cognitive workload, and satisfaction ratings using a bivariate correlation analysis. This procedure evaluates changes in pupil size in relationship to changes in self-report measurements and produces two outputs: Pearson's r correlation coefficient and significance result of the strength of the relationship. Pearson's coefficient is a measure of linear association between two measurements. Positive coefficients identify a relationship between features that either increase or decrease as a group. A negative correlation identifies a relationship where one feature increases and the other decreases.

All measurements collected are checked for normal distributions and outliers are removed. Excluded from the analysis are skewed or kurtosis distributions and outliers greater than three standard deviations from the mean. This cleaning step reduced the sample size for the pupillometry measurements collected contained in the Table 8 summary. The sample size decreased by 2-9 participants, or 6-26%, depending on the condition and five-level block.

Table 8: Pupillometry data in conditions 1-3

Condition	Block	Included		Excluded	
		N	%	N	%
Condition 1	1	28	80%	7	20%
	2	29	83%	6	17%
	3	33	94%	2	6%
Condition 2	1	31	89%	4	11%
	2	30	86%	5	14%
	3	31	89%	4	11%
Condition 3	1	30	86%	5	14%
	2	31	89%	4	11%
	3	26	74%	9	26%

Phase 2: Expert Review

Qualitative data went through a process of transcribing the verbal conversations and textual analysis. These data went through an inter-rater step that identified two codes based in response to questions 1 and 2. These codes include:

1. Implications of increasing difficulty on the users experience.

2. Implications of increasing difficulty on novice or expert users' experience.

A total of 105 codes were found based on designers' comments. Cohen's kappa statistic is used as a measure of inter-rater reliability for these codes. Cohen's kappa found substantial agreement in these codes (kappa = .701). The designer's open ended feedback (phase 2 question 3) regarding the limitations of the study are included in the limitations section.

9.2. Results

9.2.1. *Phase 1 Player Data*

Game Performance

Analysis found many performance differences, shown in

Table 9. The table includes the mean difference (Δmean) for gameplay performance measurements in blocks 1-3 (corresponding to levels 1-5, 6-10, and 11-15, respectively), separated by conditions 1-3. Rows shaded red and green refer to positive (increasing) and negative (decreasing) values, respectively. From the 33 normally distributed measurements, five of these measurements differ significantly ($p < .05$) and 25 are highly significant ($p < .01$). White cells in the table represent measurements that are not significant or normally distributed (*). These differences are summarized for each condition.

Table 9: Difference in game play performance results in conditions 1-3

Feature / Elements	C1 Δmean			C2 Δmean			C3 Δmean		
	1	2	3	1	2	3	1	2	3
Δtime (s)	3.1	1.0	1.3	3.0	0.9	2.4	-2.7	-0.8	-1.2
Δshots (#)	9.5	3.6	5.0	7.8	2.5	5.8	-7.5	-2.0	-3.3
ΔeDeath (#)	2.2	2.6	1.7	*	0.4	-0.1	0.3	-0.3	-0.1
Δaccuracy (%)	-0.08	0.06	-0.01	-0.19	-0.1	-0.14	0.18	0.08	0.08

*not normally distributed positive negative

The hypothesis once again is that increasing game difficulty through guidelines has the effect of decreasing game play performance.

- In condition 1 Target Assault, performance increased and decreased. The level time and shots fired increased, indicating a reduction in performance; however more enemies were shot during this time. The increase in the amount of enemies shot is due to the 83% increase in minion target density (a difference of 10 minions per block). Accuracy decreased in block 1 and improved in block 2.

- In condition 2 Hidden Target Scavenge, performance decreased. The time and shots fired again increased; however, the effect size for enemies shot is small since the difference is less than one target. Accuracy decreased by 10-19%.

- In condition 3, Particle Mayhem, performance increased. The level time, shots fired, and accuracy improved. The effect size in enemies shot is small since the difference is less than one target.

Cognitive Workload and Satisfaction

The within-subject analysis also found many differences in self-reports. Table 10 contains the within-subject t-test for the change in self-report. The table shows the mean difference and highlights significance in yellow for each self-report measurement. Positive values in the table mean self-report in treatments 2-4 were more demanding than treatment 1. However, with the exception of mental demand in condition 2, the mean differences are less than one point. The change in self-report based on the mode is shown in Figure 29. The vertical y-axis in the figure is the change in self-report ratings. Negative ratings signify values for treatment 1 were larger than the same values in treatments 2-4, respectively. Significant t-test results that also match the mode analysis are next reported in each condition.

Table 10: Difference in self-report t-test results in conditions 1-3

Feature / elements	C1		C2		C3	
	Δmean	sig	Δmean	sig	Δmean	sig
Δmental	0.71	.012	1.54	.001	0.54	.001
Δphysical	0.57	.027	0.46	.054	0.77	.005
Δtemporal	0.20	.433	0.49	.011	0.66	.001
Δeffort	0.57	.067	-0.26	.095	0.43	.017
Δsuccess	*	*	0.71	.001	*	*
Δfrust	*	*	0.43	.030	-0.11	.554
Δsatis	*	*	-0.06	.662	0.20	.213

*not normally distributed

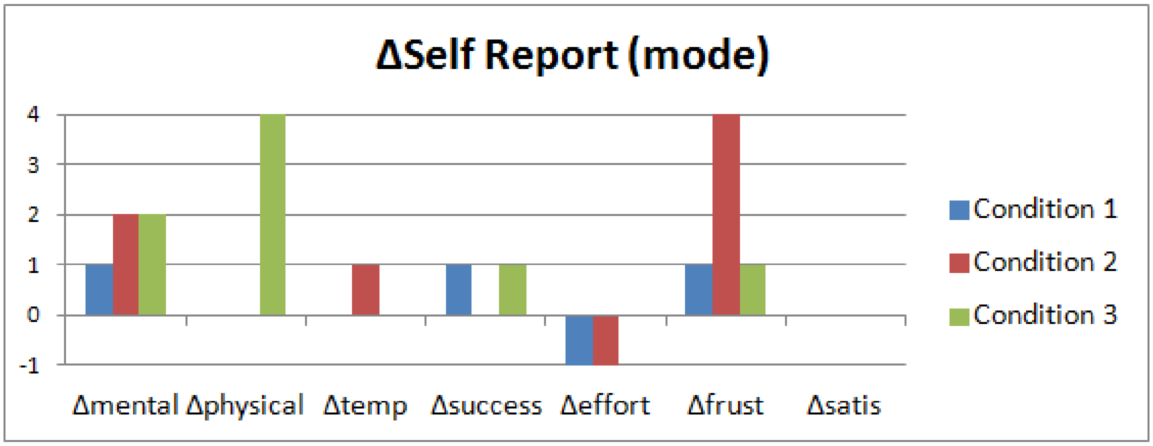


Figure 29: Difference in self-report (mode) for conditions 1-3

The hypothesis once again is that increasing game difficulty through guidelines has the effect of increasing participants' reports of cognitive demands and decreasing reports of satisfaction.

- In condition 1 Target Assault, mental demand increased.
- In condition 2 Hidden Target Scavenge, mental and temporal demand, and frustration increased.
- In condition 3 Particle Mayhem, mental and physical demand increased.

Expertise Effects on Performance, Cognitive Workload, and Satisfaction

The hypothesis once again is that given an increase in game difficulty through targeting task and interference guidelines, and in regard to the accessibility guideline, expert players demonstrate a performance advantage and report lower cognitive demands in comparison to novice players. Novice players self-report lower satisfaction in comparison to expert players.

Effects of expertise on performance found few performance differences, shown in Table 11. In total only 4 differences were found out of a possible set of 36. The table includes the mean difference, standard error mean, and significance. All findings are relative to the novice player in comparison to the expert player.

- In condition 1, the change in accuracy for block 1 decreased 10%, and time for block 3 increased one second for the novice player (p < .014 and .032). One novice player stopped the game in treatment 2 (the only one to do so in the study). This player self-reported erratic clicking as the cause for accidentally stopping the game.

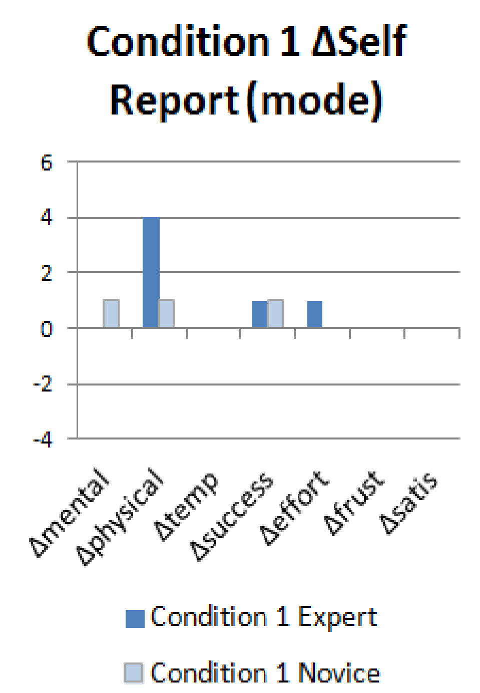
- In condition 2, the change in accuracy for block 3 decreased 8% for the novice player (p < .009).

- In condition 3, the change in enemy death for block 3 decreased by 0.4 bosses for the novice player (p < .033).

Table 11: Expertise t-test results

	variable	exp	N	Δmean	ΔStd. Error Mean	t	df	Sig. (2-tailed)
C1	Δacc (%) *block 1*	E	20	-10%	3.6%	-2.60	33	.014
		N	15					
	Δtime (s) *block 3*	E	20	1.36	0.6	-2.24	32	.032
		N	14					
C2	Δacc (%) *block 3*	E	19	-8%	3.1%	2.77	33	.009
		N	16					
C3	ΔeDeath (#) *block 3*	E	16	-0.4	0.18	2.23	32	.033
		N	18					

The same within-subject analysis separated by the player's expertise found differences in self-report in condition 1 only, shown in Figure 30. In condition 1, the changes in physical demand and effort are three and one point higher for *expert* players in comparison to novice players, respectively. These findings are also significant in the within subject t-test for the change in self-report. Although the effect size is less than one point, expert players perceived higher physical demand and effort as task difficulty increased in the second treatment played.



