Colorblind computer gaming

Simplifying the design of accessible games

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This thesis corresponds to 20 weeks of full-time work for each of the authors.

Summary. This thesis defines a model for evaluating games from a disability perspective by categorizing them and identifying their key problem areas. These issues are then broken down into their constituting components and examined from an HCI perspective. Existing color blind design principles are combined with HCI principles to provide design patterns to be used by computer game developers who wish to design color blind adapted games. The model used in this thesis can also be used for further research into other areas of disability.
Keywords: Games, color blind, disability

Contents

List of Figures

List of Tables

❖ 1

Introduction

Equal accessibility should be a strong driving force within societies with a strong reliance on information technology. Computers and their applications have made life easier by supplying a grand plethora of services and options for the common user.

1.1 Background

It is claimed that around 25% of all Swedes suffer from some sort of disability, ranging from reduced hearing to severely limited mobility (Brundell and Eliasson 2005). A large part of public services (libraries, web sites) are tooled to meet the particular needs brought on by disabilities - such as access ramps for physical buildings or properly scaling contents for web sites.

The entertainment sector has long been using various tools to help people with disabilities by for example using subtitles on movies or releasing books on CD.

We believe that one of the primary tasks for a modern society is to reduce (or better yet eliminate) the gap between a disabled and non-disabled people. In essence, a disabled person should be able to do all the things a non-disabled person can do.

One of the more common disabilities today is color blindness - a disability which affects 8-9% (around 8.3% for males and around 0.5% for females) of the the american population (Robinson et al. 1997). We have assumed that the statistics are representative for the rest of the western world. While color blindness is not as visible as for example full body paralysis, it is a legitimate disability - and more restrictive than one might think. For example, it is quite common to not be able to perceive a red ball on a grass lawn.

One of the things that made us choose to work with color blindness was its prevalence, along with the fact that it does not require players to use special input devices etcetera. In short the way the game is played is more likely to be unchanged, which would not be the case if one would research games for people with mobility-

related disabilties. On top of this color blindness is currently neither curable nor directly mitigatable (unlike for example nearsightedness, which can be corrected with special lenses).

1.2 Problem

One area where the disability discrepancy is very visible is computer gaming. Games are, like books and movies, a popular form of entertainment - and the fact that they are less adapted for people with disabilities is a rather interesting disparity.

We intend to show that disability adaption of computer games is by no means impossible, and the rules and standards laid down by the International Game Developers Association (IGDA) are very possible to implement. To illustrate this, we would like to analyze a few popular games and present the particular problems color blind computer gamers might encounter while playing them. We will also present possible ways to alleviate these issues.

The intended user base of these games have a large number of people with a certain disability - namely color blindness. According to Dataspelsbranchen's 2007 survey, at least half of the Swedish population play games on a regular basis, and half of the gamers are male (Dataspelsbranchen 2008). As such the issue of color blind gaming is especially relevant for the field - given that up to 8-9% of the intended user base may suffer from a handicap which can deduct from their overall experience and performance.

Furthermore, we would like to research how (if at all) the user's themselves work to improve the situation at hand.

1.3 Problem description

What problems do color blind gamers face, and how does the development community act in regard to these problems?

We have found that there is a lack of a model for categorizing and identifying accessibility problem factors for computer games. How does one identify issues within these games?

Furthermore we can find no design patterns pertaining to the design of color blind accessible computer games. What issues related to color blindness might be encountered, and how does one solve these?

1.4 Delimitations

We do not intend to create a better game, but to research and expand on the adaptation of current games to better suit color blind gamers.

1.5 Purpose

Our primary purpose with this thesis is to present a possible solution set to help facilitate the continued proliferation of color blind computer games.

We intend to pinpoint how game developers (professionals as well as amateurs or fans) regard these problems, and how the community thinks they may be alleviated. Furthermore we want to concretisize the process of identifying the aforementioned issues.

On a more utilitarian plane we want to shed light on the situation color blind gamers face, and show how these issues differentiate them from the gamer community as a whole.

1.6 Goals

The main goal of this thesis is to produce a set of design patterns which facilitate the design and implementation of color blind accessible games.

To achieve this we will develop a analysis model where different games can be categorized and analyzed according to certain accessibility criteria. This model is in essence a composite of two sub-models - one which categorizes a game based on its genre characteristics and one which identifies interaction characteristics (also called *foci*) within that game.

Furthermore, we intend to expose the results of this analysis to public scrutiny via a community process, thus improving quality by gathering data from a broader experience base.

1.6.1 Goal fulfillment

Our main goal, the design patterns, are considered done when they exist as a product of the described steps - they are in essence a proof of concept. The facilitating conditions, however, have more stringent demands for completion.

The community portion of our method is complete when it has run it is course. All responses (including none at all) are to be considered a legitimate result. We intend to use the respondents' answers to improve our patterns, provided that we get any.

Our models have to be able to properly categorize and analyze computer games. In detail, our genre characterization model can be said to be complete when we have characterized the different genres outlined below. Our second matrix, the color blind characterizing model, is complete when we have analyzed our chosen games.

The genre characterizations are complete when we have established them according to previous literature as well as subjected them to the scrutiny of peer review. The same peer review process is also used to determine how severe a certain

issue is. Since these factors contribute to the data used to choose problems to address with design patterns they are, as said above, a stepping stone for our final product.

1.7 Target audience

The target audience for this thesis are game designers who may have use for our results when designing games. A second target audience are other researchers who may need a method for categorizing and analyzing games.

1.8 Methodology

1.8.1 Research design

Choosing games

Choosing games for an analysis such as this is always tricky, but to broaden our potential respondent base we have chosen games that are or were top sellers and which have gotten good reviews (these two factors are more often than not orthogonal). In keeping with the previous reasoning we have tried to choose games which are (or were) relatively mainstream, thus eschewing more esoteric games such as “18 Wheels of Steel Haulin” (a truck-driving simulator) or “Deer Hunter” (hunting simulator). We have also tried to keep an even spread across genres, such as they are defined by Andrew Rollings and Ernest Adams in “On Game Design” (Rollings and Adams 2003). To simplify our information gathering process (detailed below) we have limited ourselves to games on the Windows platform.

We have evaluated these games (see 4.1) by playing them and taking screenshots of situations where colors convey some crucial meaning (for example green for friendly units and red for enemies). We later ran the screenshots through the VisCheck Photoshop plugin (Dougherty and Wade 2008), which emulates different sorts of color blindness. In cases where we discovered clear color blindness issues (for example not being able to tell friendly and enemy units apart) we added the game in question to our list. We later gathered these issues on a per game basis, and ordered the games by the number of issues they suffer from - with the most affected ones being the most prioritized.

For efficiency we have decided to limit our methodology to testing for dichromatic (protanopia, deuteranopia and tritanopia) issues. This is due to the fact that monochromacy is very rare, and that the various trichromacy conditions create the same effects as dichromatic conditions, but to a lesser degree.

Once this data was gathered we compared the issues identified to issues defined in existing accessibility guidelines. Unfortunately, we were unable to find any such pertaining to color blind computer gaming in particular. We did, however, find guidelines for the web and for application interfaces. We decided to collate a few different accessibility standards, each with a different focus (for example desktop applications and web content), and chose to focus on the points where they intersect. We then applied these common "rules" to the special case of computer games.

Using these guidelines as a basis for our reasoning, we identified a few problem categories - each representing a different characteristic of the game genre. An example foci might be the "Twitch" foci, which is how well the game allows players to perform rapid movements based on hand-eye coordination. If one is unable to react properly - players with better reaction skills will be at an advantage. These foci are outlined in detail in chapter 4.

These given categories were combined with the specific games, where each category was given a severity factor (or weight) for each specific game type. These weights were defined by how detrimental the discovered issue was to game play, where a factor 3 is more or less unplayable and 0 means the issue is barely noticeable. In order to confirm our findings, we conducted a series of interviews where the interviewee was presented with our findings and then asked to grade each given problem between 0 and 3 - in accordance with the rules specified above. This method was also used to verify that our genre characterizations are correct.

Using the collated data we developed a few design patterns where we suggest possible solutions to common problems (for example "Text not legible"/"Avoid using problem colors of similar hues on top of each other, for example bright green on bright red").

Creating discussion

Regarding our first problem, we identified a few issues color blind gamers face - and then tried to present possible solutions to those issues. If one were to concretize this with computer science terminology one might say that we created one or more design patterns for use when creating user interfaces with color blind adaption capability. To enhance clarity and familiarize the user with our ideas, we identified problems in one or more existing games, and defined how these problems might be solved. These definitions form the basis for our design rules. After we established these fundamental rules, we used these to facilitate our second problem - the community aspect. We expected the input derived from the community to further improve on our rules, evolving as the community project moved along, thus creating a feedback loop. More concretely, this was to be done by presenting the aforementioned patterns and their relation to our focus categories (as detailed above) on a few web based gaming fora.

1.8.2 Critique

Our choice of games is very likely biased to our tastes, and might not reflect the average gamer's taste. They may also be said to be biased towards games which are problematic for color blind gamers. Both these considerations are irrelevant since most gamers are likely to have at least heard of one of the games listed in chapter 2, and might therefore recognize the issues we highlight. Given that the chosen games were in part selected due to their high sales figures, one would be hard pressed to call them obscure, unknown or something to that effect.

Furthermore one might criticize the fact that we have chosen games based on Swedish tastes while our statistics for the prevalence color blindness is based on the western world as a whole. Unfortunately, we have been unable to find any statistics pertaining to Sweden in particular. We have therefore assumed that the degree of color blindness in Sweden is the same as for the rest of the western world.

One might also claim that web- and application guidelines are not applicable to computer gaming. While it is true that games more often are time-dependant than the aforementioned platforms, we feel that the common display media (i.e. computer screens) is a greater unifying factor than any potential speed difference might be a dividing factor. In essence, we feel that since both situations use a computer screen as a display medium, the difference in how fast the user has to react to the system's prompts, and who controls the pacing of the interaction, is of less importance.

1.9 Literature and resources

1.9.1 Availability

Unfortunately, there is currently very little research regarding the problem of color blind computer gaming. While some research has been done into the area of computer gaming for the severely vision impaired (i.e. blind or near-blind), the problems color blind gamers face differ greatly from the problems blind gamers face. While the research on blind computer gaming might be of use to us, much of it revolves around customizing games using other senses than vision, and that is outside of our intended sphere of research. We will therefore have to collate available information about color blindness with existing literature in the well-researched field of human-computer interaction.

❖ 2

Accessibility guidelines

Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.
(Hewett et al. 2009)

2.1 Introduction

In order to develop our own design patterns for colorblind accessibility in computer games we have examined the basics interface design, accessibility rules and IGDA design patterns.

In this chapter we will give a brief summary of the existing design principles that adheres to our subject.

2.2 Human-Computer Interaction (HCI)

One basic purpose of HCI studies is to improve and facilitate the interaction between users and computers eg. by making the computer applications more easy to understand and more intuitive to use. One way to accomplish this is to develop methods and principles for Graphical User Interface (GUI) in software, so called User Interface Design (UID). The user interface is what meets the eye/senses of the user of a computer application. The use of “icons”, “windows”, “buttons”, the given nomenclature such as “save”, “copy”, “paste” etcetera in regular software GUIs are the result of UID.

2.2.1 The masters and their principles

Several researchers exist in the HCI field. Among the most famous ones are Don Norman, Jakob Nielsen and Ben Shneiderman. They have all developed design principles/rules of thumb for optimal user friendly design. In this chapter we list their

principles in order to compare them and select the most important principles for our thesis.

According to Don Norman's "Design of Everyday Things" (Norman 2002) there are six design principles (rewritten for conciseness):

1. *Visibility* - Keep the vital system input funcitons visible to the user. The user should be able to understand what actions are available by just looking at the system.
2. *Feedback* - Strive to give the user an emediate response to any input made. The user need to know if an action happened due to her input. The feedback should be emediate, clear and in context of the task.
3. *Constraints* - Stop users from doing errors by constraining the system. For example, a word processor do not allow the user to turn off the programe without actively deciding on saving the work in progress or not.
4. *Mapping* - This term is used to describe the connection between an input and an output. The mapping should be clear so the user easily can understand what the result will be when she uses a function.
5. *Consistency* - Design the system so that a given input always gives the same result (a save-button for example). Strive to keep labeling and placement of buttons etc at the same place, so the user will be able to access and understand them all the time.
6. *Affordance* - How we perceive an object, how it can be gripped, handled, used etc. Buttons are for pressing, levers are for pulling etc.

