Improving asset readability in top-down VR games

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Abstract (English)

With this work I wanted to examine how to improve readability of battlefields in top-down games for VR by increasing the visual distinction between units. I analyzed three successful PC games within the genre and created three different user tests to come up with my results and conclusions. The results from my VR test is compared to my non-VR tests to see what one has to do to reach the same level of readability or better in VR. It turns out you need to put more time in to your assets for improving readability in VR than without VR on a non-stereo display.

Sammanfattning (Swedish)

Med detta arbete ville jag undersöka hur man förbättrar läsbarheten av slagfält i top-down spel för VR genom att öka den visuella skillnaden mellan olika enheter. Jag har analyserat tre PC-spel inom genren och skapat tre olika användartester för att komma fram med mina resultat och slutsatser. Resultaten från VR-testet jämförs med resultaten från testen utan VR för att se vad man behöver göra för att nå samma nivå av läsbarhet eller bättre i VR. Det visar sig att man måste lägga ned mer tid på sina assets för att förbättra läsbarheten i VR än utan VR på en icke-stereoskopisk bildskärm.
Terms and abbreviation

These are some terms and abbreviations I’ve used in my thesis that you will need to know to understand the text better.

- VR: Virtual reality, with stereo display
- Non-VR: A non-stereo display such as a regular PC or TV monitor
- HMD: Head-mounted display
- Unit: An interactive 3D character inside a game
1 Introduction

1.1 Background and issue
During my bachelor thesis I’ll be working at Lundmark & Marklund (2017), who is making real-
time action strategy games for PC and Virtual Reality. Although we are not the first to create
a game in this genre, we are among the first to bring these kinds of games to VR and would
like to deliver great games. One area that we think is important and would like to improve in is
readability of the battlefield.

In order to increase player reaction time and effectiveness in real-time strategy games it is im-
portant to have a clear overview of the battlefield and be able to distinguish the units within. We
currently have a problem of seeing how to best do this. VR makes it extra difficult as the screen
has relatively low resolution and the image becomes blurred around the edges of the screen, along
with other complications.

The issues are:

- How do we improve readability of a battlefield in top-down games for VR?
- How do we make units more distinct from each other?

1.2 Purpose
The purpose of the project is to explore different methods and design guidelines for creating
clear and readable assets for top-down VR games, and then make conclusions of what the most
important things to think about is while creating and/or designing your game assets. This will
make the production more efficient as well as improve the player experience.

1.3 Methodology and limitations
I’ll start of by analyzing other successful PC games within the same genre and look at how they
show their units for the player. That information will be valuable in the discussion and when
creating my own units which will be used for my own VR and non-VR tests, and as well for a web
survey.

All of my tests will be done inside a game engine where I will have one human character, create
variations of it and then compare how different the variations look to the original character. The
variations I will test and observe are limited to these six visual properties based on my preliminary
study:

- Size
- Silhouette
- Values
- Texture
- Colors
- Animation

I will not analyze how the background that the units stand on affects their readability.

The PC and VR tests are for measuring the speed of which users can make a distinction between
units. The web survey is for collecting users’ feedback of what units they believe is easier or harder
to read. My VR test will be done with HTC’s VIVE which is one of the best Virtual Reality
Headsets for PC that is available for consumers right now with room scale technology. As of
writing, the VIVE has a combined resolution of 2160 x 1200 pixels, and the user can walk around
in a room and point-and-click to interact with the environment they’re in. (2017).
2 Preliminary study

2.1 Literature

Valve has created a guide (2015) to follow when making unique and distinguishable heroes for their game *Dota 2*. The first principle that they write about is silhouette, where they state that “A hero’s silhouette must be clearly identifiable at first glance”. And then they go on writing about values, colors, areas of rest, detail, directionality, readability and more. They use values in many ways to improve readability and character identity by blocking out values, using gradients, creating focal points and adding the illusion of depth. Additionally, Valve gives each character a unique color key palette consisting of a primary color along with at least two more colors based on different color schemes.

Not only is silhouettes important, but a character will change its silhouette when they turn around (Block 2007, p. 37). That does not only apply to when a character is turning around, but as soon as an object is animating its silhouette shape may change.

According to Block (2007, p. 11) “Every visual component (space, line, shape, tone, color, movement, and rhythm) can be described and used in terms of contrast and affinity” and follows up with an example of how using too much contrast or too much affinity is not good since it may become either too intense or too monotonous.

I also came across color, values, silhouette, detail and scale in a book considering them to be part of the art fundamentals color, light, composition, anatomy, perspective and depth (Riabovitchev A., Beloel G., Castro F. R. 2013).

2.2 Observations

Here are some of my observations of units in three successful strategy games for PC after watching several replays of matches. I look at some differences and compare them to each other and the information will later be used in creating the units my tests and survey, and also for the discussion.

![Figure 1: Ensemble Studios (2005), Age of Empires III. Microsoft Studios.](image)

Every team in *Age of Empire III* has a dominant color that is displayed on the teams’ units. Different units do vary in size, however most units are humans and are approximately the same size. They do have different silhouettes, values textures and animation.