Feature / Elements	exp	Δmean	Sig. (2-tailed)
Δmental	E	0.85	.570
	N	0.53	
Δphysical	E	0.63	.027
	N	-0.07	
Δtemporal	E	0.37	.330
	N	-0.07	
Δeffort	E	0.88	.024
	N	-0.07	
Δsuccess	*	*	*
Δfrustration	*	*	*
Δsatisfaction	*	*	*

Figure 30: Expertise difference in self-report, via the mode (left) and mean (right)

Physiological Performance (Pupillometry)

In regard to hypothesis 4, the hypothesis is that an increase in game difficulty through guidelines has the effect of dilating pupil size. The mean differences in baseline pupil size for conditions 1-3 are shown in Table 12. The table shows three significant cases highlighted in yellow, where pupil size significantly *constricts*, rather than dilates. These results are found in condition 2 block 1 and condition 3 blocks 1 and 2 (p < ,038, .001, and .001, respectively). This constriction is small, only a 1-3% decrease in comparison to treatment 1, however still larger than the baseline resting pupil size. One explanation for these results is that constriction occurs as a result of learning and habituating to the task, even though self-report of cognitive workload increase in both conditions. In the first 10 levels of condition 3, an alternate explanation is that constriction occurs as a result of increased brightness on screen, since this condition increased the size of visual feedback sparks and explosions. In regard to method 2, no effects of expertise were found on pupillometry measurements.

Table 12: Difference in Pupil size in conditions 1-3

Feature / Elements	C1 Δmean			C2 Δmean			C3 Δmean		
	1	2	3	1	2	3	1	2	3
Δpupil size (mm)	-0.04%	-0.17%	-0.22%	-1.08%	-0.53%	0.17%	-2.43%	-3.35%	-0.70%

In regard to hypothesis 5, the hypothesis is that a positive correlation exists between the player's pupil size and cognitive workload and satisfaction self-reports. Out of a possible set of 63 cases (3 pupil size measurements correlated with 7 self-report measurements per condition) a total of 5 correlations were found significant. All results are within conditions 1 and 3.

- In condition 1 block 1, pupillometry positively correlated with physical demand and satisfaction ratings ($r = .472$ and $.432$, $p < .02$ and $.035$, respectively. In block 3, pupillometry again positively correlated with the satisfaction ratings ($r = .391$, $p < .036$).

- In condition 3 block 1, pupillometry negatively correlated with the satisfaction ratings ($r = -.416$, $p < .025$). In condition 3 block 3, pupillometry negatively correlated with the mental demand ratings ($r = -.466$, $p < .017$).

9.2.2. Phase 2: Expert Review with Designers

Game Performance, Cognitive Workload, and Satisfaction

Designers' views are consistent with hypothesis 1. They expected an increase in game difficulty to decrease the player's game performance and increase cognitive demands. Where appropriate, designers offered additional feedback in regard to the phase 1 results. It is important to note that not all designers commented on each condition.

Condition 1 Target Assault contained the most enemies shot, longer level times, and increased mental demand. ID 1 expected demand to increase since players need to "work harder" in regard to the targeting task: "When everything is flying around in the expert setting you need to work a little harder. If there are more targets the player has greater odds against them."

Condition 2 Hidden Target Scavenge contained a reduction in performance, and increased reporting of mental and temporal demand, and frustration. ID 4 stated. "I felt confident the decrease in target size and increase in non-target size appeared to diminish performance and increase self-report of workload. [...] because you would have to spend longer identifying what you are supposed to be shooting." ID 1 stated, "I liked seeing that ambient size is much larger and equal to the targets. You are now forced to pay attention to them. Your enemies are now hidden in the forest of huge distracting particles. The reduction in target size critically affects the player's success rate." Furthermore ID 1 and 7 viewed the increase in frustration ratings as a *positive* sign. ID 1 stated "You don't want players to feel completely calm" and ID 7 found frustration a "positive driver in doing well, as opposed to feeling no challenge. It is almost like this is a measure of challenge. This is not so much a measure of players' internal emotional states so much [...] this is still valenced on good challenge. When I get into a game it drives me to do better when I feel more challenged."

Condition 3 Particle Mayhem contained an improvement in game performance and an increase in mental and physical demand. As ID 4 stated, "these elements appear to be easily ignored by everyone". Similarly ID 7 stated the particle effects did not interfere as much with players since they are used to noise in the beginning of the game. [...] players generally expect sparks and explosions to increase in expert difficulty."

In regard to general accessibility of the game, designers discuss more generally the impact of increasing difficulty on the user's experience. ID 1 discussed the consequences of "mentally checking out" and "perception of being totally stressed" without meaningful rewards contributing to a sense of fulfillment. "You got everything working against you from motion. It did look like it was getting pretty hectic. [...] players are working harder to achieve the same results. You're asking more of them. If a player finds their efforts do not produce a happy outcome, it's more work and less play at this point." This remark suggests that players are willing to tolerate increasing demands as long as the reward is perceived to be balanced with the risk. Similar to this comment, ID

7 agrees that “challenge spurs us on [...] I mean it is an inert human reaction to why we find games fun in the first place. We feel challenged; we have to work harder to play better.” However, ID 7 clarified that the goal in the game is not to “train pilots”, but rather “sell a game”. To this extent, enjoyment is closely tied to the player’s expectations for reward, not only in regard to the targeting task, but more generally in finishing the game. Although no differences in satisfaction ratings were found, both of these comments underscore the importance of rewards associated with the cognitive demands as contributing to satisfaction in the game.

Effects of Expertise on Performance, Cognitive Workload, and Satisfaction

Designers expected greater effects of expertise on performance since the performance results found only infrequent differences, and no difference in block 2. Where differences are found, the effect size is small. For instance, ID 4 stated, “I generally expected expert players to have shorter level times” since they would find it “easier to ignore distractions”. ID1 stated, “a novice player could be completely overwhelmed, like a duck out of water, and not efficient, versus an expert who is a lot more efficient and is knocking them out of the park”. Both ID 1 and 7 agree novice players are most likely to stop playing when feeling overwhelmed, and in one case a novice player did stop in Condition 1. This player reported erratic mouse clicking, suggesting a flailing strategy, and accidently hitting the stop button. Designers also expected greater effects of expertise on players’ reporting of cognitive workload and that novice players report higher demand. As to why no effects were found in conditions 2 and 3, ID 4 stated, “novice players had been trained to become experts and that learning had already taken place.”

The counterintuitive result found in condition 1 received much comment from designers, where physical demand increased for *expert* players, rather than novice players. ID 1, 4, and 7 recognized the possibility of reporting bias to explain this result. For instance, ID 1 discussed over-reporting of demand by novice players: “Novices are not as familiar with the game, and less comfortable with the game. They perceive the game more difficult and a taxing endeavor. Therefore, they perceived themselves as having worked harder.” ID 7 also discussed why expert players under-report in the beginning of the game:

> *The expert players have an assumption that the beginning of the game will be easy. They just know that. They are more willing to spur themselves to continue because they want to check the game out. Experts are more willing to go through the game being too easy in the beginning, where a beginner will not be willing to continue if it is too hard.*

ID 1 and 7 also discussed the reward structure in the game contributing to this counterintuitive reporting. ID 1 again discussed balancing risk and reward specifically for the expert player. Although experts are able to “give the game a good run for its money”, if engaged in unrewarding “mindless-clicking” for too long...

> *They will not feel their work is paying off compared to someone who struggled a little but feels a sense of accomplishment once the level is complete. So for an expert player that figured out the system, mindless pressing is obviously not going to be as fulfilling for them as someone who is really engaged, feels good and awesome.*

This response suggests experts already learned and optimized their targeting strategy, and negatively perceived the physical demand as a repetitive targeting task. ID 7 shared a similar view regarding the reward structure:

> *[Experts] tend to think, oh well, I need to work harder for the reward; I am getting more into it at a subconscious level. At an emotional level, they are not happy about it at the moment, but ultimately, they would be happy about it if they know they could achieve that.* [attain the goal] *[...] But at what point is that challenge no longer rewarding? You find a shorter turn for a more beginning player because they give up faster. Where for an expert player, this might spur them on, and have a breaking point later on, eventually.*

Once again, remarks by ID 1 and 7 address task reward and cognitive demand as a means to understand the player's satisfaction in the game. However, it is important to restate that no effects of expertise were found on the satisfaction ratings.

9.3. Discussion

The goal for this study is twofold, first to evaluate the effects of thee perception-based guidelines on the player's experience, *targeting task, interference*, and *accessibility*. The second goal considers these effects on the player's physiological performance, via pupillometry instrumentation. In considering effects of visual designs on the player's experience, one must carefully consider the perceptual features associated with task-relevant targets among irrelevant non-target elements, and how the task fits within a larger game structure. The following is a discussion of the study results with respect to the research questions and each hypothesis. A summary of the hypothesis results are shown in Table 13.

Table 13: Summary of Player Study Results

Hypothesis	Condition	Name	Result
1	1	Effect of Targeting Task and Interference Guidelines	Accept
	2	Effect of Targeting Task and Interference Guidelines	Accept
	3	Effect of Interference Guideline	Reject
2	1-3	Combined Effects of Guidelines	Accept
3	1-3	Effect of Guideline(s) on Accessibility	Reject
4	1-3	Effect of Guidelines on Pupillometry	Reject
5	1-3	Pupillometry Trends with Self-report of Cognitive Workload and Satisfaction	Reject

Research question 1 included three hypotheses regarding the effect of perception-based guidelines on the player's experience. Hypothesis 1 stated that application of targeting task and interference guidelines to increase game difficulty has the effect of decreasing the player's game play performance, increasing reports of cognitive demands, and decreasing reports of satisfaction. Excluding the satisfaction result, Hypothesis 1 is accepted for conditions 1-2 *Target Assault* and *Hidden Target Scavenge* and rejected in condition 3 *Particle Mayhem*.