Jakob Nielsen lists ten general principles for user interface design (Nielsen 2005). These have been rewritten for conciseness. They are as follows:

1. *Visibility of system status* - The user should always be able to tell what the status of the system is. This should be achieved by system feedback on input.
2. *Match between system and the real world* - The user should be able to understand the language (and symbols) of the system.
3. *User control and freedom* - Design the system so that it allows the user to undo errors. The user should always feel in control of the system.
4. *Consistency and standards* - Do not change the labeling or naming of functions that do the same thing throughout the system. Follow conventions
5. *Error prevention* - Prevent errors by - for example - asking the users for confirmation before commiting an action.
6. *Recognition rather than recall* - Keep actions and options visible so the user do not have to remember information between separate parts of the system.
7. *Flexibility and efficiency of use* - Allow experienced users to use shortcuts (such as ctrl+c for copy) or even to make their own shortcuts.

8. *Aesthetic and minimalist design* - Keep all dialogue relevant. Do not create or write irrelevant information or design elements when not needed.
9. *Help users recognize, diagnose, and recover from errors* - Clear error messages, preferably with a constructive and easy to follow solution
10. *Help and documentation* - Make help and documentation easy to access and search.

Finally, we have picked Ben Shneidermans design principles from his book *Designing the user interface* (Shneiderman 1998) to complete the principles-part of our study of HCI. These are as follows (rewritten for conciseness);

1. *Strive for consistency* - When similar situations occur in a system, make the required actions as consistant as possible. Menues should work the same way, terminology should be the same saving a file, OK:ing a promt etc).
2. *Enable frequent users to use shortcuts* - The more familiar a user becomes with a system, the more she wants to access common parts or commands of the system through shortcuts. Key-combinations (ctrl+c to copy), hidden commandos (F8 to save) and abilities to create own macros fall under this principle.
3. *Offer informative feedback* - Users want to know if the system responded to their input. A minor or frequent action may not need a major response, but bigger actions, like deleting a file etc, do. The feedback should be instantaneous, connected to the action performed.
4. *Design dialogs to yield closure* - If a task takes several actions in sequence to finish, the user should be getting feedback at the completion of the task. A good way is to organize the task into groups, start, middle, end and keep the user informed on what step she is at.
5. *Offer error prevention and simple error handlings* - If a user makes an error, the system should reply with a simple, instructive description for recovery. The action tried should be left un-made until the error is redeemed, and not partly made or, the system should give clear and constructive instructions on the actual system status.
6. *Permit easy reversal of actions* - As much as possible, actions should be reversible.
7. *Support internal locus of control* - Allow users to be the initiators of actions and tasks, not the responders. As much as possible, leave the user in charge of the system.
8. *Reduce short-term memory load* - Minimize the load on the short term memory; the human short term memory can handle around seven plus or minus two chunks of information. Keep displays simple, keep buttons that do the same thing in the same spot etc.

All the principles of course make sense, but in the scope of our thesis, the following are the ones that we find most applicable.

2.3 Comparing and selecting principles

Comparing Don Norman (DN), Jakob Nielsen (JN) and Ben Schneiderman (BS) we find the following principles in common:

Visibility (DN) and *Feedback* (DN) compares well with *Visibility of system status* (JN) and *Offer informative feedback* (BS). These principles serve a purpose in our thesis, due to their focus on visibility.

Mapping (DN) compares well with *Match between system and the real world* (JN). BS does not offer any equal principles, but arguably, *Support locus of control* could work for comparison. These principles also serve a general purpose in our thesis, due to the mapping-information often being carried by visible input.

Consistency (DN), *Consistency and standards* (JN) and *Strive for consistency* (BS) all share the same principle. These principles also carry a lot of weight in our thesis due to their visibility dependent nature.

As stated above, the common denominator for these principles is that they all affect vision-related factors.

These principles, or tools, will help us to analyze and understand the basic problems of design and assist us with the development of our game design patterns.

In a more narrow sense, we will now describe the hands on rules of design as presented by IGDA white papers and WAI.

2.4 Web Accessibility Initiative (WAI)

The web-standardization organization World Wide Web Consortium (W3C) launched an initiative called Web Accessibility Initiative (WAI) in 1997. The idea for WAI was to develop design patterns for optimal accessibility for people with disabilities. WAI have developed a number of guidelines for accessibility, for example:

- Web Content Accessibility Guidelines (WCAG) (Vanderheiden et al. 2008) covers information such as text, images, forms and sound.
- Accessable Rich Internet Applications (WAI-ARIA) covers dynamic content and Web applications developed with different Web technologies (AJAX, DHTML)
- User agent Accessability Guidelines (UAAG) covers Web Browsers and Media Players

The guidelines that we will use in this thesis are the WCAG. It has 12 guidelines organized under four principles. Each guideline can be tested against success criteria, which are at three levels: A, AA, and AAA.

The success criteria are a measure of the impact of an error on the accessibility for the end user. Of the three levels of conformance, A is least severe and AAA is

strongest. A developer can measure her work against the guideline criteria, and If an requirement is broken, the design can (should) be re-constructed.

In our thesis, all guidelines will be taken into account, with special emphasis on the color carried information guidelines quoted from the WCAG (Vanderheiden et al. 2008):

> Guideline 1.4 Distinguishable: Make it easier for users to see and hear content including separating foreground from background.
>
> 1.4.1 Use of Color: Color is not used as the only visual means of conveying information, indicating an action, prompting a response, or distinguishing a visual element. (Level A)
>
> 1.4.6 Contrast (Enhanced): The visual presentation of text and images of text has a contrast ratio of at least 7:1 (Level AAA)

2.5 IGDA accessibility White Papers

The IGDA Accessibility group is an interest group under IGDA. The purpose of the group is to develop patterns and best practices for developers, in order to enhance gaming experience for disabled.

The group has written a white paper (IGDA 2004), discussing and describing different types of disabilities and their connection to computer games. The paper lists a number of possible approaches for developers to provide accessibility. The three following approaches from the paper coincide well with our thesis:

Color Schemes for Color Blind - Providing an alternate set of color schemes could allow those who are color blind to select the art that appears the best for their particular vision.

High Contrast Mode for Low Vision - The ability to alter the contrast and other features such as the lighting could help those with low vision see the displayed scenes more clearly. In a 3D game this can be achieved by using black and white cartoon style rendering as an option.

Ability to Set Unit Color - The ability to control the color of the different units in the game could assist those with low vision in identifying enemies, teammates, and other important units within a game.

❖ 3

Human color vision

The subject of color is huge, and a complete field of science in itself. In this chapter, we are just going to present the most basic principles of color and human color vision.

3.1 Color - basic principles

To see a color we need light. Light is measured in wavelengths, and a perceived color of a surface is determined by the wavelength of the light reflecting of the surface. The human eye is normally capable of seeing wavelengths from 375nm (extreme violet light) to 750nm (extreme red light). Lower or higher than that span falls outside the “visible light”.

An opaque, white surface reflects all wavelengths equally, therefore it is considered white. An opaque black surface doesnt reflect the wavelengths very well, and is therefore considered black. Other colors reflect different wavelengths, and thus can be said to “have” a color (actually meaning the color of the light frequency it reflects).

As an example, a wavelength of 650 nm is mostly considered “red”, a wavelength of 550 nm is considered “green” and a wavelength of 450 nm is considered “blue” (Kaiser 1996).

There are other principles for light and non-opaque surfaces, but we are not getting into that in this thesis as it is outside our scope - and it has little relevance to this thesis.

3.2 Hue, Saturation and Lightness

“Human Color Vision” (Kaiser 1996) states that a color can be described with three variables: hue, saturation and lightness.

The hue is the nuance of the color. In daily talk when describing a color we say green, red, blue etc. Hues differ a lot more than just basic colors, but it gives most people an understanding on what color is being discussed.

The saturation is how strong or vivid a color is. A low saturation makes the color look more washed out, almost grey. A high saturation makes the color very strong and bright.

Finally, the lightness of the color decides how bright the color is. A low lightness makes the hue barely discernable, going as low as black, and a high lightness dilutes the color to a pastel-shade, up to white.

Colors close in hue but with equal saturation and lightness can be hard to tell apart, especially if they are not adjacent to each other.

3.3 Human color vision

The working parts of a human eye are, very briefly described, the lens, the retina and the optic nerve (Kaiser 1996).

Light enters the lens via the pupil, and hits the retina at the back part of the eyeball. On the retina, photoreceptor cells receive the light and transmits the information via the optic nerve to the visual cortex at the back of the brain. There are two kinds of photoreceptor cells, called “rods” and “cones”. The “rods” main purpose is to function in low light environments, and do not detect color well. The cones on the other hand, activate in brighter light and distinguishes colors well. The cones do not activate in low light, which explains why we are “colorblind” in the dark.

There are three kinds of cones, short (S), medium (M) and long (L), each with a different pigment. The short, medium and long standing for the wavelength sensitivity. As we have seen, the frequencies of colors in the visual light spans from 380 to 750 nm (Kaiser 1996).

The S-cones are sensitive to short wavelengths, and can therefore be said to be perceptant of violet and blue hues. The M-cones are sensitive to medium frequencies, ranging from approximately 500 to 600 nm, covering green and yellow hues. The L-cones are sensitive to long wavelengths, approximately from 600 to 750, covering orange and red hues.

Colorblindness is simply loss of, or having less of, at least one of either S, M or L cones.

3.4 Types of color blindness

There are several kinds of color blindness, ranging from reduced color vision to complete lack of ability to see colors[1] - but they are most often categorized into

[1] Comparable to watching a grayscale image

three different types of color blindness; Monochromacy, dichromacy and anomalous trichromacy (Kaiser 1996).

Monochromacy can be said to be the complete lack of ability to see color - and might also be called *true color blindness*. Colors are seen as different degrees of lightness rather than actual colors. This might be likened to a “black-and-white” film. Furthermore, individuals with this condition usually suffer from miscellaneous other symptoms, including but not limited to light sensitivity. Monochromacy is a genetic disorder, and is very uncommon.

Dichromacy is defined as the inability to differentiate between some hues due to only having two types of working cones. This most often manifests as red-green (protanopia/deuteranopia) or blue-yellow (hereditary tritanopia) color blindness. Both types of dichromacy is the inability to differentiate between the aforementioned colors (i.e. red-green for protanopia). Both disorders are genetic in nature, but occurs differently between sexes, where males are more susceptible to protanopia/deuteranopia. Hereditary tritanopia occurs equally in both sexes, but is very rare.

Anomalous trichromacy is a less severe form of color blindness, which also involves the inability to properly discern different hues. In essence, this means that all of the sufferer’s cones are working, but in a less than optimal way.

These conditions and their characteristics make up one of the corner stones of our game analysis, and as such familiarity with them is crucial for the understanding of our research. This thesis will focus on dichromatic color vision deficiencies.

❖ 4

Analyzing games

There are several types of games; sports, action, strategic war games, tricky puzzle games etc. In this chapter we explain the categories and how we determined them. We also determine what attributes categorizes a genre.

4.1 Game genres

According to “Gameplay and Design” (Oxland 2004), “Game Design Perspectives” (Laramee 2002) and “On Game Design” (Rollings and Adams 2003) game genres can be categorized as follows below. Each genre is described with its main foci, and what type of challenge the player faces. In this description we will omit some genres that can be sub-categorized under other genres (due to shared foci and game mechanics), such as sport games can fit under action games etc.

Game genres can be said to be based on the game mechanics, and commonly occurring elements within the game. Presented below are the different categories according to the literature presented above. The foci described at the end of each section is explained in detail in the next section of this chapter.

The foci presented in this thesis are extrapolated from the literature listed above. They represent the most important characteristics of each genre.

4.1.1 Action games

Action games are the common First-person shooters (FPSs), such as Doom, Quake and Counterstrike. The genre can also include non-violent games, such as sport games and platform games (Super Mario Bros). Several of today’s FPS games can be played over network, which makes any difficulty-settings irrelevant.

Common for all the sub genres is the high tempo, fast reaction skills and hand-eye coordination required by the player. Information in such games need to be easily observed and singled out in a stressful environment. Sportsgames and vehicle simulators are put under this category due to similar foci.

Main foci: Twitch and quick observation.