The player has the option to turn on health bars above each unit which make them easier to spot, but they do not help in distinguishing units within a team.
Each team in Starcraft 2 also has a color that is visible in all units, but the colors are less vibrant. Teams may also play as different races which all have completely different units and consequently they have different models, silhouettes, values, textures and animation. Units also vary in size a lot more compared to units in Age of Empire III.

Here the player has the option to turn on health bars as well, but they differ in that they represent each unit better by scaling the bar and displaying shield and energy meters appropriately.

Like the two other games, Total War: WARHAMMER also has a color for each team, but in this game the team color is not shown on the units themselves. Instead the color is shown on markers on the ground when the player hovers with their cursor over or selecting one or more units. Although colors and values vary less in this game compared to the other two, Total War: WARHAMMER has the most variants of unit sizes. On the other hand, the amount of units on the battlefield and the ability the zoom out a lot giving the player a wide view over the map makes some units very small on the screen.

Many units come in a group and have a shared health bar over them and a banner indicating what type of units they are, and the player may toggle the health bars and banners on and off at any time.

2.3 Six visual properties

I chose to limit my visual properties to size, silhouette, values, texture, colors and animation because from my literature study and game observations they seem to be part of the art fundamentals and can also be applied directly to each individual unit in a game.
3 Method

3.1 Data collection

Here I’ll show how I prepared my survey and user tests with the intention to get data out of what is more or less important for reading units swiftly. The plan was to both measure users’ reading speed and taking their opinions on unit distinction.

I was given a model for a default character provided by Lundmark & Marklund which would stand as the base unit. I rigged, textured and animated this unit and then created 12 different variations of it based on the six visual properties I’ve mentioned earlier. If they were visually pleasing or not was not a concern. The focus was having multiple variations and each variation having two sets; one subtle (easy) and one more extreme (hard).

Figure 4: Screen capture of the base unit and its 12 variations

Here are descriptions of each unit, based on unit 1:

- Unit 1: Base unit
- Unit 2: Slightly larger
- Unit 3: Slightly different silhouette
- Unit 4: Slightly different range of values
- Unit 5: Slightly different texture on some parts of the unit
- Unit 6: Different colors, but very near on the color wheel (Riaovitchev et al. 2013, p-18)
- Unit 7: Slightly different running animation
- Unit 8: 50% bigger
- Unit 9: Completely different silhouette
- Unit 10: Very bright and high-contrast values
- Unit 11: Slightly different texture all over the unit. Still keeping the same colors and values
- Unit 12: Opposite colors on the color wheel
- Unit 13: Drastically different running animation

These were all displayed against a neutral gray background and the base unit and its variations also had the same positions and rotation in every image. In the VR and non-VR test the participants will see the units run, unlike in the web survey where they will be displayed as still images.
3.1.1 Survey

To collect opinions on the subject of distinguishable units I created a two-part survey (Johansson 2017) where each part consists of seven images that the survey participants must evaluate. The first six images in both parts will focus on one separate visual component that the participant must assess one at a time. The question asked for all of those images are “How easy is it to distinguish the two units in this image?”, and one of the units are always unit 1; the base unit. The participants gives them a number between one and five where one is difficult and five is easy.

Figure 5: Unit number 5 next to unit number 1, as displayed in the survey

The last image shows all previous units in one image. The participants are asked to “Rank how distinguishable each unit is to the original unit 1”. This means a unit can not get the same rank as another. Rank 1 is the lowest rank and stands for the least distinguishable. Rank 6 is the highest rank and stands for the most distinguishable.

Figure 6: Image for unit ranking in part 1 of the survey

The first part of the survey has unit variations that are more subtle and difficult to read, and the second part is more extreme and easy to read.

The survey was sent out to Computer Graphics and Computer Engineering students at LTU (2017) and takes about 5-10 minutes to complete.
3.1.2 Non-VR Test

I made an application that measures participants speed of finding differences in units.

It has 12 levels, one for each unit, that every participant plays in a random order. On every level there were 12 units, half of them base units and the other half one of the variation units. Before they appear on screen a timer of three seconds start and then each unit get a random position on the ground, but in a way that two units would never stand inside of each other. When the participant has clicked on each variation unit it automatically proceeds to the next level, until all levels are completed. The data I collected were time spent per level and amount of missed clicks per level. A miss click were counted every time someone clicked on the standard unit or the ground that they stood on. The data were then automatically emailed to me as soon as the test was completed.

Before actually starting the test a tutorial had to be played through. I gave the participant instruction they could read in English or Swedish and then they had to try out two levels with simple cylinder-like units to get an understanding of how the test worked.

This test application was sent out to third-year Computer Graphics and Computer Engineering students at LTU, and takes about 4-8 minutes to complete.
3.1.3 VR Test

The VR test works very similarly to the non-VR test. When it’s in VR the participants receive the same instructions and goals, but they have the option to walk around in the room, look around the units, move closer to the units and they have a VR controller instead of a mouse that they can point and click with.