It is important to note that no difference in the reporting of satisfaction was found in conditions 1-3, yet designers frequently discussed satisfaction in relationship to the task risk, reward, and players' perceived cognitive demands. For instance, the increase in physical demand result for expert players in condition 1, or the increase in frustration result in condition 2, received much reflection by designers. These results offer many new insights into the player's perceptions in the game in comparison to Huniche's [70] or Klimmit's [82] study of player satisfaction and enjoyment. Huniche's study did not find a relationship between subjects' perceptions of difficulty and performance, while this study does in consideration of the changes in perceptual features in associated with game elements. In Klimmit's study, performance, self-report of satisfaction, and enjoyment consistently decreased as game difficulty increased. This study found only mental demand consistently increased in conditions 1-3 as game difficulty increased. This work is an important first step in studying the player's satisfaction and enjoyment in games at a higher level of detail, based on perception based-guidelines, a clear task, and the player's perceived cognitive demands. Additional remarks concerning the satisfaction ratings are discussed in the limitations sections.

In condition 1*,* hypothesis 1 is correct for the targeting task and interference guidelines. Once again in Target Assault, the ratio of the difference is highest for minion target density and ring non-target speed. In other words, this condition contained the highest number of targets to shoot and distractions through the fastest ring speed. Players were less efficient as the level time and shots fired game play performance values increased. Additionally, self-report of mental demand increased. More minion targets were shot as a result since these elements require only one shot, rather than two. Further verification is provided by ID 1 that expected players to work harder as more targets are flying around in the expert difficulty setting.

In condition 2*,* hypothesis 1 is again correct for the targeting task and interference guidelines. Once again, in Hidden Target Scavenge, boss and minion target size decrease, and become more similar to the ambient non-target size. Additionally the ambient non-target size becomes more dissimilar respective to the non-target visual feedback size. Players were less efficient as the level time and shots fired game play performance again increased. In addition, self-report of mental demand, temporal demand, and frustration increased. This is the only condition where a frustration result is found as a negative affective valence. Further verification is provided by ID 1 and 4 that expected increased difficulty to "identify what you are supposed to be shooting" and that enemies are "now hidden", respectively. Even with increasing frustration and temporal demand ratings, and reduction in performance, designers found this result a sign of good challenge in the short term. As ID 7 stated, this is the "kind of challenge that spurs us on." More specifically, players are willing to tolerate increasing difficulty in pursuit of the level advancement goal, so long as the reward of attaining the goal is perceived to be balanced with the risk.

In condition 3, hypothesis 1 is rejected for the interference guideline. Once again in Particle Mayhem, the ratio of the difference is highest for non-target visual feedback sparks and explosion size. In other words, these elements increase the amount of visual distraction and reduce the visibility of targets in the game. Even though self-report of mental and physical demand increased, players became *more* efficient overall as the level time, shots fired, and accuracy gameplay performance *improved*. Further verification from ID 4 and 7 stated that the particles could be "easily ignored by everyone" and that "players generally expect sparks and explosions to increase in expert difficulty", respectively. This finding suggests that given a defined task and game structure, non-target dissimilarity associated with visual feedback may not have as detrimental effects on performance, as originally discussed in the similarity theory [34].

Hypothesis 2 for research question 1 is therefore correct in evaluation of the combinatorial effect of guidelines on game difficulty. Both conditions 1 and 2 increased difficulty via the targeting task and interference guidelines, where condition 3 only increased difficulty through interference. In condition 3, the results show no difference in task performance and only negative effects on the player's reporting of cognitive workload. In other words, condition 3 is less difficult in comparison to conditions 1-2. It is important to recall the similarity theory of attention considered combinatorial effects of interference on the user's task performance, via T-NT similarity and NT-NT dissimilarity. The result from hypothesis 2 validates this combined effect on game difficulty in the context of a game.

Hypothesis 3 for research question 1 evaluated the accessibility guideline in conditions 1-3. Hypothesis 3 stated that given an increase in game difficulty through perception-based guidelines, expert players demonstrate a performance advantage, and report lower cognitive demands in comparison to novice players. Novice players report lower satisfaction in comparison to expert players. In conditions 1-3, the hypothesis is rejected and this result was not anticipated by all three game designers.

In condition 1 Target Assault*,* hypothesis 3 is rejected for the accessibility guideline. No difference in gameplay performance was found in 10 of 12 variables. Where significance was found for accuracy and time, the effect size is small, less than 10% and one second difference. Interestingly, expert players perceived *higher* physical demand and effort as task difficulty increased in the second treatment played. Although designers commented on this counter intuitive result as possibly due to report bias, this result led to a discussion of the intrinsic reward associated with the cognitive demands of the targeting task. For instance, ID 1 and 7 discussed “mindless-clicking” for expert players, the novice players’ willingness to persevere in such a task, and the rewards in completing all 15 levels and finishing the game. For this condition in particular, the repetition of mouse clicking on minion targets indicated a problem, and game designers considered the task and reward in closer detail. Although this result is found for expert players rather than novice players, the discussion that followed exemplifies game approachability [31] in relationship to perception-based guidelines.

In condition 2 Hidden Target Scavenge and condition 3 Particle Mayhem*,* hypothesis 3 is rejected for the accessibility guideline. In both conditions, no difference in gameplay performance was found in 11 of 12 variables. Where significance was found for accuracy in condition 2 and enemy death in condition 3, the effect size is again less than 10% difference or one enemy death. In other words, no substantial expertise effects were found in either condition. Further verification is provided by ID 4 who stated that “novice players had been trained to become experts and that learning had already taken place.” These results are signs that novice players perceived and performed relatively similar to experts. Results for condition 2 suggest the game was difficult for all players, while condition 3 is more accessible and approachable for reasons discussed previously. These findings are also consistent with previous work that evaluated attentional learning between expert and novice gamers outside the context of a game [56,149]. This work demonstrates similar findings in only a few minutes of play, rather than several hours.

Research question 2 included two hypotheses regarding the player’s pupillometry measurements as a proxy to cognitive workload, and relationship with self-report of cognitive workload and affect. Hypothesis 3 stated that application of targeting task and interference guidelines to increase game difficulty has the effect of increasing pupil size as an index of cognitive workload. Hypothesis 3 is rejected in conditions 1-3 due to few and unexpected results found. Pupil size unexpectedly c*onstricts*, rather than dilates, in a total of three cases (one in condition 2 and two in condition 3). One explanation for these results is learning effects due to the fixed-targeting task and ordered sequence of levels. Another explanation for constriction in condition 3 is due to increased brightness of visual feedback size. Monitoring the change in screen brightness during game play and increasing the temporal resolution of the pupillometry data are areas of future work.

Hypothesis 4 for research question 2 evaluated trends between the player’s pupillometry measurements, self-reports of cognitive workload, and satisfaction. In conditions 1-3, the hypothesis is rejected. Out of a possible set of 63 cases (three pupil size measurements correlated with seven self-report measurements per condition) a total of five correlations were found significant. A positive correlation between pupil size and reporting of cognitive demand was found in one case. Otherwise the opposite or mixed results were found, most notably for the satisfaction ratings. One explanation for these findings is that the game did not include any intrinsic positive or negative reinforcement, or winning and losing states, outside the targeting task and level repetition. The affective pupillometry study by Janisse [76] found a noticeable effect with this kind of reinforcement feedback. Pupillometry in game research is a challenging topic and this area alone should be the focus of a future study. These findings are nevertheless an important first step to integrate and triangulate pupillometry instrumentation within the context of a game.

9.3.1. Limitations

The perception-based guidelines are limited to the EMOS game. Replication of the same features and elements in similarly structured levels and goals in a railed shooter game may not lead to identical results. It is important to restate the underlying assumption behind their application into a railed shooter genre game. This genre is well known for rewarding achievement and skill mastery as difficulty increases over time. The EMOS game concentrated on a common task, reward, and game structure found in this genre, although many variations of this genre exist. With this limitation in mind, it is important to restate the design choice to constrain the extraneous positive or negative feedback in the EMOS game, which may contribute to the lack of satisfaction findings. The targeting task only rewarded level advancement without further embellishment, and players were not penalized if they failed, which may bias self-reporting. Once finished with the game, winning or losing feedback was subdued, and only the final number of enemies shot and the score were presented on the user interface. Due to the neutral feedback in the game and short duration of playing, the participant's compensation may influence self-reports as an extrinsic reward. Follow-up studies that consider the player's perceptions of frustration or satisfaction may consider positive and negative rewards, and feedback, associated with cognitive task demands.

Designers commented on limitations of the study, in terms of criteria for defining participants' expertise, short study duration, and concerns regarding the targeting task. In regard to defining the player's expertise via the gaming habits survey, the user study recruited a range of player abilities in a game playable by everyone. Therefore the results reflect a range of inexperienced and experienced players that may not normally play or enjoy a railed-shooter game. Increasing the number of participants in the study, refining the questions to be more genre specific to a target audience, or defining additional sub-groups beyond novice or expert, may improve the accuracy of the expertise results found, and thus the accessibility guideline. As discussed by ID 7, fun for beginner or fun for advanced, may be entirely different games:

> *I think there is a big defining line for people who are not used to playing games and people who are. I would want to really define that because I think this will really change the kind of results collected. Once you tease that out, you can look at gamers in general and focus on questions specific to the general gamer experience, such as the pacing, abilities, and what is the ramp up from there. I almost see it as two different solutions.*

The short 1-2 minute play duration is another limitation of the study and not general to longer play sessions. As ID 7 explained, even though no participant intentionally stopped playing EMOS, eventually some would stop. Therefore, ID 7 suggested increasing difficulty *after* five minutes of play, as an approach to “make the game an accessible experience for everyone”. Results are therefore limited to the short play period tested and additional questions may be necessary to gauge players’ long term motivations for sustained play. For instance, ID 7 posed more detailed questions such as, “How confident do you feel that you can get better in this game and win this game?” Alternatively, “Would you keep playing this game after 15 minutes or one hour?”