4.1.2 Strategy games

Strategy games have two distinguished categories: Real-time strategy (RTS), such as StarCraft, and Turn-based strategy (TBS), such as Civilization. Real time strategy games have some of the requirements from the action genre such as reaction skills and attention during stress, while turn taking strategy games regularly do not have this element at all. In common, the two main categories of strategy games requires the player to think several steps ahead, assess threats and possibilities, and pay attention to details such as resources and development tiers. The ability to get a full view of the game is necessary for the player to be able to plan accordingly. Also, several of the genres titles can be played over network, including more players than one, which makes them more fast paced or more unpredictable than playing solo against an Artificial Intelligence (AI).

Due to their likeness in foci, puzzle games (The Incredible Machine), management simulators (Railroad Tycoon) and artificial life (The Sims, Spore) games are put under this category.

Main foci: Attention to detail, effects of choice, literacy, long-term planning and some situational awareness.

4.1.3 Role-playing games (RPGs)

RPGs share foci with both action games and strategy games in such as they have elements of action and elements of planning. This genre can therefore be subdivided under either action or strategy.

However, the main element of RPGs is the character development (improving attributes for the character such as strength, spellpower etc). Most RPGs have a limited number of points to allot in such a way, so planning ahead and being able to comprehend the effects of a choice is vital, as the avatars attributes - and thus the game performance - is directly connected to the attributes.

Another aspect of RPGs is the ability for the player to design their avatar. Gender, hair color, clothing, skin tone etc allows the player to personalize the avatar to their liking.

Main foci: Effects of choice, customizability, literacy as well as some attention to detail, situational awareness, long-term planning and problem solving ability.

4.1.4 Adventure games

Adventure games rarely have any elements of fast reaction or hand eye coordination. Most adventure games put focus on riddles or puzzles, where attention to detail and

the ability to think ahead is crucial requirements of the player. The ability to spot small objects to manipulate or pick up, and find out ways to combine or use these objects and sequential problem solving/thinking - is necessary to be able to complete the game.

Main foci: Attention to detail, problem solving and literacy.

4.1.5 MMO games

MMOs and Massively multiplayer online role playing games (MMORPGs) share foci with both action and strategy games (real time). Rollings and Adams actually say that MMO games are more of a technology than a real genre, and Oxland points out the fact that they are mostly old genres in a multi player mode. However, due to the popularity of MMOs we feel it necessary to include them in our research.

Major elements of MMO is the continuous world (the game continues when the player has turned his client off) and player-player interaction. Most of the social interaction takes place in written form (chat), so language, reading and writing abilities and also socio-cultural understanding is essential for players of a given MMO.

Main foci: Twitch, quick observation, situational awareness, effects of choice, social skills, literacy as well as some attention to detail, long-term planning and customization.

4.2 Identifying and validating foci importance

In the previous section it was established what the main foci are for each of the genres. This was identified with support in the literature. However, to further validate the importance of each foci, a survey was conducted. Nine respondents, experienced in computer gaming and the game genres, were given the list of the foci and their descriptions, and ample time to read. The respondents were allowed to have the list at hand during the survey, and could at any time go back and check if they needed to remind themselves of the meaning of a foci name. By using this methodology, we ensured that the answers reflected how well the respondent thought our foci explainations corresponded with their experience with video games rather than how much the players knew about our foci.

After having read the foci list, one respondent at a time was given a table with genres and foci. The task was to evaluate a given focus for a given game genre. This was done by setting a score from 0 to 3, where 0 meant “not at all important” and 3 meant “game breaking important”. The respondent was fully introduced to the task and could anytime ask the test leader if something was unclear.

In order to preserve the validity of the respondents’ answers the test leaders took great care in never offering opinions and only focused on explaining the game

situation illustrated by the screenshot. Furthermore the test leaders only provided information when prompted by the respondents.

Once all respondents had filled in one table each, we created a new table of mean values based on the respondents values.

With the literature-foci identification and the respondent-validated values we feel that we have a good understanding of how each focus adheres to each genre. These values are our genre-foci factors.

4.3 Genre foci

Described below are the foci and their characteristics, along with the resulting value set from the user evaluation.

4.3.1 Foci characterization

Twitch (TWI)

The ability to rapidly make decisions and react according to these. Very dependant on hand-eye coordination. Mainly used in action games, MMOs and some RTSs

Table 4.1. Foci: Twitch

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Twitch	3.000	0.222	1.889	1.444	0.667	2.222

Quick Observation (QO)

The ability to take in details at a glance. Mainly used in action games, MMOs and some RTSs.

Table 4.2. Foci: Quick Observation

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Quick observation	2.778	0.667	2.333	1.556	1.000	2.222

Attention to Detail (ATD)

The ability to effectively micromanage a given situation or scenario. Mainly used in strategy and adventure games, but it is commonly found across all the genres we have described.

Table 4.3. Foci: Attention to detail

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Attention to detail	1.222	2.444	2.778	1.889	2.667	1.667

Situational Awareness (SA)

Being able to quickly (and continually) survey and mentally catalogue the given situation. This ability is one of the main foci of MMOs, but is frequently used in games in general.

Table 4.4. Foci: Situational awareness

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Situational awareness	2.444	2.111	2.444	1.889	1.889	2.556

Effects of Choice (EOC)

The ability to understand direct cause and effect relationships. For example, understanding the relationship between skills and abilities in a classic role playing game. This ability is a staple of strategy and role playing games. It is also fairly common in MMOs.

Table 4.5. Foci: Effects of choice

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Effects of choice	0.889	2.444	2.667	2.889	1.556	2.667

Long-term planning (LTP)

The ability to establish and execute a strategy. For example, building roads to a future city in a strategy game. This is yet another staple for strategy games, but it is also quite common in role playing games - both online and offline.

Table 4.6. Foci: Long-term planning

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Long-term planning	0.556	2.889	2.667	2.222	1.333	2.222

Problem Solving (PS)

The ability to solve puzzles, riddles and miscellaneous other problems. One of the main foci of adventure games. It does appear quite frequently in other game genres, but is often less advanced.

Table 4.7. Foci: Problem solving

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Problem solving	0.889	1.111	1.111	1.889	3.000	1.000

Social Skills (SS)

The ability to act within acceptable boundaries in a social environment. Very important for MMOs, but also somewhat important in RPGs in general.

Table 4.8. Foci: Social skills

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Social skills	0.222	0.667	0.556	2.222	1.444	3.000

Customizability (CU)

This foci is really the odd one out, as it focuses on the game more than the players perception thereof. This foci defines how important it is for the user to be able to customize parts of the game - such as his character's appearance or the game's user interface. This is one of the defining foci of RPGs, but it is quite commonly found in other game genres.

Table 4.9. Foci: Customizability

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Customizability	0.667	0.778	0.667	2.444	0.667	2.333

Literacy (LIT)

The ability to correctly understand and communicate using textual function within the game. Also the ability to use the chat function itself. This foci is a core feature of RPGs, MMOs and adventure games.

Table 4.10. Foci: Literacy

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Literacy	0.667	1.889	1.556	2.667	2.111	2.667

4.3.2 Genre-foci factor matrix

This matrix correlates foci and genres and their given factors, which illustrate how important a foci is for a given genre. Each foci is given a factor weight between 0 and 3, where 3 is the most severe (something crippling) and 0 means that the measure is irrelevant or inapplicable. A score of 1 means that the game is very dependent on the measure, but that it does not impact game enjoyment all that much. A score of 2 means that the game might still be playable, but at a much greater difficulty or at a great loss of enjoyment. The maximum total score is 45 points. The table uses a few acronyms, as explained above.

Table 4.11. Genre-foci factors

Foci	Action	TBS	RTS	RPG	Adventure	MMO
Twitch	3.000	0.222	1.889	1.444	0.667	2.222
Quick observation	2.778	0.667	2.333	1.556	1.000	2.222
Attention to detail	1.222	2.444	2.778	1.889	2.667	1.667
Situational awareness	2.444	2.111	2.444	1.889	1.889	2.556
Effects of choice	0.889	2.444	2.667	2.889	1.556	2.667
Long-term planning	0.556	2.889	2.667	2.222	1.333	2.222
Problem solving	0.889	1.111	1.111	1.889	3.000	1.000
Social skills	0.222	0.667	0.556	2.222	1.444	3.000
Customizability	0.667	0.778	0.667	2.444	0.667	2.333
Literacy	0.667	1.889	1.556	2.667	2.111	2.667

4.4 Summary of chosen games

The analyzed games are the ones shown in table 4.12.

These games were chosen based on their popularity, as seen in the ”Top list” column. The time slots for these are denoted as week/year, so 18/09 is week 18 of 2009. Top lists were gathered from the Swedish Game Industry[1].

[1] http://www.dataspelsbranschen.se/

Table 4.12. Analyzed games

Name	Genre	Year	Top list	Comment
World of Warcraft: Wrath of the Lich King	MMORPG	2008	18/09	Second expansion to World of Warcraft (2004/2005).
Empire: Total War	Strategy	2009	18/09	Combines both real time and turn based elements.
Chronicles of Riddick: Assault on Dark Athena	First-person shooter	2009	18/09	Update of "Escape from Butcher Bay", with added expansion.
Fallout 3	Role-playing game	2008	45/08	Revamped gameplay and graphics.

4.5 Meet the games

With this section of the thesis we intend to give a short and concise introduction of each of the games we analyzed.

4.5.1 World of Warcraft: Wrath of the Lich King

Wrath of the Lich King is the third expansion to WoW, the most successful MMORPG so far. WoW has over 11 million[2] subscribers, and centers around the conflict between two factions - the Horde (consisting of various monstrous races such as orcs, trolls and anthropomorphic bovines) and the Alliance (humans, elves, dwarves, gnomes).

Gameplay is combat-centric with classic roleplaying elements such as character customization. Characters are class based, but there is also a fairly advanced skill system which allows players to practice different crafts (blacksmithing, tinkering etcetera). Being an online game, social interaction plays a very large role in the game experience.

Since WoW is an Everquest style MMORPG, which in essence means that it has a third person viewpoint and FPS-like controls coupled with a level and combat centric play style, WoW's main foci are archetypal for the type of MMO defined above. It will therefore be evaluated as such.

4.5.2 Empire: Total War (ETW)

The Total War series is a line of strategy games where the player takes control over a historical culture and by trade, taxes and war gain money to expand their cities and

[2] WoW has 11.5 million subscribers as per Nov 21, 2008. See http://us.blizzard.com/en-us/company/press/pressreleases.html?081121.

build more powerful armies. The game uses classical development-trees, where one unit is dependant on the existence of other, for example cavalry troops are dependant on stables etc.

The game is composed by a strategic map over the world, which shows the different factions, cities, armies and fleets. On this map, the player can move her units, select one of her cities to improve them and develop more armies. The strategic view is turn-based, so a player can spend as much time as she likes pondering her next move. When a player gets into combat with an opposing faction, she can choose to shift the game from strategic view to real time combat view, where one actually sees the troops. Most games are campaign-related with certain objectives (e.g. capture 50 regions), and takes several hours to win.

Earlier examples have seen feudal Japan, medieval Europe and viking theme and the imperial version covers the age of muskets and cannons, ranging from mid 17th century to late 19th century.

4.5.3 Chronicles of Riddick: Assault on Dark Athena

Chronicles of Riddick: Assault on Dark Athena is a FPS sprung from the movie series with the same name. It is a combination of an updated version of the original *Chronicles of Riddick: Escape from Butcher Bay* and the new expansion pack called *Assault on Dark Athena*. The player assumes the role of Riddick, and plays out the eventual escape from the Butcher Bay prison along with the later attack on a space ship called Dark Athena.

The game is a fairly conventional FPS, but with an inclination towards stealth gameplay. Riddick can hide in shadows, and a while into the game he acquires a sort of night vision (called *eye shine*). In addition to the standard shooting mechanics the game also has a well developed hand-to-hand fighting system, where movements are combined with attacks to form certain moves. The game makes extensive use of modern graphics effects, and uses lighting to set the mood for most of the game.

4.5.4 Fallout 3

This game is a remake of the popular 90's FallOut series. The older versions were turn-based isometric 3D while this version is first person where the player can interact with almost all the environment. The player creates a character and leads it through a series of adventures and quests in a post-apocalyptic USA. The world is a mix of high technology and late fifties.

4.6 Analysis methodology

Outlined below is the methodology we used to analyze the games described in the previous section. We'll start by describing how we found problematic situation within the game, followed by how we verified these against our focus groups. To ensure that the reader better understands our methodology we have included a section on method critique, in hopes of dispelling some potential worries.

4.6.1 Identifying situations

Each analysis was done by playing through the game (or parts thereof) and actively looking for potential color blindness issues. These situations were then captured as a screen shot, and run through the VisCheck Photoshop plugin (Dougherty and Wade 2008) as detailed in chapter 1. If we encountered issues, we analysed the situation and explain why we feel how and why this causes problems for color blind gamers. To further justify our analysis, we conducted the user evaluations described in section 4.6.2.

4.6.2 User evaluation

In order to establish a justified evaluation on the weight of the issues we found, we decided to conduct a user evaluation.

The evaluation was carried out in two separate sessions. The first one allowed for some changes, which were carried out before the second session.

Preparation

Before starting, the respondents were asked whether or not they were familiar with computer games, and whether or not they had full color vision. This was done by handing out a simple form. Two of our ten subjects did suffer from protanopia or deuteranopia. On the form we had added our foci with their explanations. All the test subjects were allowed to familiarize themselves with the foci, and also had these at hand during the session. They were fully instructed in what was expected of them: to give a score on images based on severeness of lost color information.

Sessions

In each session, five persons were, one by one with only the testleaders present, shown the images from the games. First we showed one original full color image, and in case the person did not understand the context of the image, we gave brief explanations. After having seen the color image, the subjects were shown the same

image rendered with the Visicheck filter to simulate the colors of protanopia, deuteranopia and tritanopia.

While observing the image rendered in new colors (or lack thereof) the test subject was to estimate the severeness of the perceived loss of information on a scale 0 to 3.

When we had all the images scored an average was calculated for each image/foci-combination. These averages make up our game-foci factors, which characterize how severe a fault is for a given game.

During the first session, we realized we had left out pertinent situations in some of the games, and we decided to get more images and conduct a follow up test with these images included. We added a picture of WoW potions (icons of bottles with the same shape, but different colors depending on the effect) and corrected the door-light from the Riddick images. After these changes, we conducted the test on five more respondents.

4.6.3 Method critique

We only conducted the test on two groups of five. All the images displayed were from our own findings. It can be argued that we should have found more situations in game, used more people to help us identify problems in games and tried them on a larger group of respondents. It might also be argued that we should have had more color blind respondents - but we feel that the filtered images mitigate this disadvantage to a sufficient degree.

However, it is not the purpose of this thesis to find all problems in all the games selected. We want to establish the fact that high selling popular games do have issues for color blind computer gamers. All situations selected and screendumped are connected to one or more of the foci (based on the game genre) and the rule set from chapter 2.

4.7 Identifying issues

4.7.1 World of Warcraft (WoW)

While we have found WoW to be a well-rounded game, it is not without it is issues - and some of them are fairly crippling for someone who is color blind.

Hostility markers

WoW uses a few different colors to denote to what degree a certain creature's or player's allegiance conflicts with the player's own allegiance. These are denoted as

blue (friendly, Player versus Player (PvP) mode disabled), green (friendly, PvP mode enabled), yellow (neutral, or hostile but passive) and red (hostile). These colors are used consistently over the entire user interface, both in unit frames, name color and as position markers within the world.

Unfortunately the red, yellow and green colors used are all of very similar saturation and lightness, with only hue differentiating them. If one suffers from red-green color blindness, this makes it all but impossible to differentiate whether the entity in question is hostile or not. This is illustrated by the figure 4.1, where the left side is protanopia filtered and the right side is filtered for deuteranopia.

Fortunately, the different factions often use different character models - so this is less of a problem in PvP combat. It should however be noted that the Alliance *Night Elf* and the Horde *Blood Elf* races might be confused at distance, especially if they are of the same character class. However, it greatly affects the Player versus Environment (PvE) aspects of the game since the Non-player character (NPC) factions sometimes use the same models as players. These shortcomings are very severe, and affect quite a few different foci.

Table 4.13. WoW hostility marker: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Hostility	1.1	2.1	1.2	1.7	0.8	0.2	0.5	1.2	0.1	0.5

Fig. 4.1. WoW hostility marker

Aggro marker

WoW recently added an aggro marker for the characters own portrait. Aggro is how agressive an NPC is towards the character. If the player is at the top of the aggro list, the NPC will start attacking them. This shows as an outer glow around the players portrait. The glow is yellow when the player is on the aggro list but not the main target, and turns red when the player reaches the top of the list and gets the attention of the NPC. Figure 4.2 shows the glow when the player is on the list on the left, and the glow color when the player is the NPCs main target on the right. From top to bottom, the different simulations are normal vision, protanopia, deuteranopia and tritanopia.

As one can see from the image, a player with red-green color blindness (i.e. either protanopia or deuteranopia) will have issues with this filter. While he will be able to see the glow caused by being on the list itself (but not at the top), he might have trouble telling if it is red or yellow. The latter glow, which turns from red to a very dark brown might not be visible at all in a dark environment. This might confuse the player and make him think that his aggro has somehow disappeared - which is a potentially disastrous situation.

Fig. 4.2. WoW aggro glow - on list/target

Table 4.14. WoW aggro glow: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Aggro	1.7	2.0	1.2	1.9	1.4	0.7	0.8	0.2	0.2	0.0

Talents

In WoW each character has a talent tree, where the player can spend points to acquire or improve different abilities. The allocation of said points is semi-permanent as the player has to pay an NPC money to reset them. In recent patches, players have been given the ability to have multiple talent configurations, but may only use one at a time. As one might expect, unlocking such a slot costs a fair amount of in-game money.

The talent tree view in WoW suffers from a few crippling flaws in regard to color blind adaptation. As seen in figure 4.3, a talent which can be assigned additional points has a green border, and a “filled” talent is golden. On the left side we have

Fig. 4.3. WoW talent borders

an “unfilled” talent, and a “full” (maximum number of point allocated) talent on the right. From top to bottom, the image illustrates normal vision, protanopia, deuteranopia and tritanopa. As one can see, the color for an unfilled and a filled talent may be more or less indistinguishable.

This poses a problem for the player’s ability to plan his talents - and thus affects the “Long-term planning” foci. It also makes it all but impossible to see if a talent is filled or not, thus crippling the players ability to see the true effects of his choice. Since talents are ordered in tiers, where one might have to buy a certain talent or

spend a certain amount of points in previous tiers to be able to take talents further down the tree, this disadvantage can cause serious issues for the player.

Table 4.15. WoW talent borders: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Talents	0.8	2.4	2.0	1.7	2.0	1.9	0.5	0.3	0.8	0.1

Money markers

As with the other markers in WoW, money is consistently marked as coin-like blobs of different color - yellowish for gold, gray for silver and a light brown for copper.

As seen in figure 4.4, the colors tend to float together, and telling gold and copper apart is sometimes very difficult. This can lead to issues such as paying 50 gold instead of 50 copper for an item (a factor 10000 difference in price). This shortcoming affects the “attention to detail” and “effects of choice” foci. However, the colors are only really mistakable at a glance, and as such the issue in itself is rather trivial.

Fig. 4.4. WoW money markers

Table 4.16. WoW money markers: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Money	0.0	0.5	0.5	0.6	0.5	0.5	0.1	0.5	0.1	0.0

Item coloration

WoW once again uses colors to convey meaning when denoting item quality. This is in essence a measure of how good an item is for it is given level value. The values can be seen in table 4.17. All items with a quality above *Common* will have to be

Table 4.17. WoW item quality colors

Color	Quality	Value
Gray	Poor	Worthless
White	Common	Used at lower levels, later worthless
Green	Uncommon	“Standard” magic items
Blue	Rare	Good magic items
Purple	Epic	Very good items, requiring a lot of effort to obtain
Orange	Legendary	The best obtainable items. Extremely rare.
Gold	Heirloom	Level-adjusting item attached to a specific account

bound[3] to the character for them to be used, and some will even be bound when they are picked up. Normally, *Uncommon* items are bound on equip and *Rare* and better items are bound when picked up. There are some *Rare* or *Epic* items which bind on equip, but these are very rare. Heirlooms are bound to an account rather than a character.

Unfortunately, the difference between some item categories are next to impossible to make out by color alone if one suffers from color blindness. Each cell denotes which colors the color at the start of that row can be confused with. Our findings can be seen in figure 4.5.

Fig. 4.5. WoW items

[3] A “bound” item in WoW is an item which has been locked to a specific character. It can not be traded to other players, but it can be destroyed or sold to certain computer-controlled characters if the player so chooses

Table 4.18. WoW items: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Items	1.0	2.0	1.2	1.0	1.7	0.8	0.5	0.7	0.3	0.3

Potions

When adventuring in WoW player avatars can improve themselves temporarily, or replenish lost resources with the aid of magic potions. Potions are single use, and are consumed once they are used. Some potions are on a timer, meaning the player can not take more than one potion every couple of minutes. Some potions are hard to come by, and cost in-game money.

To use a potion, the player clicks the icon of the potion with the wanted effect. The icons for different potions often share the same image, but is colored differently depending on the effect. For example; a life replenish potions is red, a potion for increased attack power is yellow and so forth. The situations for potion use differs depending on what effect the player wants. For example, a life replenishing potion is mostly consumed in combat, under stress. Since the potions both cost in game currency and sometimes have a timer, a mistakenly used potion can alter the outcome of combat for the player. This is illustrated by figure 4.6.

Fig. 4.6. WoW potions

Table 4.19. WoW potions: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Potions	1.6	2.2	1.6	1.8	2.2	1.2	0.4	0.0	0.0	0.0

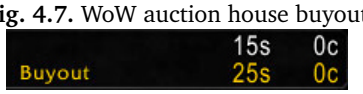
Modifiability & Recent improvements

WoW is very customizable - but only to a certain extent. For example, one is not able to change the hostility markers, nor change how talents are colored.

During the writing of this thesis, Blizzard released a new client with some color blind adaptation. Unfortunately, this failed to solve some of the more serious problems - such as the coloration of hostility markers and the issues with the talent system. It did however solve issues such as money markers and item quality coloration.

One of the features of the “Color blind mode” Blizzard introduced is that it replaces the coin markers with colored text, where the gold icon is replaced with a gold-colored “Gold” text. WoW also has an *Auction House* system, where players can sell items using a system similar to eBay (but using in-game money). In this system, auctions may be given a buyout[4] price. Unfortunately, the buyout price is always gold colored, which might lead to some unfortunate issues. As seen in figure 4.7, this has the possibility of being very confusing - regardless of their color vision.

Fig. 4.7. WoW auction house buyout



[4] By paying this the player wins the auction immediately

4.7.2 Chronicles of Riddick: Assault on Dark Athena

Door indicators

As per usual in action games, the lock status of a door is usually indicated by either a red (if locked) or green (if open) light. As seen in figure 4.8, these might be difficult to tell apart.

This is mostly a trivial issue, but can be fairly frustrating to the player who tries to escape from enemies in a time-critical situation.

Fig. 4.8. Riddick doors

Table 4.20. Riddick doors: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Riddick: Doors	2.2	2.0	1.2	1.8	1.2	1.0	1.2	0.0	0.0	0.0

Key code panels

Key code panels are colored a matte green when unlocked and a greenish yellow when locked. As seen in figure 4.9, these colors are near identical to someone suffering from protanopia or deuteranopia. In essence, this causes the same issues as

the door indicators mentioned above - but aren't quite as detrimental due to the relative rarity of these panels.

Fig. 4.9. Riddick keypads

Table 4.21. Riddick keypads: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Riddick: Key panels	1.5	1.7	1.0	1.3	1.2	0.7	1.2	0.0	0.0	0.0

Visibility indicator

Assault on Dark Athena contains some stealth elements where Riddick hides in shadows. When he is invisible to enemies, his vision gets a light blue tint, as seen below.

While this seems fairly severe, the actual impact on game play is identical to that of the doors in general. The environment itself doesn't blur or skew - it simply gets tinted blue.