The mouse controls and targeting rules also received comments. ID 1 noticed that the mouse-clicking controls were not clarified to players in the study setup. The fact that players could change targeting performance by continuous mouse pressing to rapidly fire or single clicks to fire individual shots may influence the player’s frustration ratings. “As a player I would feel frustrated if I’m trying to fire but am limited by the tool.” To this extent, designers suggested including additional targeting metrics into the analysis, such as tracking the spatial and temporal patterns of mouse clicks on the screen within the three fixed trajectories of motion in the game. The benefit of this approach allows designers to check whether players’ behaviors match their expectations, or to identify optimal or failed strategies in certain perceptual conditions.

9.4. Conclusion

This study considered the impacts of visual designs on the player's experience, based on two research questions associated with five hypotheses. The first question evaluated effects of three perception-based guidelines of elements in motion on the player's experience in the EMOS experimental railed shooter game. The second evaluated the use of pupillometry instrumentation within the context of a game as a physiological proxy to player's cognitive workload. The features under investigation include *speed*, *size*, and *density* in association with target and non-target game elements in continuous motion. Analysis triangulated quantitative data collected from 105 participants who played the game and qualitative feedback from three expert designers. For the first research question, hypothesis 1 is accepted in two of three experimental conditions, such that application of the targeting task and interference guidelines, with the intent to increase game difficulty, has the effect of decreasing the player's game play performance and increasing reports of cognitive demands. This hypothesis is rejected in a third condition that applied only the interference guideline, via non-target dissimilarity to increase game difficulty. This finding supports the second hypothesis regarding the combined effects of targeting task and interference perception-based guidelines on task difficulty, congruent with the similarity theory of visual attention [34]. These results validate the effects of targeting task and interference perception-based guidelines on the player's experience. No significant change in the player's reporting of satisfaction is found as the EMOS game minimized positive or negative feedback associated with the task and completion of the game. Rejected is a third hypothesis that evaluated the accessibility guideline, whereby expert players demonstrate a performance advantage and report lower cognitive demands in comparison to novice players. Given the EMOS task and game structure, novice players' performed as well as experts, and interestingly, expert players' report increasing cognitive demands when game difficulty increases through application of the targeting task and interference guidelines. Finally and for methodological reasons, rejected are the remaining two hypotheses regarding the player's pupillometry measurements. Pupillometry results nevertheless suggest areas of improvement in future work.

10. Conclusions and Future Work

This dissertation studied the visual design in video games as a vital part of the overall design. The visual richness in what we *see* influences what we *think* and *feel* while playing: however, this topic is inherently difficult to pin down within a design domain. This is especially true in regard to perceptual qualities of motion and their change over time, so a perception-based framework and a theory of attention were brought in to consider these relationships in closer detail. Game designers have enormous tacit knowledge in this domain, so they were recruited to consider this framing to address the visual design in this way. There are many contributions of this inquiry, including the generality of the approach given questions of ecological validity, the validated guidelines congruent with the similarity theory of visual attention, the mixed and pragmatic methodology, and implications for design practice. These contributions are discussed in more detail next.

10.1. Ecological Validity and Generality of Approach

The degree to which ecological validity was achieved in this work is summarized for each user study, followed by the affordances and limitations with this approach. In the first user study, the perception based framework was applied to well known commercial games and was successful in evaluating complex visual designs in instances of high cognitive demand. In the second user study with designers, the EMOS toolset was easy for designers to use and allowed them to produce variety of solutions for an intended target audience. Quantitative analysis of these solutions found evidence of the similarity theory of visual attention as one method by which designers increase task difficulty. The perception-based guidelines developed were robust in considering any possible manipulation of perceptual features that could be manipulated. In the final user study with players, application of the guidelines into experimental conditions were based on common manipulations found in the designer study. These conditions were named as game levels one might find in this genre: *Target Attack*, *Hidden Target Scavenge*, and *Particle Mayhem*. Given the quantitative validation of the effects of guidelines on the player's experience, the design review showed examples whereby designers leveraged the perception based framework to discuss specific visual designs and implications for a target audience.

Questions concerning the affordances and limitations of the EMOS instrument are summarized here. The primary affordance is that both designers and players viewed the instrument as a game. The game and toolset collected data and supported a quantitative investigation congruent with a theory of attention. This was possible through meticulous effort to define the task, level structure, and changeable perceptual features associated with game elements in this genre. As discussed by designers in the designer and player studies, there are several limitations of the instrument. This includes the abstract representation of elements and emphasis on perceptual features of motion, as brightness and color are also critical factors to consider in investigations concerning the visual design of a game. These are areas of future work discussed in section in 10.5.1.

Given the degree to which ecological validity was achieved and affordances and limitations of the EMOS instrument, the generality of this approach is summarized. Generality of the perception-based framework can apply to any game with visible elements. One can easily deconstruct a visual design by identifying the visual task in association with both target and non-target element types, what perceptual feature(s) change, and the camera constraint in altering the presentation of elements. Generality of the two perception-based guidelines are specific to the EMOS railed-shooter game. As discussed previously, much effort went into defining the game task and manipulating perceptual features found in this genre. EMOS is nevertheless a very simple game and a game developer or researcher may wish to expand upon these guidelines. This may be accomplished by modifying the existing EMOS game or replicating the process to develop a new experimental game as a means to evaluate new guidelines.

10.2. Empirical Guidelines

Success of the perception-based framework is shown by the empirical guidelines developed. The guidelines remove ambiguity in how we *see* visual designs and their implications for game design. In summary, Chapter 9 validated two perception-based guidelines using this framework: *targeting task* and *interference.* Both are defined by the manipulation of perceptual features associated with game elements and their impact on game difficulty. These guidelines show evidence of the theory of similarity [34] within the context of a game, for instance to understand their combined effects on game difficulty on the player's task performance and rating of cognitive workload. With so much complexity to be found in visual designs in action games as perceptual features continuously change, these guidelines allow a designer to systematically diagnose the visual design under certain tasks and visual conditions.

Numerous insights were also found in application of guidelines that speak to the *accessibility* of visual designs on game difficulty for novice or expert gamers. Given empirical guidelines, this work is an important first step in computationally modeling the player's experience and allows consideration of alternative theories of attention to be studied within the context of a game. This finding is relevant to researchers in perception and attention that currently study gamer and non-gamer audiences [54,55,67,149] and is an invitation to consider further investigations within the context of a game.

10.3. Research through Design

The guidelines were not possible without a pragmatic [11,25] and mixed [25] methodological stance that include qualitative design reflection and quantitative analysis. This stance is a research-through-design contribution [48,180] as *design choices* were documented over the course of multiple chapters. Qualitative reflection by game designers in a research setting is presently missing in the HCI and games research community. During the development of the EMOS game, only a selection of features of motion and their relationship to elements, among many possible solutions, could be encoded into the toolset and game. This required several design choices in how one might apply a perception-based framework into a game. Given the EMOS toolset, expert designers reflected upon these choices made in the latter stages of this process. Designers' tacit knowledge in this domain and voice in this process provided insight that would otherwise be overlooked with empirical approaches alone. For instance, their remarks as to the manipulation of features underscoring *training* novice players to become expert players or *balancing* the design by decreasing difficulty as irrelevant distractions increase difficulty. In the player study, their feedback includes surprise, as the expectation of expertise effects were not found in the evaluation of game accessibility. Finally, designers incorporated a perception-based framing to systematically discuss the impacts on the player's reporting of cognitive demand and satisfaction. These remarks and the artifacts created are valuable contributions for game designers and game researchers.

10.4. Implications for Design Practice

There are several practical implications for game design practitioners, including leveraging a perception-based framework to evaluate their own game designs, formulating guidelines to minimize ambiguity in discussions concerning the impacts of visual designs on the player's experience, and to consider innovative game mechanics based on theories of visual attention. As stated in the Chapter 2 Theoretical Background, design is well known for borrowing theoretical perspectives from other disciplines and the field of visual attention is no exception. Multiple game design frameworks recognize the sensory and visual aesthetics found in dynamic game content have impacts on the player's experience, yet these do not systematically account for the changes in perceptual features underscoring their designs. The perception-based framework presented in Chapter 5 provides practical commercial game examples that lead to useful guidelines to organize complex visual game content. In Chapters 7 and 9, expert game designers used this framework within the context of the EMOS experimental game to discuss the impacts of specific perceptual conditions on the player's experience. This approach helps design practitioners systematically evaluate game designs and facilitates communication between game programmers, artists, and external stakeholders. For instance, in issues concerning learning and instructional designs [31,49].

The empirical guidelines documented in Chapter 8 are concise in defining the organization of visual game content and their impacts on the user's experience. The guidelines reduce the trial and error associated with iterative design and allow a designer to be more efficient developing designs for different audiences. While the player study results found increased cognitive demands given increased complexity of visual designs, designers may leverage these findings to consider changes to increase satisfaction for players. Furthermore, guidelines may be integrated into gray box testing in the conceptual phases of design where tasks and game elements are intentionally abstract. Designer ID 1, who worked in a 3D first-person shooter game company, saw this approach applied into a commercial game "when you strip down the fancy textures and graphics, commercial games still consist of elements moving around, large and small, fast and slow targets, medium size targets, small targets, slow targets, etc."

And finally, an attention based theoretical scaffolding provides opportunities to generate new patterns of game play. Understanding the player's patterns of attention is a topic often discussed in conjunction with navigable 3D environments [93,108,134,152]. Alternative theories of attention may be applied to consider new patterns of play in these environments as discussed by several game designers. For instance, the discussion by Bjork et al. [13] concerning distracting, swapping, or splitting the player's attention, or Lemarchand's [92] discussion of getting and holding attention, vigilance while executing tasks under stress, and attention bottlenecks. New attention based patterns of game play may be developed through experimental games in this way.

10.5. Future Work

10.5.1. Contexts for Toolset Enhancements

Future work can enhance the EMOS toolset through the introduction of additional perceptual features. For instance, an EMOS revision [103] allowed for the manipulation of motion trajectory, since these fixed features received much discussion from designers. Additional features in this revision that can be manipulated include brightness contrast, direction, wavy and angular speed, and shapes of motion. This version allows independent manipulation of elements, since target elements and ambient non-targets previously moved as a group in the EMOS game. Future work may consider evaluating the manipulation of color, brightness, and motion features simultaneously.