Fig. 4.10. Riddick hide mask

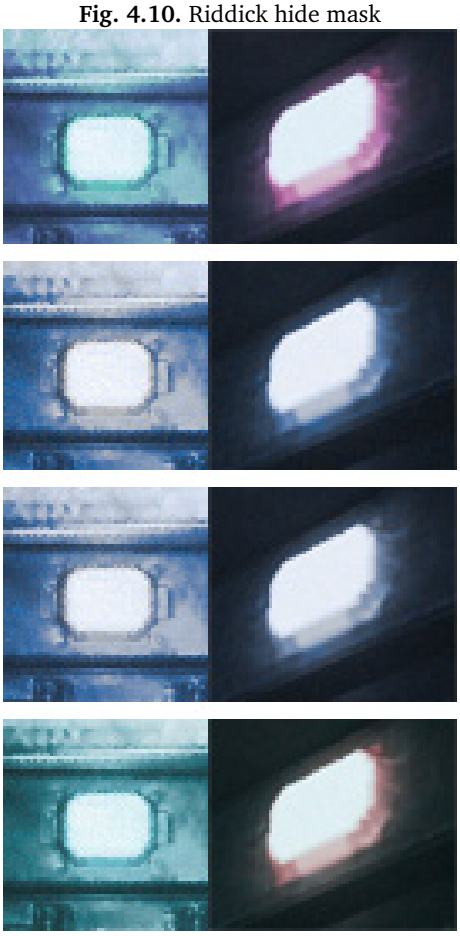


Table 4.22. Riddick hide mask: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Riddick: Hide mask	2.4	2.6	1.6	2.4	1.8	1.0	1.8	0.1	0.0	0.0

4.7.3 Empire: Total War (ETW)

Choosing a faction

When starting a new campaign game, the player is allowed to choose from a number of factions, e.g. Great Britain, France, Austria, Sweden, Spain, Preussia etc. Every faction is described with pros and cons respectively, and the starter provinces are shown in bright green on a world map in faded yellow/brown. When applying the Visicheck filters on the world map, it becomes harder to distinguish what starter regions the selected faction have. It is still visible, and may not be game-stopping, but it takes a little extra time to clearly make up ones mind on what faction to play. This is illustrated by figure 4.11

Fig. 4.11. ETW faction map

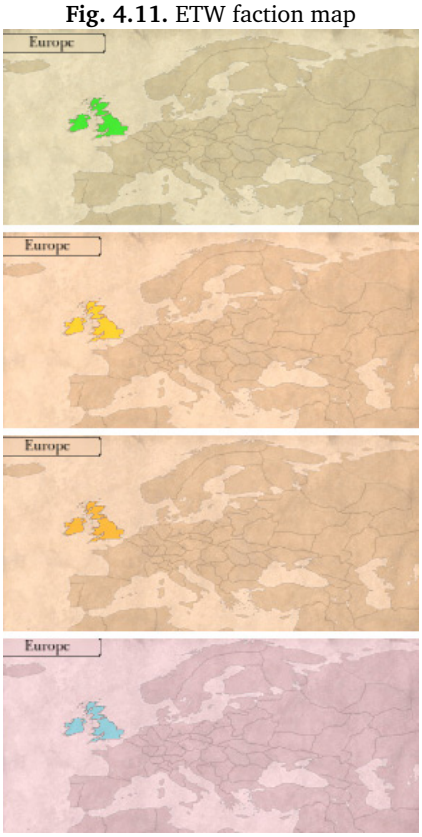


Table 4.23. ETW faction map: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Faction	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Moving troops on the strategic map

To move a troop the player selects it by left clicking, moves the cursor to where the troop should go and right clicks to make the troop walk there. Every troop has a limited range/turn. Should the player want her troop to move by itself in subsequent turns she just clicks on the end goal for the troop, and every turn the troop will move up to its maximum range. The path of the troop is shown in a color scheme: green (as far as the troop will travel this turn), red (as far as the troop will travel next turn) etc with the colors purple, orange, blue and yellow. The different colors give the player a hint on how many turns it will take for the troop to arrive at its final goal. This is shown in figure 4.12.

However, a colorblind person will have a hard time seeing these colors on the forest-green background. This will make it difficult for a player to tell how many turns her move with that troop will take. This could be important when moving troops to bolster an army about to attack an enemy, positioning an assassin just in time before an attack etc.

Table 4.24. ETW strategic troop movement: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Strategic	0.2	1.5	1.7	1.3	0.9	1.9	0.5	0.1	0.0	0.3

Fig. 4.12. ETW strategic troop movement

Minimap colors

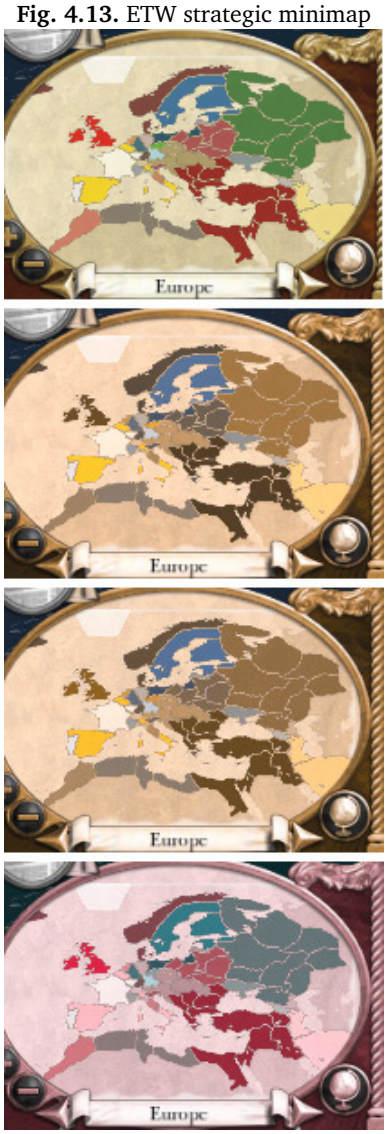
The minimap shows what faction owns what part of the world. The minimap is color coded based on the factions. With a color deficient seeing, some of the regions seems to have the same color, and are hard to tell apart - as seen in figure 4.13.

In a campaign where it is important to beat the AI by capturing the most regions, this may cause confusion.

Table 4.25. ETW strategic minimap: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Minimap	0.4	1.6	1.7	1.4	0.9	1.6	0.8	0.1	0.0	0.2

Fig. 4.13. ETW strategic minimap



Troop recruiting and requirements

To recruit new troops for the armies, the player selects a town where the troops will be recruited, and selects the “recruitment” tab. In order to gain new troops, the player must upgrade or develop new buildings. By right clicking a building, the player can tell what kind of units are available from that building, and also what kind of units that will be available once the player have created the required buildings.

However, in this view, the available troops are lined with a golden border, and the not-yet-available troops (which require some additional building in this town) are lined with a red border. This is illustrated in figure 4.14. Applying the Visicheck

filter to this image again shows us little to none difference in color, making it hard to tell why we are not allowed to build certain troops or choosing what building to buy next.

Fig. 4.14. ETW troop recruitment

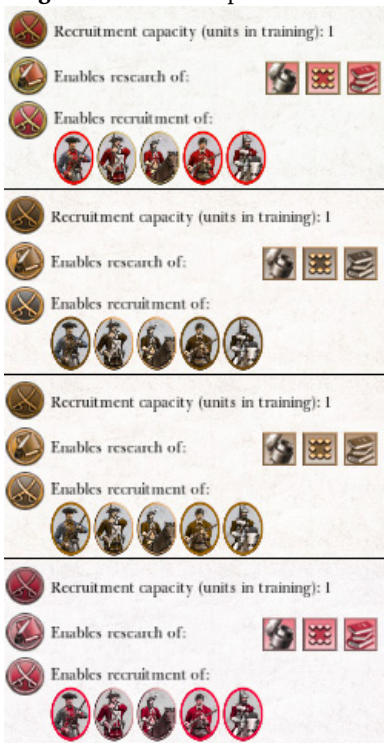


Table 4.26. ETW troop recruitment: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Troop recruit	0.0	1.3	1.2	1.0	1.4	1.3	0.3	0.0	0.1	0.1

Troops in the field

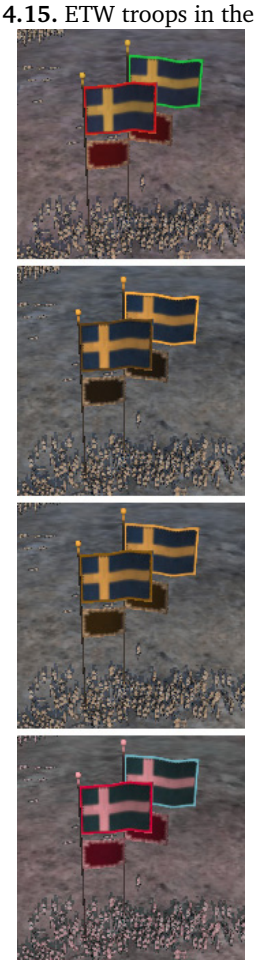
In combat view, the player sees her own troops and manages them in real time. The player may set up her troops before selecting to start the battle. The troops are mostly units of infantry, cavalry and artillery. One unit consists of several soldiers of the same kind. Each of the players units as well as the enemy troops are marked with a flag for that faction. Enemy unit flags have a thin red outline and friendly troops a thin green outline. Also, hovering a friendly or enemy unit will show a color on the

ground at the enemies feet, green respectively red. Since this battle takes place in real time, somewhat quick decisions need to be taken, and it is therefore important that the player can tell her troops apart from the enemy. For this example, we have chosen to play a single battle, with opposing combatants from the same faction, thus giving them the same flag. This is to enhance our point that the color coded information in the RTS-view is lacking for a player suffering from protanopia or deuteranopia. This problem can be seen in figure 4.15.

Table 4.27. ETW troops in the field: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Troop in field	1.7	1.8	1.4	1.9	1.0	0.9	0.7	0.1	0.0	0.2

Fig. 4.15. ETW troops in the field



Tactical minimap

Using the minimap, the player can get an overview on where the troops are disposed and what troops are engaged in combat or just idling. Also, a progress bar next to the map indicates what side has the upper hand, using red and green color for enemy progress and player progress respectively. The information this carries is somewhat lost when applying the Visicheck filters, as seen in figure 4.16.

Table 4.28. ETW Tactical minimap: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Tactical minimap	1.3	2.1	1.6	2.0	1.0	1.6	0.6	0.0	0.0	0.1

Fig. 4.16. ETW, tactical minimap

Troop view

The players GUI offers an overview of what troops are available, their numbers, type off troop etc. It also shows what troop is engaged in battle, being shot at and so forth. If a troop is being run over and tries to surrender, it also shows on the troop-overview. This is indicated by a miniature white banner in the corner of the troop icon, but also by coloring the troop in a red hue. However, if a player fails to notice the miniature white banner, it is hard to tell if a troop is actually breaking or just in regular combat. This is illustrated in figure 4.17

Fig. 4.17. ETW troop view

Table 4.29. ETW troop view: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Empire: Troop view	0.8	1.1	0.7	1.1	0.6	0.6	0.2	0.0	0.0	0.0

Modifiability

Unfortunately, *ETW* is not very modifiable at all. The player is unable to modify the GUI in the regular game, and graphically the player can not change anything but the resolution, quality of 3D rendering and gamma.

4.7.4 Fallout 3

In-game interaction

Having analyzed several angles of this game, we find it hard to come up with any major issues. In the cases we did find problems from our point of view, the game offered a remedy, easily accessible to the player.

A lot of the gameworld is interactable. For example computer screens, doors, handles, mundane items, NPCs etc. To interact with something in the game the player simply faces the object to see an information text (what action is possible) and press the action key. Some actions are hostile in the game, for example picking a lock or hacking a computer. Doing these actions while an NPC watches may trigger hostile actions. To help the player distinguish illegal actions from legal, the action-text changes color. A legal action has the same color as the rest of the GUI, and the hostile action is orange-red. Using the default GUI color settings, it is hard to tell non-hostile actions from hostile actions based only on color (leaving all decisions to the morale of the player) - as seen in figure 4.18.

Fig. 4.18. Fallout 3 interaction

Table 4.30. Fallout 3 interaction: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Fallout 3: Interaction	0.5	1.0	1.0	0.9	1.8	0.7	0.9	0.6	0.1	0.7

Radar information

In the GUI lower left of the screen, a radar shows the player in what direction the closest living beings are. These are shown as bars on a flat lined compass to give the player a hint on in what direction a living being is. A friendly being have the same color as the GUI, and a hostile being is red-orange. Again, using the default settings, it is very hard to tell on the radar if an indicator is hostile or not. This is illustrated in figure 4.19

Fig. 4.19. Fallout 3 radar

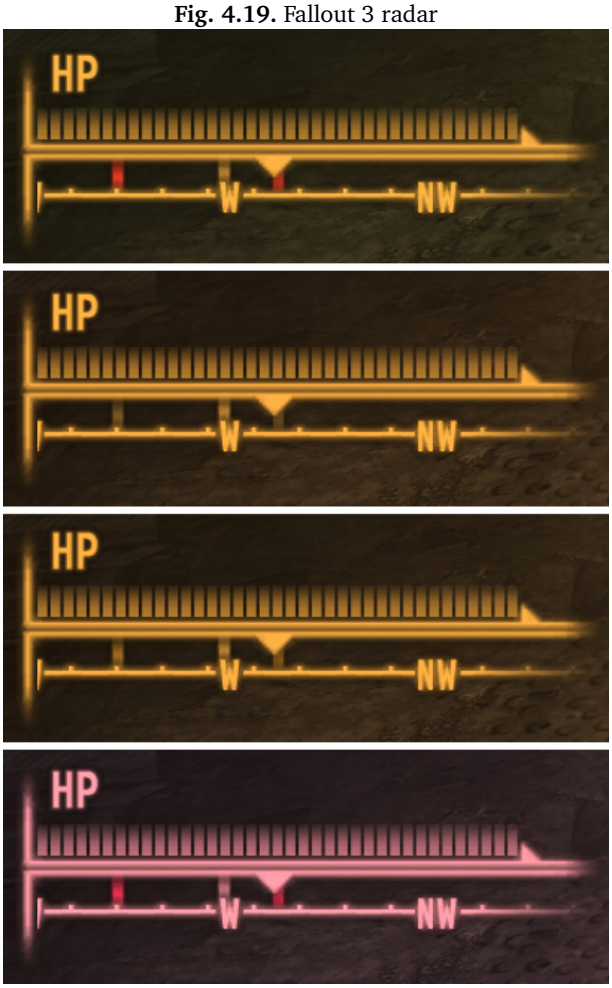


Table 4.31. Fallout 3 radar: Foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
Fallout 3: Radar	1.8	2.0	1.3	1.8	1.2	0.9	0.7	0.2	0.0	0.2

4.7.5 Results

The summarized results of the game evaluation are as seen in table 4.32.

Table 4.32. Game foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT
WoW: Hostility	1.1	2.1	1.2	1.7	0.8	0.2	0.5	1.2	0.1	0.5
WoW: Aggro	1.7	2.0	1.2	1.9	1.4	0.7	0.8	0.2	0.2	0.0
WoW: Talents	0.8	2.4	2.0	1.7	2.0	1.9	0.5	0.3	0.8	0.1
WoW: Money	0.0	0.5	0.5	0.6	0.5	0.5	0.1	0.5	0.1	0.0
WoW: Items	1.0	2.0	1.2	1.0	1.7	0.8	0.5	0.7	0.3	0.3
WoW: Potions	1.6	2.2	1.6	1.8	2.2	1.2	0.4	0.0	0.0	0.0
Riddick: Doors	2.2	2.0	1.2	1.8	1.2	1.0	1.2	0.0	0.0	0.0
Riddick: Key panels	1.5	1.7	1.0	1.3	1.2	0.7	1.2	0.0	0.0	0.0
Riddick: Hide mask	2.4	2.6	1.6	2.4	1.8	1.0	1.8	0.1	0.0	0.0
Empire: Faction	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Empire: Strategic	0.2	1.5	1.7	1.3	0.9	1.9	0.5	0.1	0.0	0.3
Empire: Minimap	0.4	1.6	1.7	1.4	0.9	1.6	0.8	0.1	0.0	0.2
Empire: Troop recruit	0.0	1.3	1.2	1.0	1.4	1.3	0.3	0.0	0.1	0.1
Empire: Troop in field	1.7	1.8	1.4	1.9	1.0	0.9	0.7	0.1	0.0	0.2
Empire: Tac minimap	1.3	2.1	1.6	2.0	1.0	1.6	0.6	0.0	0.0	0.1
Empire: Troop view	0.8	1.1	0.7	1.1	0.6	0.6	0.2	0.0	0.0	0.0
Fallout 3: Interaction	0.5	1.0	1.0	0.9	1.8	0.7	0.9	0.6	0.1	0.7
Fallout 3: Radar	1.8	2.0	1.3	1.8	1.2	0.9	0.7	0.2	0.0	0.2

Table 4.33. Weighted foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT	Sum
WoW: Hostility	2.44	4.67	2.0	4.35	2.13	0.44	0.5	3.6	0.23	1.33	21.7
WoW: Aggro	3.78	4.44	2.0	4.86	3.73	1.56	0.8	0.6	0.47	0.0	22.23
WoW: Talents	1.78	5.33	3.33	4.35	5.33	4.22	0.5	0.9	1.87	0.27	27.88
WoW: Money	0.0	1.11	0.83	1.53	1.33	1.11	0.1	1.5	0.23	0.0	7.76
WoW: Items	2.22	4.44	2.0	2.56	4.53	1.78	0.5	2.1	0.7	0.8	21.63
WoW: Potions	3.56	4.89	2.67	4.6	5.87	2.67	0.4	0.0	0.0	0.0	24.65
Riddick: Doors	6.6	5.56	1.47	4.4	1.07	0.56	1.07	0.0	0.0	0.0	20.71
Riddick: Key panels	4.5	4.72	1.22	3.18	1.07	0.39	1.07	0.0	0.0	0.13	16.28
Riddick: Hide mask	7.2	7.22	1.96	5.87	1.6	0.56	1.6	0.02	0.0	0.0	26.02
Empire: Faction	0.0	0.07	0.24	0.21	0.24	0.29	0.0	0.0	0.0	0.0	1.06
Empire: Strategic	0.04	1.0	4.15	2.74	2.2	5.49	0.56	0.07	0.0	0.57	16.82
Empire: minimap	0.09	1.07	4.15	2.96	2.2	4.62	0.89	0.07	0.0	0.38	16.42
Empire: Troop recruit	0.0	0.87	2.93	2.11	3.42	3.76	0.33	0.0	0.08	0.19	13.69
Empire: Troop in field	3.21	4.2	3.89	4.64	2.67	2.4	0.78	0.06	0.0	0.31	22.16
Empire: Tac minimap	2.46	4.9	4.44	4.89	2.67	4.27	0.67	0.0	0.0	0.16	24.44
Empire: Troop view	1.51	2.57	1.94	2.69	1.6	1.6	0.22	0.0	0.0	0.0	12.13
Fallout 3: Interaction	0.72	1.56	1.89	1.7	5.2	1.56	1.7	1.33	0.24	1.87	17.77
Fallout 3: Radar	2.6	3.11	2.46	3.4	3.47	2.0	1.32	0.44	0.0	0.53	19.33

4.8 Issue analysis

4.8.1 Methodology

Table 4.33 illustrates how severely each foci affects a given game. These numbers are reached by multiplying the category-foci factor with the game-foci factor, thus reaching what we call a severity value. The values of each row will then be added together to form a total severity value, which is used to determine which problems are the most severe.

As this is a fairly large amount of data we will limit ourselves to choosing the 10 most severe problems and further analyzing these. These are shown in table 4.34

Table 4.34. Top 10 foci values

Problem	TWI	QO	ATD	SA	EOC	LTP	PS	SS	CU	LIT	Sum
WoW: Talents	1.78	5.33	3.33	4.35	5.33	4.22	0.5	0.9	1.87	0.27	27.88
Riddick: Hide mask	7.2	7.22	1.96	5.87	1.6	0.56	1.6	0.02	0.0	0.0	26.02
WoW: Potions	3.56	4.89	2.67	4.6	5.87	2.67	0.4	0.0	0.0	0.0	24.65
Empire: Tac minimap	2.46	4.9	4.44	4.89	2.67	4.27	0.67	0.0	0.0	0.16	24.44
WoW: Aggro	3.78	4.44	2.0	4.86	3.73	1.56	0.8	0.6	0.47	0.0	22.23
Empire: Troop in field	3.21	4.2	3.89	4.64	2.67	2.4	0.78	0.06	0.0	0.31	22.16
WoW: Hostility	2.44	4.67	2.0	4.35	2.13	0.44	0.5	3.6	0.23	1.33	21.7
WoW: Items	2.22	4.44	2.0	2.56	4.53	1.78	0.5	2.1	0.7	0.8	21.63
Riddick: Doors	6.6	5.56	1.47	4.4	1.07	0.56	1.07	0.0	0.0	0.0	20.71
Fallout 3: Radar	2.6	3.11	2.46	3.4	3.47	2.0	1.32	0.44	0.0	0.53	19.33

Each of these problems will be analyzed according to the standards set down in chapter 2, thus anchoring our finding in previous research.

4.8.2 Analyzing problems

Methodology

Our solutions are anchored in the research of Norman, Nielsen and Shneiderman, and by simply applying their principles to the problems at hand we have found very simple and straightforward solutions.

One might claim that many of our solutions are simple almost to the point of banality - but in all honesty that simply proves that these issues are easily remedied.

The silver bullet

Several of the problems presented in this thesis could be solved by allowing more user freedom in the games. Developers installing color picker systems into their

games, where the player could set all GUI colors themselves would remedy most, if not all, of the problems we have discovered.

We have, however, chosen to disregard this blanket solution since we feel that it would greatly complicate the GUI development of a given game. We also feel that this would be a sub-optimal solution to most of the situations here, given that the games we have analyzed are already done and released. Furthermore, we feel that it would be unreasonable of the game to require the player to manually set the colors for each and every element in the game when the problems might be solved with much less work.

WoW: Talents

The main problem with the WoW talent display is that a user affected by protanopia or deuteranopia is for all practical purposes unable to differentiate a ”filled” talent slot from an unfilled one without either knowing the number of points one can put in that talent or by hovering over it. This fault is a classic example of how to not conform to Norman's *Visibility* and *Feedback* principles (Norman 2002) as well as the analogues outlined in chapter 2. The user is simply unable to quickly perceive the system's status or any significant change in it.

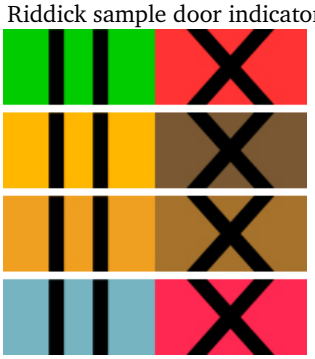
Our solution proposal for this issue is quite simple - one simply adds a slash followed by the maximum number of points one can allocate to the point display box. This means that for a five point talent the box reads “3/5” instead of “3”. While this displays information both color blind and unaffected players had to hover to display, the solution does not favor one group above the other. This solution is directly derived from the WAI: WCAG Guidelines, section 1.4.1 “Use of color” (chapter 2 section 4 in this thesis).

Riddick: Hide mask & doors

We have decided to combine these two issues into one as they are quite similar. As with most of our problems, the situation affects Norman's *Visibility* principle (Norman 2002) as well as the related principles from Schneiderman and Nielsen. On top of this it also hinders the player's ability to make use of the *Mapping* (Norman 2002) elements in the game. The player simply cannot differentiate a locked door from an unlocked one.

Our two solutions is to further clarify the status of the door's lock by adding either a symbol to the light (WCAG Guidelines 1.4.1), or making it positional like a traffic light. In the first case the door could have simple yet *Mapping*-increasing symbols embedded in the light (or the light shaped like them). For example a parallel pair of lines for an open door, and crossed lines for a closed door, as seen in Figure 4.20.

Fig. 4.20. Riddick sample door indicator symbols



In the other case, one could simply make the light two-part and light the relevant part as needed. For example, the top half could be a green light for open and the bottom half a red light for closed.

Both approaches map well to our real world, as they are symbols and signals we encounter daily - thus giving the game a greater match with Nielsen's principle *Match between system and the real world*.

WoW: Potions

Using the same icon for a bottle and only changing color to signal the content/effect of a potion leads to problems in regard to Norman's *Visibility* and *Mapping* principles. If there is no easy way to distinguish similarly colored bottles from each other, the player will face a mapping problem. The player will have problems telling what will happen should he use a potion.

We suggest that more information is added to the bottle icons (WCAG Guidelines 1.4.1). For example, there should be room for single letters or abbreviations on the icon, telling the players what type of bottle he is about to use.

Empire: Tactical minimap

This design is cluttered, and shows several problems with *Visibility, System Status* and *Feedback* principles laid down by Norman. It also breaks Nielsen's rule of *esthetic and minimalistic design*.

Following WCAG Guidelines *1.4 Distinguishable* and *1.4.6 Contrast(Enhanced)*, the icons should be more abstract, and the design should show letters, like C for cavalry etcetera. Also, the battle gauge visibility and contrast should be enhanced by adding a line in contrasting color (e.g. black or white) between the two color fields, separating them. This solution would also satisfy the IGDA rule *High Contrast Mode For Low Vision*, even if we do not suggest a separate mode for the game.