Future work may also consider applying the perception-based framework into a different genre game, and developing toolsets best suited to manipulate these designs. The current investigation only considered a game structure and task based on achievement play and skill mastery. There are many different kinds of game structures and play styles that can benefit from the development of new experimental games given this framework. This process allows for new perception-based guidelines. Of course, embedding this toolset into a commercial game is also possible, for instance in a game that includes more complex tasks, control modality, and intrinsic rewards. Much caution must be exercised here, as a number of constraints were needed even in a simple railed-shooter game. As was the case in the Chapter 5 Commercial Game Analysis, the camera constraint substantially influenced perceived difficulty, regardless of the perceptual features associated with elements. One could analyse moment-to-moment temporal segments of gameplay given well defined camera is constraints. Furthermore, evaluation within a commercial game requires triangulating gameplay performance metrics and the player’s physiological performance at a higher temporal resolution, as discussed in the next section.

10.5.2. Temporal Resolution and Pupillometry

The EMOS game changed perceptual features on a level-to-level basis, however the player engaged in the targeting task on a moment-to-moment basis. The summative analysis across levels could only identify general effects based on 5-level blocks and not a more detailed picture of the player's targeting behavior. For instance, further work could track the spatial and temporal patterns of mouse clicks to identify failed or successful strategies given certain perceptual conditions. This level of detail could inform designers whether the player's behave as expected.

Tools and techniques to support pupillometry visualization and integration with a gameplay logging framework are also needed, as was done for eye fixations and saccades in the context of games [156][113]. A contribution in this area should include tools for pupillometry noise reduction, for instance smoothing algorithms [84], and screen luminance metrics. Higher temporal resolution in pupillometry response allows more precise analysis of the player's game performance. For instance, related work that modeled the player's experience [117] did so in time increments of 0.25 and 1 second. In the context of the EMOS game, a higher pupillometry temporal resolution may allow an analyst to examine successful or failed patterns in the player's targeting strategy. This approach could obviously be strengthened through a combination of eye gaze and pupillometry at once.

10.5.3. Modeling the Player's Experience

The validation of perception-based guidelines is one step closer in a larger research effort to develop computational models of the player's experience. The work documented here demonstrated that visual features, their relationship to game elements, and impact on the player's experience must not be overlooked in sensory rich and dynamically changing designs. Models of the user's experience should include the visual aspects of the design, in addition to the rules or game structures. Since the guidelines are empirical, game researchers can expand upon this work to inform perception-based models of the player's experience, as was done for work that considered gameplay performance, the user's physiological affective states, and self-reports [100,112,117].

The process of validating guidelines can benefit from an additional review step by an expert game designer as an alternative to a purely empirical method of analysis [100,117]. For example, researchers may consider developing a system to dynamically adjust the difficulty of a visual scene given certain performance benchmarks, positive or negative effects on the player's experience.

11. References

1. Adams, E. *Fundamentals of Game Design*. New Riders, Berkeley, CA, 2009.

2. Alexander, C. *A Pattern Language: Towns, Buildings, Construction*. Hill and Wang, Oxford, 1961.

3. Alotto, B. How Level Designers Affect Player Pathing Decisions: Player Manipulation through Level Design. Master's Thesis. 2007.

4. Ambinder, M. Valves Approach To Playtesting. *Game Developers Conference*, San Francisco, 2009.

5. Atwood, M.E., McCain, K.W., and Williams, J.C. How Does the Design Community Think About Design? *Proceedings of Designing Interactive Systems (DIS)*, ACM (2002).

6. Bartle, R. Hearts, Clubs, Diamonds, Spades: Players who suit MUD's. In E. Zimmerman and K. Salen, eds., *The Game Design Reader: A Rules of Play Anthology*. MIT Press, Cambridge, MA, 2006.

7. Bartram, L. and Nakatani, A. What makes motion meaningful? Affective properties of abstract motion. *PSIVT '10 Proceedings of the 2010 Fourth Pacific-Rim Symposium on Image and Video Technology*, (2010).

8. Bartram, L., Ware, C., and Calvert, T. Moticons: detection, distraction and task. *International Journal of Human-Computer Studies 58*, 5 (2003), 515–545.

9. Bartram, L. and Ware, C. Filtering and Brushing with Motion. *Information Visualization 1*, 1 (2002), 66–79.

10. Bernhaupt, R. *Evaluating User Experience in Games: Concepts and Methods*. Springer, 2010.

11. Biesta, G.J.J. and Burbules, B.C. *Pragmatism and Educational Research*. Rowman & Littlefield Publishers Inc., New York, NY, 2003.

12. Bizzocchi, J. Games and Narrative, an Analytical Framework. *Loading Online Journal*, (2007).

13. Björk, S. and Holopainen, J. Games and Design Patterns. In E. Zimmerman and K. Salen, eds., *The Game Design Reader*. MIT Press, Cambridge, MA, 2006.

14. Block, B. *The Visual Story: Seeing the Structure of Film, TV, and New Media*. Focal Press, Boston, MA, 2001.

15. Boot, W., Blakely, D., and Simons, D.J. Do action video games improve perception and cognition? *Frontiers in Psychology 2*, 226 (2001).

16. Buchanan, R. Wicked Problems in Design Thinking. *Design Issues 8*, 2 (1992), 5–21.

17. Burgess, J. Building and Supporting Narrative Through Level Design. *Game Developers Conference*, (2010). San Francisco, CA.

18. Byrne, E. *Game Level Design*. Charles River Media, Hingham, MA, 2005.

19. Canossa, A. and Drachen, A. Play-Personas: Behaviours and Belief systems in User-Centred Game Design. Springer (2009).

20. Castel, A., Pratt, J., and Drummond, E. The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica 119*, 2 (2005), 217–230.

21. Chang, D., Dooley, L., and Tuovinen, J.E. Gestalt Theory in Visual Screen Design – A New Look at an Old Subject. *Seventh World Conference on Computers in Education*, Australian Computer Society Inc. (2002).

22. Ching, F. *Form, Space & Order*. Van Nostrand Reinhold, New York, 1996.

23. Church, D. Formal Abstract Design Tools. In E. Zimmerman and K. Salen, eds., *The Game Design Reader: A Rules of Play Anthology*. MIT Press, Cambridge, MA, 2006.

24. Clinton, K. *Agile game development with Scrum*. Addison-Wesley, Upper Saddle River, N.J, 2010.

25. Creswell, J. and Clark, V. *Designing and Conducting Mixed Methods Research*. Sage Publications, London, 2007.

26. Creswell, J. *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. Sage Publications, Thousand Oaks, CA, 2006.

27. Csikszentmihalyi, M. *Flow: The Psychology of Optimal Experience*. Harper Perennial, New York, 1991.

28. Dalsgaard, P., Halskov, K., and Harrison, S. Supporting Reflection In and On Design Processes. *Proceedings of Designing Interactive Systems (DIS)*, ACM (2012).

29. Damásio, A. *Descartes' Error: Emotion, Reason, and the Human Brain*. Putnam Publishing, 1994.

30. Desurvire, H., Caplan, M., and Toth, J.A. Using heuristics to evaluate the playability of games. ACM-SIGCHI (2004).

31. Desurvire, H. and Wiberg, C. User Experience Design for Inexperienced Gamers: GAP - Game Approachability Principles. In *Evaluating User Experiences in Games*. Springer-Verlag, London, 2010.

32. Dormans, J. Engineering Emergence: Applied Theory for Game Design, Doctoral Thesis. 2012.

33. Drachen, A. and Canossa, A. Towards Gameplay Analysis via Gameplay Metrics. *Proceedings of MindTrek*, ACM (2009).

34. Duncan, J. and Humphreys, G.W. Visual search and stimulus similarity. *Psychological Review 96*, 3 (1989), 433–458.

35. Dunlop, B. *Building a Dream, the Art of Disney Architecture*. Harry N. Abrams Inc, New York, 1996.

36. Erfani, M., Seif El-Nasr, M., Milam, D., et al. The Effect of Age, Gender, and Previous Gaming Experience on Game Play Performance. *Human-Computer Interaction 332*, (2010), 293–296.

37. Ermi, L. and Mayra, F. Fundamental Components of the Gameplay Experience: Analyzing Immersion. In S. Castell and J. Jenson, eds., *Worlds in Play, International Perspectives on Digital Games Research*. Peter Lang, New York, 2007, 37–53.

38. Findeli, A. Moholy-Nagy's Design Pedagogy in Chicago. In V. Margolin and R. Buchanan, eds., *The Idea of Design, A Design Issues Reader*. 1995, 29–43.

39. Fisher, B., Fels, S., MacLean, K., Munzner, T., and Rensink, R. Seeing, Hearing, and Touching: Putting It All Together. .

40. Fleck, R. and Fitzpatrick, G. Reflecting on Reflection: Framing a Design Landscape. *Proceedings of OZCHI*, ACM (2010).

41. Frayling, C. Research Paper 1. In *Research in Art and Design*. Royal College of Art, 1993.

42. Freeman, D. *Creating Emotion in Games*. New Riders, Boston, MA, 2003.

43. Freitas, S. de and Maharg, P., eds. *Digital Games and Learning*. Continuum International Publishing Group, London, 2011.

44. Friedman, K. Theory construction in design research: criteria: approaches, and methods. *Design Studies 24*, (2003), 507–522.

45. Fullerton, T., Swain, C., and Hoffman, S. *Game Design Workshop, designing, prototyping, and playtesting games*. CMP Books, San Francisco, CA, 2004.

46. Fulton, B. The ABC Framework: Understanding and Measuring Human Experiences. *Foundations of Digital Games Workshop on Play Experience*, (2012).

47. Gamma, E., Helm, R., Johnson, R., and Vlissides, J. *Design Patterns - Elements of Reusable object oriented software*. Addison-Wesley, USA, 1994.