WoW: Aggro

The color blind player will face problems of reading the *System Status* and *Feedback*, thus affecting the similarly named principles.

Since the game already have a color picking system in place, at least for text, we see no hindrance for the player to be allowed to pick this color by themselves. A small icon (WCAG Guidelines 1.4.1) could be added to enhance the system status/feedback information. For example a little “smiley” that goes from happy to angry or some similar, culturally connected icon.

Empire: Troops in the field

When looking at the images of the battle field and the troop banners, we see problems with *Visibility*, *Affordance* and *Mapping*. The visibility is problematic, since we cannot easily tell enemy from friend. If the player cant tell which troop is which, it is hard to tell what troop to order, and what orders to give.

This is easily remedied by either adding more information to the banners (WCAG Guidelines 1.4.1), making the differences stronger or a combination of the both. For example, adding icons to the enemy flag (a skull, crossed swords etc) would allow the player to immediately tell enemy from friend.

WoW: Hostility

The WoW hostility markers problem is a breach of Norman’s *Visibility* principle (Norman 2002). There are two problems: the color of the name tag of the hostile entity, and the color of the ground marker (a colored “dot” around the feet of the entity).

If we remove the color carried information (like a colorblind person would see it), the visibility is completely lost. Hence, this information should be carried (WCAG Guidelines 1.4.1) in more ways than just color. One simple solution would be to change the ground marker, from being the same shape as a friendly target to be another, easily distinguishable simple shape, for example a star or square.

The name tag of the entity suffers from the same problem. The information relies solely on color. A very easy solution would be to add more information to the name tag by adding special characters like $\ll$, *, = etcetera around the name. By using for example $\ll$*Hostilename*$\gg$ we have added more information which is color-independent. These changes to the WoW hostility markers could also be alternate for players who prefer not to see them.

WoW: Items

Again we see problems of a *visibility* (Norman 2002) nature. Also, it is viable to claim problems of *mapping* since the player will not know (at a glance) the effect of using an item.

The name of the item needs to carry more information about its quality besides the text color (WCAG Guidelines 1.4.1).

By adding a number of plus signs (+) in front of the name depending of the quality, a player can quickly understand what quality an item has. For example: an unusual item gets one +, a rare item gets two ++ etcetera. An example of a rare item would thus be ++*Steel shinguards of the Bear*++.

WoW already uses this method to signify the difficulty of crafting items with the game's built-in color blind filter enabled, and as such the player can easily transpose the meaning of the plus signs between situations.

Fallout 3: Radar

Here, we face problems with Nielsen's *system status* rule (are there friends or enemies around?) and Norman's *visibility* rule (not being able to tell friend from foe).

Solving this problem is fairly simple - one would simply use different icons for friendly and hostile entities (WCAG Guidelines 1.4.1).

❖ 5

Establishing patterns

In this chapter we have taken the experiences gathered from the top 10 problems and their solutions suggested by us, in chapter 4 and condensed them into design patterns. These patterns are based on the design principles laid down by Norman, Shneiderman and Nielsen in combination with our own findings, and are intended to be used as a rule set to further conform to their principles.

5.1 Methodology

In chapter 4 we dissected each given problem, found it is root causes and presented a possible solution to the problem at hand. In this chapter we will condense these solutions into a set of design patterns by formalizing them into the aforementioned ruleset.

To confirm our findings we will also subject these patterns to public scrutiny from both the scientific community as well as normal gamers.

5.2 Common denominators

This section outlines the most common error types we have discovered. They are ordered by their relation to the previously mentioned principles of Norman et al, and in order of severity - where the first is the most severe.

5.2.1 *Visibility*

Given the nature of the medium, it is hardly surprising that this is the most affected principle. All our problems stem from the user's inability to perceive the nuances of the images on the screen.

5.2.2 *Feedback* and *Visibility of system status*

The effect on these two principles are all byproducts of the *Visiblity* problems we described earlier. Since the user is unable to properly interpret the image on the screen, the user is as such unable to take in feedback or see what the system is trying to tell it.

5.2.3 *Mapping*

As with the aforementioned principles, this principle is a byproduct of the *Visibility* problems within the game. Once again the user is unable to interpret the image on the screen, and as such is less able to interact with the game environment.

5.2.4 The core problem

As seen above, the problems are all related to a lack of coherence with Norman's *Visibilty* principle. In short, if the user can't see what he is doing he can't understand what action to perform, and he can't understand why some actions cause the game to behave strangely. It is therefore of the utmost importance that the game maintain coherence with the *Visibility* principle.

5.3 Achieving *Visibility*

As seen in 4.8.2, *Analyzing Problems*, we have a few types of solutions. These are characterized in the subsections to 5.4 below. For completeness, they will also be cross-examined with W3C's WCAG and IGDA's accessibility white papers.

5.3.1 Multiple information carriers

Games should use more than one way to convey information to the user. One great example of when this is needed is the WoW talents. The problem was solved by adding two extra characters to each talent's text box, instead of just using the border's color to convey information. This is the main focus of the WCAG's rule 1.4.1, *Use of Color*.

This problem is also very apparent in the case of Riddick's doors. If the game designers had used one more way of conveying information, the problem simply would not exist.

The carriers do not have to be purely graphical however. As seen in our examples for WoW item quality, hostility markers and potions, the game might use special textual markings to denote the system's status.

In addition, the different information carriers should be clearly distinguishable from each other so that they are properly visible for someone suffering from color vision deficiencies. The WCAG guideline 1.4.6, *Contrast (enhanced)*, especially highlights this - as does IGDA's *High Contrast Mode for Low Vision* guideline.

5.3.2 Iconography

As a way of conveying information via multiple carriers, games should use *geometrically diverse* icons. Once again, Riddick's doors illustrate this very well.

However, one should take care not to clutter the interface with a myriad of small icons. This problem is very apparent in Empire's tactical minimap. While the iconography is diverse, the icons themselves are so small that they resemble amorphous blobs more than distinct shapes. If this is coupled with poor color representation, it takes the game back to square one. This problem is essentially related to the WCAG guideline 1.4, *Distinguishable* - a cluttered information area will make the information itself much harder to distinguish.

5.4 The Patterns

By pattern we mean a design instruction, or guide, to a game designer or developer in order to help them to avoid unnecessary problems like the ones we have encountered. These design patterns are intended to have a high level of abstraction within the context of computer games. For example, some of the patterns cohere with more than one type of genre and foci (as defined in chapter 4 of this paper). The patterns are not listed in any kind of order, and should be viewed as a basic source of inspiration. The patterns follow the same format as the patterns Dr Martijn van Welie presents on his web site (van Welie 2008).

Our ambition is that a developer shall easily find their issue and the solution to it. The pattern is divided into five parts; what is the problem, suggested solution, when to use, how to achieve the solution, why the problem should be remedied. The last part is for this thesis only. It is a pointer to our earlier findings, where the problem is being discussed.

5.4.1 Pattern: Hostility

Problem

User can't easily tell if another player/NPC is an enemy or a friend.

Solution

Differentiate enemy/friend information more than with just colors.

Use when

When a user need to make a quick choice based on detection of animosity or friendliness (in a FPS, while adventuring in an MMO).

How

Consider the time critical information regarding other players available to the user. Is the information solely based on color schemes? If so, consider adding more information; icons with clear faction information, shape of foot marker, name tag information, etcetera.

Why

Being able to distinguish friends from enemies in a stressful environment is very important. A user who is less able to process this information has a serious disadvantage. By enhancing the information visibility both normal seeing and color blind users are helped.

Example of problem

We have shown examples of this problem with the Fallout 3 radar, WoW hostility and Empire: Troops in the field.

5.4.2 Pattern: System Status

Problem

User can't easily recognize feedback from actions or understand what status the game is in.

Solution

Use sound, animations and flashing lights to direct the user's attention to the relevant information.

Use when

When the user need to make decisions based on information conveying information regarding changes in system status.

How

If color is the single information carrier of feedback/system status changes, consider adding blinking/movement or some animated element in order to attract attention.

Why

The user want to make correct decisions and take relevant actions responding to the system status. To facilitate this, the developer should enhance the users awareness of the system.

Example of problem

We have shown examples of this problem with WoW: Talents, WoW: Aggro and in some aspects of the Empire: Tactical Minimap.

5.4.3 Pattern: Items

Problem

Users rely primary on colors to differentiate between in game items (potions in WoW, item quality etcetera).

Solution

By use of iconography/shapes/characters/text the items can be made easier to tell apart.

Use when

If several items with different effects share the same shape/icon, and an error can be detrimental to the game experience (for example using a mana potion instead health potion in WoW)

How

Item icons can be marked in such a way that they can easily be distinguished. For example, single characters or abbrevations can be used, background patterns etcetera can differ.

Why

Users with color vision deficiencies may hesitate to use or equip certain items due to lack of information, or may use wrong item when stressed.

Example of problem

We have shown examples of this problem with WoW: Potions and WoW: Items.

5.4.4 Pattern: Mapping

Problem

The user can not easily read her surroundings or use an item due to lack of visible information.

Solution

Enhance mapping with icons or similar (for example the Riddick door lamp lacks mapping, enhancing it with icons for open/closed helps the user to tell if a door is locked or not).

Use when

There is a risk that a user is hindered in her decision making process due to lack of information.

How

Use of icons, images, and other forms of input rather than just colors.

Why

Color blind users may make bad actions based on weak or misinterpreted input. The developer should allow the user to understand the environment regardless of color vision status.

Example of problem

We have shown examples of this problem with Riddick: Hide mask and doors, WoW: Potions and in some aspects ETW: Troops in the field.

❖ 6

Community feedback

This chapter outlines how we attempted to gather information from the gaming community. Unfortunately, the response from the community was fairly weak. We have however decided to keep the chapter for posteritiy.

6.1 Method

6.1.1 Collecting comments & opinions

Collecting research data from web fora raises a number of issues and challenges. In the article "Social Science Research in Virtual Worlds" (Lankshear and Leander 2008) a number of issues are lined up. As we collect our data from comments and posts on Internet based fora, we consider these circumstances:

- In a web forum, it is difficult to establish whether or not the collected data is valid. The members of the forum may well be something completely different than what they claim to be. For example, a color seeing person could claim to suffer from protanopia etcetera.
- The Internet media is more fickle and transient than for example data in books. The fora we decide to join can suddenly disappear, alter their nature or in other ways change in such a way that our main data collection will lose validity.
- Some members may not want to reply, or possibly only reply in a taunting manner if the researcher lacks the knowledge or "social status" the forum members adhere to. This elitism is common in more secluded fora.

According to Lankshear and Leander there are mainly two methods of data gathering from the web.

The first method is to observe only. Reading without any input in the debate, collecting data and analyzing without informing the forum attendees. This method may be considered morally dubious as the attendees are unaware of the fact that

their comments may be subject to analysis and end up in a final report. On the other hand, the researcher will have fresh, non-censored material to collect and analyze.

The other method Lankshear and Leander propose is the one where the researcher introduces himself, presents his purpose and goal, actively joins the debate and in some cases conducts personal interviews with members of the forum. This method is more correct in a moral point of view, but some valuable spontaneous comments may be lost.

In order to deal with elitism from forum members, we carefully select what fora to join. By reading several older posts, we gain an understanding of the atmosphere in the forum before joining it ourselves.

Finally, the transient nature of the web presents a problem for us, as detailed above. By collecting and storing some of our material as screen dumps (as both text and images) we preserve the validity of our finding even though the actual site might disappear.

We needed to set at time limit on this section of our research. We decided to allow 3 weeks to pass, measuring the replies daily. If the discussion matted off, we would let it go for another full week. If no more responses had come in, we decided to gather what we had and leave the discussion. The entire span of this research section was four weeks.

To gain interesting feedback from both the playing community and the game designers, we decided on *Sweclockers*[1] and *IGDA*[2]. Sweclockers is a forum for computer interested people. The discussions on this page range from computer hardware, overclocking CPUs, game related discussions and other similar topics. We have a long experience from this forum, the attitude and the general level of dialogue. It seemed feasible that this forum would supply us with comments from the user perspective. Based on the fact that we also are users of games rather than developers, the Sweclockers forum was the one we decided to actively participate in.

The professional point of view, we hoped to get from the IGDA-forum. This forum is used by game developers and producers. Since we are not game developers ourselves, we decided to leave any replies unchallenged and just take in any comments we got.