48. Gaver, W. What Should We Expect From Research Through Design? *CHI Proceedings*, ACM (2012).

49. Gee, J. *What Video Games Have to Teach Us About Learning and Literacy*. Palgrave Macmillan, New York, 2003.

50. Gibson, E.J. and Pick, A.D. *Ecological Approach to Perceptual Learning and Development*. Oxford University Press, Cary, NC, 2003.

51. Gibson, J. *The Ecological Approach to Visual Perception*. Houghton Mifflin, Boston, 1979.

52. Gordon, I.E. *Theories of Visual Perception*. Psychology Press, New York, NY, 2004.

53. Granholm, E. and Steinhauer, S., eds. Pupillometric measures of cognitive and emotional processes. *International Journal of Psychophysiology 52*, 1 (2004).

54. Green, S. and Bavelier, D. Action video game modifies visual selective attention. *Nature 423*, (2003), 4.

55. Green, S. and Bavelier, D. Effect of Action Video Games on the Spatial Distribution of Visuospatial Attention. *Journal of Experimental Psychology: Human Perception and Performance 32*, 6 (2006), 1465–1478.

56. Green, S., Li, R., and Bavelier, D. Perceptual Learning During Action Video Game Playing. *Topics in Cognitive Science 2*, 2 (2009), 15.

57. Griesemer, J. Useful Research: Recommendations Designers will Actually Act on. *Games User Research Summit*, (2010). San Francisco, CA.

58. Grodal, T. Video Games and the Pleasure of Control. In D. Zillmann, ed., *Media Entertainment: The Psychology of its Appeal*. Lawrence Erlbaum Associates, New Jersey, 2000.

59. Hart, S. NASA-Task Load Index (NASA-TLX); 20 Years Later. *Proceedings of the Human Factors and Ergonomics Society*, (2006), 904–908.

60. Hart, S.G. and Staveland, L.E. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In A. Hancock and N. Meshkati, eds., *Human Mental Workload*. North Holland Press, Amsterdam, 1988.

61. Hashimoto, A. and Clayton, M. *Visual Design Fundamentals: A Digital Approach, Third Edition*. Course Technology PTR, Boston, MA, 2009.

62. Heeter, C., Lee, Y.-H., Medler, B., and Magerko, B. Beyond Player Types: Gaming Achievement Goals. *Proceedings of SIGGRAPH Players and Game Worlds*, ACM (2011).

63. Heeter, C. Play Styles and Learning. In R.E. Ferdig, ed., *Handbook of Research on Effective Electronic Gaming in Education*. IGI Global, 2008.

64. Henriette, H. Let the Game Tester do the Talking: Think aloud and Interviewing to learn about the Game Experience. In K. Isbister and N. Schaffer, eds., *Game Usability: Advice from the Experts for Advancing the Player Experience*. Morgan Kaufmann, San Francisco, CA, 2008.

65. Hoeg, T. The Invisible Hand: Using Level Design Elements to Manipulate Player Choice. Master's Thesis. 2008. Guildhall at Southern Methodist University, TX.

66. Huber, D. and Healey, C. Visualizing Data with Motion. *Visualization*, IEEE (2005), 527–534.

67. Hubert-Wallander, B., Green, S., and Bavelier, D. Stretching the limits of visual attention: the case of action video games. *Cognitive Science 2*, 2 (2010).

68. Hullett, K.M. The Science of Level Design: Design Patterns and Analysis of Player Behavior in First-Person Shooter Levels. Doctoral Thesis. 2012. University of California Santa Cruz, CA.

69. Huniche, R., LeBlanc, M., and Zubek, R. MDA: A formal approach to game design and game research. *AAAI Workshop on Challenges in Game AI*, AAAI Press (2004).

70. Huniche, R. The case for dynamic difficulty adjustment in games. *Proceedings of the ACM SIGCHI International Conference on advances in computer entertainment technology,* ACM (2005).

71. IJsselsteijn, W., Poels, K., and De Kort, Y.A.W. The Game Experience Questionnaire: Development of a self-report measure to assess player experiences of digital games. Fun of Gaming (FUGA) workshop. 2008.

72. Isbister, K., Flanagan, M., and Hash, C. Designing Games for Learning: Insights from Conversations with Designers. *CHI Proceedings*, ACM (2010).

73. Isbister, K. and Schaffer, N., eds. *Game Usability: Advice from the Experts for Advancing the Player Experience*. Morgan Kaufmann, San Francisco, CA, 2008.

74. Isbister, K. *Better Game Characters by Design: A Psychological Approach*. Morgan Kaufmann, Burlington, MA, 2006.

75. Itti, L., Koch, C., and Niebur, E. A model of saliency-based visual attention for rapid scene analysis. *Pattern Analysis and Machine Intelligence, IEEE Transactions on 20*, 11 (1998), 1254–1259.

76. Janisse, P. Pupil Size, Affect, and Exposure Frequency. *Social Behavior and Personality 2,* 2 (1974), 125–146.

77. Jenkins, H. Game Design as Narrative Architecture. In E. Zimmerman and K. Salen, eds., *The Game Design Reader*. MIT Press, Cambridge, MA, 2004.

78. Juul, J. *Half-Real: Video Games between Real Rules and Fictional Worlds*. MIT Press, Cambridge, MA, 2005.

79. Kenny, A., Koesling, H., Delaney, D., McLoone, S., and Ward, T. A Preliminary Investigation into Eye Gaze Data in a First Person Shooter Game. *19th European Conference on Modelling and Simulation*, IEEE (2005).

80. Kim, J., Gunn, D., Schuh, E., Phillips, B., Pagulayan, R., and Wixon, D. Tracking real-time user experience (TRUE): a comprehensive instrumentation solution for complex systems. *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems,* ACM (2008), 443–452.

81. Kingstone, A. and Bischof, W.F. Perceptual grouping and motion coherence in visual search. *Psychological Science 10,* 2 (1999), 151–156.

82. Klimmt, C., Blake, C., Hefner, D., Vorderer, P., and Roth, R. Player Performance, Satisfaction, and Video Game Enjoyment. In *Entertainment Computing – ICEC 2009*. Springer, Heidelberg, 2010.

83. Klimmt, C. and Hartmann, T. Effectance, self-efficacy, and the motivation to play video games. In P. Vorderer and J. Bryant, eds., *Playing video games: Motives, responses, and consequences*. Lawrence Erlbaum Associates, Mahwah, 2006, 132–145.

84. Klingner, J. Measuring cognitive load during visual search task by combining pupillometry and eye tracking, Doctoral Thesis. 2010.

85. Koster, R. *A Theory of Fun for Game Design*. Paraglyph Press, Scottsdale, AZ, 2004.

86. Lang, P. The emotion probe. *American Psychologist, 50*, 5 (1995), 372–385.

87. Lankoski, P. and Björk, S. Theory Lenses: Deriving Gameplay Design Patterns from Theories. *Proceedings of MindTrek*, ACM (2011).

88. Laurel, B., ed. *Design Research*. MIT Press, Cambridge, MA, 2003.

89. Lavie, N. Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences 9*, 2 (2005).

90. Lazzaro, N. The Four Keys to Fun: Designing Emotional Engagement and Viral Distribution without Spamming Your Friends. 2009.

91. LeBlanc, M. Tools for Creating Dramatic Game Dynamics. In E. Zimmerman and K. Salen, eds., *The Game Design Reader: A Rules of Play Anthology*. MIT Press, Cambridge, MA, 2006.

85. Lemarchand, R. Attention NOT Immersion: Making your games better with psychology and playtesting, the Uncharted Way. *Game Developers Conference*, San Francisco, 2012.

93. Linderoth, J. Why gamers don't learn more: an ecological approach to games as learning environments. *Journal of Gaming and Virtual Worlds 4*, 1 (2012).

94. Lockyer, M., Bartram, L., and Riecke, B. Simple Motion Textures for Ambient Affect. *Computational Aesthetics*, ACM (2011).

95. Loftus, G.R. and Loftus, E.F. *Mind at Play: The Psychology of Video Games*. Basic Books Inc., New York, NY, 1983.

96. Logas, H. Mise-en-scène Applied to Level Design: Adapting a Holistic Approach to Level Design. *Proceedings of Digital Games Research Association (DIGRA)*, (2005).

97. Lunenfeld, P. The Design Cluster. In *Design Research: Methods and Perspectives*. MIT Press, Cambridge, MA, 2003, 63–69.

98. Lynch, K. *The Image of the City*. MIT Press, Cambridge, MA, 1960.

99. Malone, T.W. *What Makes Things Fun to Learn: A Study of Intrinsically Motivating Video Games*. XEROX Palo Alto Research Centre, Palo Alto, CA, 1980.

100. Mandryk, R. and Atkins, S. A Fuzzy Physiological Approach for Continuously Modeling Emotion during Interaction with Play Technologies. *International Journal of Human-Computer Studies 6*, 4 (2007), 329–347.

101. Mateas, M. and Stearn, A. Procedural Authorship: A Case-Study Of the Interactive Drama Façade. (2005).

102. Meier, S. The Psychology of Game Design (Everything You Know Is Wrong). 2010.

103. Milam, D., Seif El-Nasr, M., Bartram, L., Lockyer, M., Feng, C., and Tan, P. Toolset to explore visual motion designs in a video game. *SIGCHI extended abstract*, (2012).

104. Milam, D., Seif El-Nasr, M., Bartram, L., Upton, F., Aghabeigi, B., and Tan, P. Evaluation of visual motion game from eye fixation and pupillometry metrics. *Proceedings of Foundations of Digital Games (FDG)*, ACM (2012).

105. Milam, D., Seif El-Nasr, M., and Wakkary, R. Looking at the Interactive Narrative Experience through the Eyes of the Participants. *1st Joint International Conference on Interactive Digital Storytelling*, (2008), 96–107.

106. Milam, D. and Seif El-Nasr, M. Design Patterns to Guide Player Movement in 3D Games. *SIGGRAPH*, (2010).

107. Milham, I. Creating Horror and Immersion with the Art of Dead Space. Game Developers Conference (2011), San Francisco, CA.

108. Moura, D., Seif El-Nasr, M., and Chaw, C. Visualizing and Understanding Players' Behavior in Video Games: Discovering Patterns and Supporting Aggregation and Comparison. *SIGGRAPH*, ACM (2011).