In both fora, we introduced ourselves, described our work and posted our findings (the design patterns), asking the readers for feedback. We expected more processed and experienced feedback from IGDA, since game developers use that forum, and more user-feedback from Sweclockers. However, as we will show, neither of these fora gave much feedback at all. The ambition was to allow one of the forum to live its own life as described above, and the other to actively participate and create discussion.

[1] http://www.sweclockers.com
[2] http://www.igda.org/forum

6.1.2 Analyzing the feedback

We wanted to use the feedback from the fora as an early critique and feedback to our findings. We also hoped for new material, things we have not thought of in our design patterns. We have read the replies in both fora, sorting them in good feedback (suggestions, alternate problems etc), negative feedback (comments with no real value to our thesis such as slander) and finally irrelevant feedback (comments that are outside the scope of the thesis such as “my uncle is colorblind”). Below we present the relevant feedback from the four week exposure.

6.2 Results

Outlined below are the answers we collected, ordered by site. These quotes are provided verbatim where in English (IGDA) and translated as true to the original language as possible (Sweclockers), including foul language.

6.2.1 IGDA

The IGDA forum spawned exactly one reply. This forum was left alone, with no further input from us during the four week exposure. This was a good feedback, suggesting a color wheel used by British Broadcasting Corporation.
Poster 1: [sic!]

> The most significant effect of color blindness on computer user interfaces is a significant reduction in the color spectrum available to communicate to the user. People who are not color blind can distinguish among a greater number of colors than people who are color blind.
>
> The BBC published color wheels, along with RGB values, that non color blind developers can use to select colors that color blind people can distinguish. That is, colors that are sufficiently different to the vision of people who are color blind.
>
> BBC removed these color wheels from their Web site in 2008. However, we copied them to our Web site, www.7128.com before that. Check out: http://www.7128.com/resources/resources_color_blind.html
>
> I used these color wheels in an application I built where the client was color blind.

6.2.2 Sweclockers

The following three comments are from Sweclockers. This forum was the one we actively participated in. All comments were written in Swedish and have been translated for the purpose of this chapter.

Poster 1: [sic!]

> I suffer from this handicap myself, and I can only agree with the assertions of the pdf, if only game makers would be able to realize that color blindness exists and is a hell of a disadvantage, maybe we could get some better solutions...
>
> It can't be so damn hard to put a choice of "simplifying for the color-blind" in the settings.
>
> In WoW I had a hell of problems to see which items were "epic", if blizzard had thought things through, they could have written "epic", "rare" or "common" on items rather than to color-code them.
>
> Do not have much comments to make, however, I think you have covered most things there, then there must be other games that are harder for us color blind than those which you have as an example, have you tried playing Audiosurf e.g. Not easy for a color blind, in general there are too many "pair colored objects together-games" in which there is at least 2 colors which are to similar.

Poster 2: [sic!]

> I think this is an interesting problem. Basically, I think Your report is good but there are some things that could be improved. I think you should give more examples in your patterns. The text of your pattern is a bit short. You could also write more on how you approached the study of the games and then be a bit more specific about the problems you discovered. And as someone said screenshots should be included in the report, with only the "problem" visible. You can also try to use two column layout in LaTeX to "pack up" report some since it is quite airy. I also see no references to all of your sources. You mention them in the text but they should have a proper reference also.

Poster 3: [sic!]

> I myself am color blind and the only problem I had when I was playing computer games was when I played WoW and would raid Karazhan[3]. Think it was Netherdrake[4] or SMB boss where you had to block the rays of different colors and I had problems and telling the rays apart. I had to tell the raid[5] that I could not make it. About telling the difference between rare and epic items it was never a big problem for me because it is not the color that

[3] A dungeon in WoW
[4] A monster in Karazhan
[5] A raid is a congregation of players, trying to beat harder encounters together. Usually 10 or 25 people make up a raid

determines whether an item is good or not but the stats[6], but surely you can fix it so that you know if you have epic or not.

6.3 Analysis

The fora exposure did not create any pattern-improving results. However, it can be argued that two of the replies were from alledgedly color blind computer gamers, who find their disability to be problematic when playing computer games. Also, the BBC color scheme is good to have, however it is not within the scope of this thesis to present actual color solutions to our problems.

[6] Value and effect of an item in WoW

❖ 7

Conclusions

Writing this thesis has taken the better part of a year, and it has been quite an experience. Not only have we learned a lot about how color blindness works, but also about how it affects those who have it. We now have a greater understanding of how a less visible and yet common disability can cause quite a lot of problems for those who suffer from it. We believe that game developers should take this fairly large group of gamers into account when they develop games - especially since it is quite easy to solve these issues. In fact, we were surprised to find that the solutions to these problems were so simple - which makes us wonder why no one has addressed this issue before.

7.1 Goal fullfilment

We set out with the ambition to create design patterns in order to give game developers tools to measure their work in a color blind context. We also wanted to see how the game designer and gamer communities addressed this problem, if at all.

We have shown how we came to the final results, the patterns. We also believe that the methods, concepts and terminology we developed can be used in future research within the area. However, our second goal did not produce any convincing results. This may be because of our choice of method or the fact that the gamers and developers does not give this issue much thought.

7.2 Conclusions & discussion

We have shown that color blind computer gamers face fairly severe issues when playing games - and that these issues seem to be directly related to how complex a game's interface is. This is probably because there are more elements for the game developer to contend with and as such there will be more errors. This is illustrated

very well when one compares *Riddick* to *WoW*, where the latter has a more complex interface and significantly more issues.

To be able to properly identify these issues we developed a model for evaluating games. We started by defining a couple of genres, and evaluating different focus areas (*foci*) for these. We then sorted each game into a genre, and evaluated each game to see if and to what degree it had issues regarding a certain foci. Both of these evaluations were done by using qualitative user surveys. The results of each survey were then combined to give a weighted problem value for each foci. The sums of these values were then used to select the most severe problems. By using this method we have identified the main issues with each game and the severity of them. This method can easily be applied to other games, and it is most likely usable for other accessibility issues, such as hearing impairment, attention deficiency disorders etcetera.

These problems were broken down by applying HCI principles, and we were then able to propose solutions to the identified problems.

Since most of the games tested have interfaces which are fairly well suited for their purpose it seems that game developers apply HCI patterns to their products. Unfortunately the general HCI principles do not cover color blindness in particular, and as such we believe that the developers may not consider the problems color blindness pose. In short, it seems that since it is not part of the standard rules and patterns it may be that it is simply forgotten.

We have provided a small selection of patterns to alleviate these issues, and we hope that these will serve as a basis for further research into this area. While our actual pattern collection is rather small, and only covers the mere basic issues faced by color blind gamers, we hope that our research method might be used for future studies of other games and genres.

The result of this thesis points a light on a bigger issue; if one out of ten suffers from color blindness, is this really to be considered abnormal? Would it not be more fair to classify this as a common state, such as left handedness? If 5-10% of a game's player base experience the problems we have found, and, as we have shown, the solution is ready at hand, claiming minimal effort from the designer, why is this not a part of regular procedure? Roughly calculated, it means that between 500 000 and 1 000 000 players in WoW meet some of these problems every time they play.

One might argue that there are certainly other problems we simply can not find since we are not color blind and as such it is hard for us to imagine all the possible problems this group face. While this is undoubtedly true it is very possible that we did find some problems that color blind gamers would not find as they are not aware of what they are missing due to their disability.

Very few developers would, for example, make a GUI for a game that was not reversible for a left handed player - the vast majority of modern commercial games

will allow players to customize their interaction by changing mouse sensitivity or remapping buttons and keys. We do not believe that the developers leave out this group on purpose. It must simply be due to not being aware of the problem. Why should anyone be left out of the entertainment that games provide, just because they are not “normal”? What does it mean, in fact, to be normal? In essence, we believe it is time for a change in attitude, challenging the terms “normal” and “abnormal”. Hopefully this thesis will help in that challenge.

7.3 Future research

This topic is as of yet very new, and as such needs to be explored further. To facilitate this research we suggest that people use the methodology we established in this thesis as a base, and develop more patterns by analyzing a broader spectrum of games. Hopefully, this work can also inspire to do similar studies regarding other disabilities.

7.4 Acknowledgments

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❖ 8

Acronyms

AI Artificial Intelligence
ATD Attention to Detail
BS Ben Schneiderman
CU Customizability
DN Don Norman
EOC Effects of Choice
ETW Empire: Total War
FPS First-person shooter
GUI Graphical User Interface
HCI Human-Computer Interaction
IGDA International Game Developers Association
JN Jakob Nielsen
LIT Literacy
LTP Long-term planning
MMO Massively multiplayer online
MMORPG Massively multiplayer online role playing game
NPC Non-player character
PS Problem Solving
PvE Player versus Environment
PvP Player versus Player
QO Quick Observation
RPG Role-playing game
RTS Real-time strategy
SA Situational Awareness
SS Social Skills
TBS Turn-based strategy
TWI Twitch
UAAG User agent Accessability Guidelines

UID User Interface Design
W3C World Wide Web Consortium
WAI Web Accessibility Initiative
WAI-ARIA Accessable Rich Internet Applications
WCAG Web Content Accessibility Guidelines
WoW World of Warcraft

References

Brundell and Eliasson 2005 Brundell, S. and F. Eliasson (2005). Dator och internet i hemmet. http://hi.se/Global/pdf/2006/05346-pdf.pdf. In Swedish. Visited March 26 2010.

Dataspelsbranchen 2008 Dataspelsbranchen (2008). Populärt nöje. http://www.dataspelsbranschen.se/media/1732/dsb-faktafolder%20screenview.pdf. In Swedish. Visited March 26 2010.

Dougherty and Wade 2008 Dougherty, B. and A. Wade (2008, July). Vischeck: Home. http://www.vischeck.com/. Visited March 26 2010.

Hewett et al. 2009 Hewett, T. T. et al. (2009, July). Acm sigchi curricula for human-computer interaction. http://old.sigchi.org/cdg/cdg2.html. Visited March 26 2010.

IGDA 2004 IGDA (2004). Accessability in games: Motivations and approaches. Technical report, International Game Developers Association.

Kaiser 1996 Kaiser, P. K. (1996). *Human Color Vision*. Optical Society of America.

Lankshear and Leander 2008 Lankshear, C. and K. N. Leander (2008). Social science research in virtual worlds. *Research Methods in the Social Sciences 1*(5), 42–111.

Laramee 2002 Laramee, F. D. (2002). *Game Design and Perspectives*. Charles River Media.

Nielsen 2005 Nielsen, J. (2005). 10 heuristics for user interface design. http://www.useit.com/papers/heuristic/heuristic_list.html. Visited March 26 2010.

Norman 2002 Norman, D. (2002). *The Design of Everyday Things*. MIT Press.

Oxland 2004 Oxland, K. (2004). *Gameplay and Design*. Addison Wesley.

Robinson et al. 1997 Robinson, B. et al. (1997). The prevalence of selected ocular deseases and conditions. *Optometry and Vision science 74*(2), 79–91.

Rollings and Adams 2003 Rollings, A. and E. Adams (2003). *On Game Design*. New Riders Publishing.

Shneiderman 1998 Shneiderman, B. (1998). *Designing the user interface: strategies for effective human-computer interaction, third edition*. Addison Wesley.

van Welie 2008 van Welie, M. (2008). Interaction design pattern library. `http://www.welie.com/patterns/index.php`. Visited March 26 2010.

Vanderheiden et al. 2008 Vanderheiden, G. et al. (2008). Web content accessibility guidelines (wcag) 2.0. `http://www.w3.org/TR/WCAG20/`. Visited March 26 2010.

❖ A

Questionnaires

A.1 Foci severity evaluation

The respondents were asked do provide a yes or no answer to whether they are familiar with computer games (they all answered “Yes”) and whether they were computer blind, and if so what kind of color blindness they suffered from. Two of our ten respondents were color blind, and both of them put this down as “red-green” color blindness. Furthermore they were given the following instructions, in writing:

> **Instruction:**
> Grade each foci/image pair from 0 to 3, according to severity. Empty cells will be considered as zeroes.
> The severity of each grade is as follows:

Severity	Explaination
0	None. Negligible or no impact on game play.
1	Low. Annoying but not really detrimental to game play.
2	Severe. Disruptive to game play.
3	Critical. Ruins game play or makes the game impossible to play.

This was followed by the foci definitions from chapter 4, as seen in 4.3 Genre foci.