109. Murray, J. *Hamlet on the Holodeck, The Future of Narrative in Cyberspace*. MIT Press, Cambridge, MA, 1997.

110. Myers, D. *The nature of computer games: play as semiosis*. P. Lang, New York, 2003.

111. Nacke, L., Lindley, C., and Stellmach, S. Log Who's Playing: Psychophysiological Game Analysis Made Easy through Event Logging. In *Fun and Games*. 2008, 150–157.

112. Nacke, L. and Lindley, C. Affective Ludology, Flow and Immersion in a First-Person Shooter: Measurement of Player Experience. *Loading Online Journal 3*, 5 (2009).

113. Nacke, L., Stellmach, S., Sasse, D., Niesenhaus, J., and Dachselt, R. LAIF: A logging and interaction framework for gaze-based interfaces in virtual entertainment environments. *Entertainment Computing 2*, (2011), 265–273.

114. Neisser, U. *Cognitive Psychology*. Prentice Hall, 1967.

115. Niedenthal, S. Complicated Shadows: The Aesthetic Significance of Simulated Illumination in Digital Games. Doctoral Thesis. 2009.

116. Nielsen, J. Heuristic evaluation. In J. Nielsen and R.L. Mack, eds., *Usability Inspection Methods*. John Wiley & Sons, New York, NY, 1994.

117. Noor, S., Yannakakis, G., and Togelius, J. Crowd-Sourcing the Aesthetics of Platform Games. *IEEE Transactions on Computational Intelligence and AI in Games,* (2012), 17.

118. Norman, D. Twelve Issues for Cognitive Science. *Cognitive Science 4*, (1980), 1–32.

119. Norman, D. *The design of everyday things*. Basic Books, Norwood, Mass, 2002.

120. Pagulayan, R., Keeker, K., Thomas, F., Wixon, D., and Romero, R. User Centered Design in Games. In A. Sears and J. Jacko, eds., *Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications*. Lawrence Erlbaum Associates, New York, 2008.

121. Pagulayan, R., Steury, K., Fulton, B., and Romero, R. Designing for fun: User-testing case studies. In A. Monk and P. Wright, eds., *Funology: From Usability to Enjoyment*. Kluwer Academic Publishers, Norwell, MA, 2003, 137–150.

122. Partala, T. and Surakka, V. Pupil size variation as an indication of affective processing. *Int. J. Human-Computer Studies 59*, (2003), 183–185.

123. Petrillo, F., Pimenta, M., Trindade, F., and Dietrich, C. Houston, we have a problem...: a survey of actual problems in computer games development. *Symposium on Applied Computing (SAC)*, ACM (2008), 707–711.

124. Picard, R.W. *Affective Computing*. Technical Report No. 321: M_I_T Media Laboratory Perceptual Computing Section, Cambridge, MA, 1995.

125. Picard, R.W. *Affective Computing*. MIT Press, Cambridge, MA, 1997.

126. Pinelle, D., Wong, N., and Stach, T. Heuristic Evaluation for Games: Usability Principles for Video Game Design. *CHI Proceedings*, ACM-SIGCHI (2008).

127. Pook, G. Information Processing vs. Pupil Diameter. *Perceptual and Motor Skills 37*, (1973), 1000–1002.

128. Poundstone, W. Game Theory. In K. Salen and E. Zimmerman, eds., *The Game Design Reader: A Rules of Play Anthology*. MIT Press, Cambridge, MA, 2006.

129. Pruitt, J. and Grudin, J. Personas: practice and theory. *Proceedings of the 2003 conference on Designing for user experiences*, ACM (2003).

130. Purpura, S. Overview of Quantitative Methods in Design Research. In B. Laurel, ed., *Design Research: Methods and Perspectives*. MIT Press, Cambridge, MA, 2003, 63–69.

131. Rebetez, C. Rapid Reporting. *Game User Research Summit*, (2012).San Francisco, CA.

132. Rigby, S. and Richards, R.M. *Glued to games: how video games draw us in and hold us spellbound*. Praeger, Santa Barbara, CA, 2011.

133. Rodriguez, A. and Steiner, K. Exploring Eye Tracking for Games User Research: A case study of lessons learned. 2010. http://tiny.cc/g35wz.

121. Rogers, S. Everything I Learned About Level Design I Learned from Disneyland. *Game Developers Conference*, San Francisco, 2009.

135. Rouse III, R. *Game design: theory & practice*. Wordware Publishing, Inc., Plano, TX, 2005.

136. Rouse III, R. Cinematic Game Design, Game Developers Conference, San Francisco. 2006.

125. Rouse III, R. Environmental Narrative: Your World Is Your Story. *Game Developers Conference*, San Francisco, 2010.

138. Ryan, W. and Siegel, M.A. Evaluating Interactive Entertainment using Breakdown: Understanding Embodied Learning in Video Games. *Breaking New Ground: Innovation in Games, Play, Practice and Theory*, DIGRA (2009).

139. Salen, K. and Zimmerman, E. *Rules of Play: Game Design Fundamentals*. MIT Press, Cambridge, MA, 2004.

140. Samarinas, A. Illuminating Minotaur's Lair: Light Design and Navigation in Gameworlds. Master's Thesis. 2009. IT University of Copenhagen

141. Schön, D. *The Reflective Practitioner*. Basic Books Inc., 1983.

142. Schuytema, P. *Game Design: A Practical Approach*. Charles River Media, Boston, 2007.

143. Seif El-Nasr, M., Drachen, A., and Canossa, A., eds. *Game Analytics: Maximizing the Value of Player Data*. Springer-Verlag, 2013.

144. Seif El-Nasr, M. and Yan, S. Visual Attention in 3D Video Games. *SIGCHI international conference on Advances in computer entertainment technology*, ACM (2006).

145. Seif El-Nasr, M. Automatic Expressive Lighting for Interactive Scenes. Doctoral Dissertation. 2003. Northwestern University, Evanston, IL.

146. Seif El-Nasr, M. Interaction, Narrative, and Drama Creating an Adaptive Interactive Narrative using Performance Arts Theories. *Journal of Interaction Studies 8*, (2007), 209–240.

147. Sherry, L. and Lucas, K. Video Games Uses and Gratifications as Predictors of Use and Game Preference. In B. Greenberg and K. Lachlan, eds., *Playing video games: Motives, responses, and consequences*. Lawrence Erlbaum Associates, Mahwah, 2006, 132–145.

148. Shirinian, A. Dissecting The Postmortem: Lessons Learned From Two Years Of Game Development. *Gamasutra Online Magazine*, 2008, 4.

149. Sijing and Ian, S. Playing shooter and driving videogames improves top-down guidance in visual search. *Attention, Perception, & Psychophysics,* (2013).

150. Simons, D.J. Current Approaches to Change Blindness. *Visual Cognition 7*, 1-3 (2000), 1–15.

151. Smith, G. Tanagra: An Intelligent Level Design Assistant for 2D Platformers. *Proceedings of the Conference on Artificial Intelligence and Interactive Digital Entertainment (AIIDE),* (2010).

139. Smith, H. and Worch, M. What Happened Here? Environmental Storytelling. *Game Developers Conference,* San Francisco, 2010.

140. Smith, R. Helping Your Players Feel Smart: Puzzles as User Interface. *Game Developers Conference*, San Francisco, 2009.

154. Soraci, S. and Murata Soraci, K., eds. *Visual Information Processing*. Praeger Publishers, London, 2003.

155. Stapleton, A. Research as Design-Design as Research. *Proceedings of Digital Games Research Association (DIGRA),* (2005).

156. Stellmach, S., Nacke, L., and Dachsel, R. Advanced Gaze Visualizations for Three-dimensional Virtual Environments. *Proceedings of ETRA*, ACM (2010).

157. Straley, B. and Druckmann, N. Creating the cinematic experience of Uncharted 2. *Game Developers Conference*, (2010).

158. Sundstedt, V., Debattista, P., Longhurst, P., and Chalmers, A. Visual Attention for Effcient High-Fidelity Graphics. *Proceedings of the 21st spring conference on Computer graphics (SCCG)*, ACM (2005), 169–175.

159. Sundstedt, V. Gazing at Games: Using Eye Tracking to Control Virtual Characters. *Proceedings of SIGGRAPH*, ACM (2010).

160. Swann, C. Action Research and the Practice of Design. *Design Issues 18*, 1 (2002), 49–61.

161. Sweetser, P., Johnson, D., Ozdowska, A., and Wyeth, P. GameFlow heuristics for designing and evaluating real-time strategy games. *Proceedings of the 8th Australasian Conference on Interactive Entertainment: Playing the System*, ACM (2012).

162. Sweetser, P. and Wyeth, P. GameFlow: A Model for Evaluating Player Enjoyment in Games. *ACM Computers in Entertainment (CIE) 3*, 3 (2005).

163. Sweller, J., Van Merrienboer, J.J.G., and Paas, F.G.W.C. Cognitive Architecture and Instructional Design. *Educational Psychology Review 10*, 3 (1998), 46.

164. Tavinor, G. *The Art of Videogames*. Wiley, Malden, MA, 2009.

165. Treisman, A.M. and Gelade, G. A feature-integration theory of attention. *Cognitive Psychology 12*, 1 (1980), 97–136.

166. Tsai, Y.-F., Viirre, E., Strychacz, C., Chase, B., and Jung, T.-P. Task Performance and Eye Activity: Predicting Behavior Relating to Cognitive Workload. *Aviation, Space, and Environmental Medicine 78*, 5 (2007).

167. Tufte, E. *Envisioning Information*. Graphics Press, Cheshire, Connecticut, 1990.

168. Tullis, T. and Albert, B. *Measuring the User Experience: Collecting Analyzing, and Presenting Usability Metrics*. Morgan Kaufmann, Burlington, MA, 2008.

169. Upton, B. Narrative Landscapes: Shaping Player Experience through World Geometry. *Game Developers Conference*, (2007).

170. Vlachos, A. Water Flow in Portal 2. *SIGGRAPH Course on Advances in Real-Time Rendering in 3D Graphics and Games*, (2010).

171. Ward, P. *Picture Composition*. Focal Press, San Francisco, 2003.

172. Ware, C. *Visual thinking for design*. Morgan Kaufmann Publishers, San Francisco, CA, 2008.

173. Wertheimer, M. Untersuchen zur lehre von der Gestalt [Laws of Organization in Perceptual Forms]. *Psychologische Forschung [Psychological Research] 4*, 1 (1923), 301–350.

174. White, J. Shooting in San Vanelona: the Visuals of EA's Skate. 2009.Game Developers Conference Canada, Vancouver, BC.

175. Wolf, J. Guided Search 2.0: A revised model of visual search. *Psychonomic Bulletin & Review 1*, 2 (1994), 202–238.

176. Yu-Fei, M. and Hong-Jiang, Z. Contrast-based Image Attention Analysis by Using Fuzzy Growing. *Proceedings of the eleventh ACM international conference on Multimedia*, ACM (2003).

177. Zagal, J., Ladd, A., and Terris, J. Characterizing and Understanding Game Reviews. *International Conference On The Foundations Of Digital Games*, ACM (2009).

178. Zimmerman, E. Play as Research. In B. Laurel, ed., *Design Research: Methods and Perspectives*. MIT Press, Cambridge, MA, 2003.

179. Zimmerman, J., Erik, S., and Jodi, F. An Analysis and Critique of Research through Design: towards a formalization of a research approach. *Conference on Designing Interactive Systems (DIS)*, ACM (2010).

180. Zimmerman, J., Forlizzi, J., and Evenson, S. Research Through Design as a Method for Interaction Design Research in HCI. *CHI Proceedings*, ACM (2007).

181. Zupko, J. System for Automated Lighting. Doctoral Thesis. 2009.

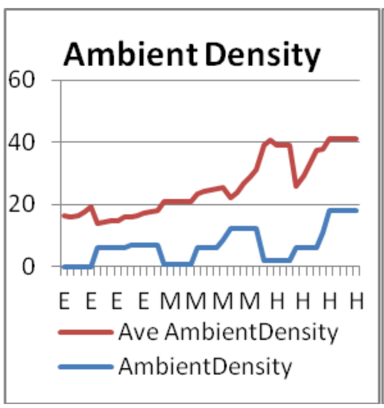
Appendices

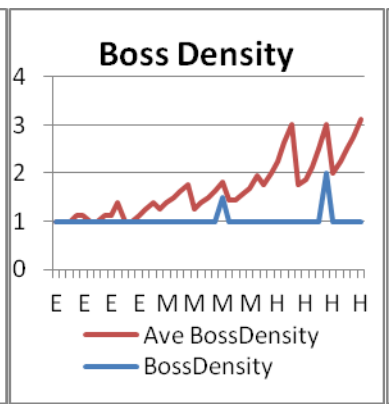
Appendix A.

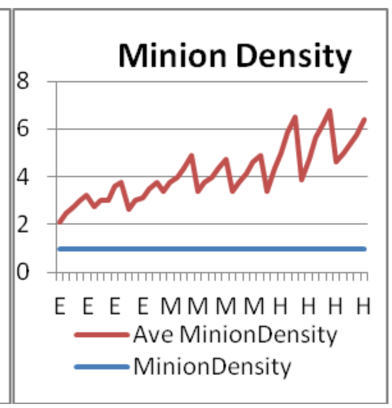
Example Verification of EMOS Toolset Results (ID 8)

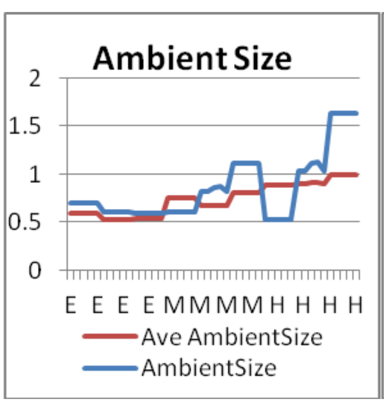
Verification Step 1 Review Group Average

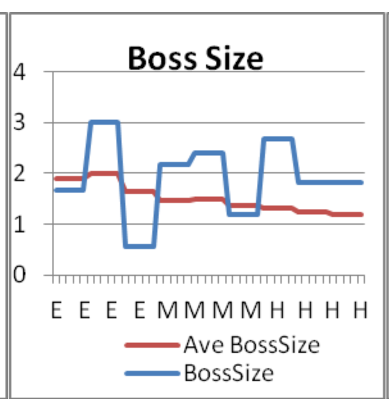
Hello ID8, I want to summarize the feedback and trends that I found in my study. This should only take a few minutes to review and then complete two verification steps. Briefly, the project goal was to define values for the density, size, and visual feedback for game targets and distractions. I was particularly interested in what way expert selections changed between novice and expert settings. Please review the following summary and charts and reply to this message in regards to the accuracy of the findings. E= Easy M=Intermediate and H=Hard difficulty setting. The charts include your selections (in blue) in comparison to the group (in red). Additional comments are welcome but not required.

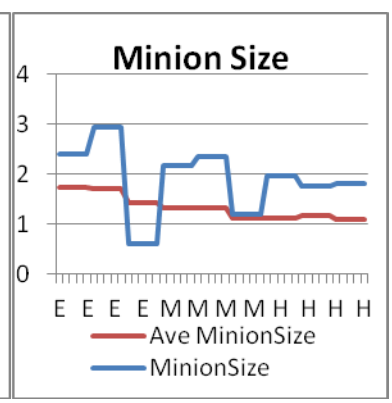


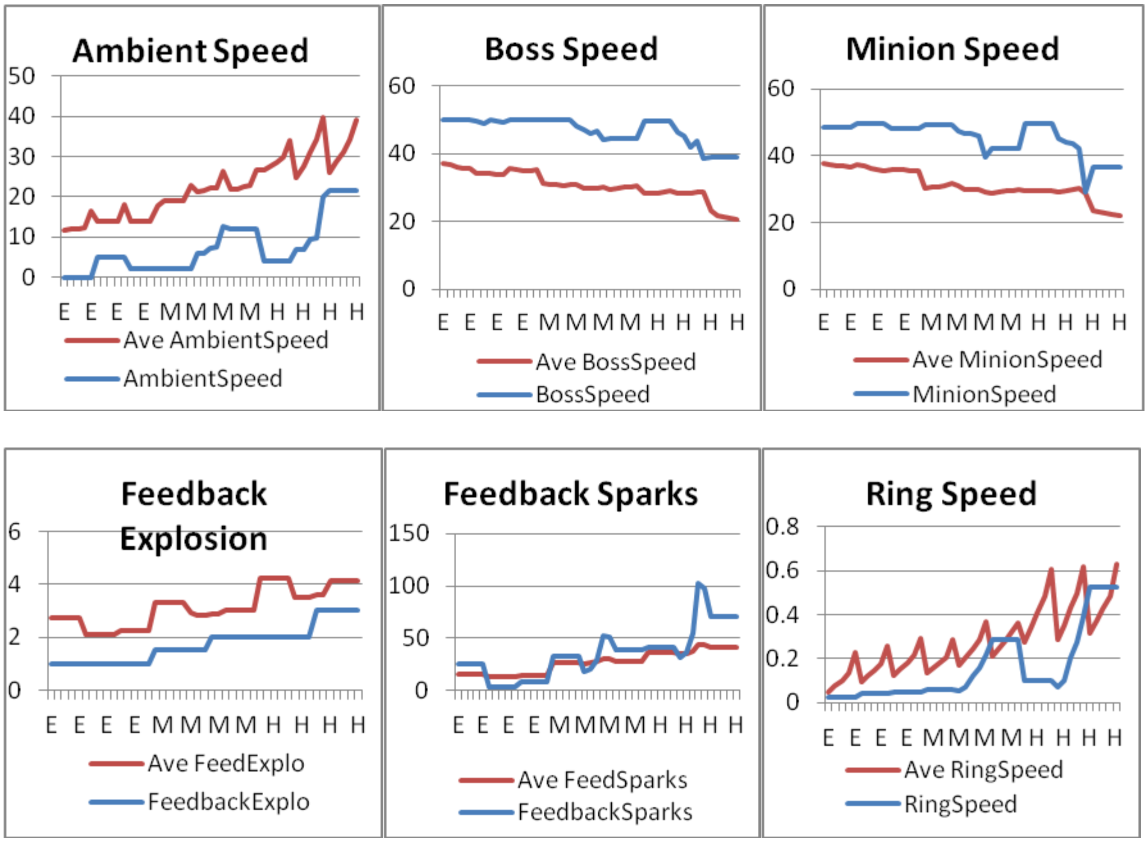












- I expected the density and speed to increase, and size to decrease as a measure of difficulty.

- Your selections agreed with the group, however, the values are skewed to be easier overall in the expert setting. For example, you have a lower density, slower speed, and often a larger target size.

- In addition, I was surprised to find that 7 of 8 experts reduced the target speed in the expert setting, rather than increase it.

Verification Step 2 Review Trend Summary

In addition, I identified three trends the group used to increase difficulty:

1. Increase Similarity: When features of game targets and distractions become more similar, they become more difficult to tell apart. You applied similarity in the following way:

    a. Between Targets and non-target elements (ambient) speed

    b. Between Targets and non-target elements (ambient) size

2. Add Challenge Ramps: Rather than a gradual and predictable increase in difficulty, periodic ramping allows for large intensity peaks, followed by easy valleys.

    a. You did not apply ramps. The Boss density has small peaks, yet these are not periodic.

3. Add Visual Noise: The amount of additional non-targets on the screen, including ambient density and visual feedback, which adds to the "clutter". You added noise in the following way:

    a. For ambient Density, Visual feedback sparks, and explosions

Verification Step 3 Review "New Configuration" based on Group Average

Although there may be disagreements in your response and the group response, please review the "new configuration" file, which contains the group average settings (red line on the pdf chart). [web link to playable game]

Please state whether you believe this new configuration still satisfies the project goal above. Any additional comments, in preparation for a large user study evaluating player's attitudes and behaviours, are also welcome but not required.