To get participants for this I went to Baldergymnasiet (2017), a school where I asked students to partake in my test. We set up the VR rig in the school’s main corridor and everyone was welcomed to try it out.
4 Result

Below I will present the most important and relevant results from my user tests and survey. As a reminder, here are every visual property with their corresponding level number:

1. & 7. Size on screen
2. & 8. Silhouette
3. & 9. Value
4. & 10. Texture
5. & 11. Color
6. & 12. Animation

Every test had two sets of units that included all six visual properties. I will refer to the first set as the hard levels because in those levels it was more difficult to distinguish units than in the second set that I refer to as the easy levels, where it was more effortless to distinguish units.

4.1 VR and non-VR tests

Figure 9: Comparing results from non-VR and VR user tests.

Figure 9 shows the average time users spent per level. The left side represents the harder levels, and the right side represents the easier levels. We can see that generally it took longer time for non-VR users than VR users on the harder level, but on the easier levels non-VR was faster. In both tests the slowest level was the one with change in texture, on the hard and easy difficulty. On the harder levels silhouette was fastest to complete on VR, and color was fastest for non-VR. On the easier levels value and color was fastest in both tests.

One thing to notice is that for silhouette and texture the time improvement from hard to easy for VR users were both less than only 0.5 seconds.
Figure 10: Comparing results from non-VR and VR user tests.

Figure 10, left side, shows the average time users spent on each visual property, easy and hard levels added together. We can now see that the times for VR and non-VR become more equal. The average total time for all of the twelve levels for VR were 17.9 seconds faster than non-VR, landing on 152.4 seconds.

Figure 10, right side, shows the same average times as on the left, but with added average miss clicks per visual property on top of them. You could say that this is what the average time per visual property would look like if the user got a one second penalty for every time they did not click on the correct unit. We can see that the whole graph for VR is above non-VR’s graph, but not by much.

Figure 11: Comparing results from non-VR and VR user tests.

Figure 11, left side, shows average amount of miss clicks per hard level. Clearly VR users miss click more, but both VR and non-VR has large difficulty with level 4.

Figure 11, right side, shows average amount of miss clicks per easy level. Non-VR barely has any miss clicks at all, while VR has a large miss click spike at level 10.
Figure 12, top, shows the relationship between average time and average miss clicks per visual property. The top chart displays graphs for VR and bottom chart is for non-VR. We can see that the graphs for miss clicks follow the graphs for time, i.e. the longer a level takes to complete the more missed clicks.

4.2 Web survey

Figure 13 shows the average score that the participants gave each variation unit after asking how easy they are to distinguish from the original unit. Giving a score of six means it’s easy to distinguish the unit. Amongst the harder units animation got the highest score and value got the lowest. Amongst the easier units color got the highest score and texture the lowest.
Figure 14: Participants’ average ranking of visual properties. 6 means most distinguishable and 1 means least distinguishable.

Figure 14 shows the average rank for each visual property. The participants had to give each variation unit a unique rank between one and six, where a six means they are the most distinguishable.

Figure 15: Comparing ranks and score for each visual property.

Figure 15 shows the total average score and average rank for each visual property. As we can expect the curves for the ranks follow the curve for the scores. And again the texture receives a bad result.
5 Discussion

As I expected from my VR and non-VR tests the results between them are different, but they also have a lot in common when it comes to the overall difficulty of each visual property.

I believe that one of the more major differences was that non-VR were faster at completing levels when units were more distinct from each other, but when the units are similar to each other VR was faster. To be honest I didn’t know what to expect. I thought that VR users would have it more difficult on most levels, but at the same time they have the ability to move closer to units which should make it easier. Nevertheless, VR users were miss clicking a lot more in both cases, and that may be why VR users have completed the harder levels faster. And because of that, I would argue that VR users do not have it easier to distinguish units that are visually similar. Selecting the wrong units may also have a lot worse consequences in a real game than in my test application, so minimizing them is important. That’s why I added a chart where I added the miss clicks on top of the time for each level (fig. 10). There you can see that non-VR beats VR on every visual component, but not by a large margin.

What was the most interesting to see from the results were which visual property made the biggest difference in readability. I will go through each visual property one by one before discussing my methods and then come to a conclusion to how we can improve the readability of a battlefield in top-down games for VR.

5.1 Visual properties

5.1.1 Size

Varying unit size can be difficult to do depending on what kind of world your game takes place in. In a game like Age of Empire III it’s difficult to make large size variation because it would not be logical to have a five meter tall knight walking around. There are not many large units that we can relate to from 100 years ago. But instead they can have other large assets and say “If it’s small then it’s a unit and if it’s big then it’s a structure” and make distinctions between assets in that way. On the other hand, in Total War: WARHAMMER it’s very logical to have a five meter tall monster because their fantasy universe supports that and we can relate to it.

If you have a universe that supports a large variation of unit sizes then you can make use of it, otherwise don’t think about too much. My results show that increasing a unit’s size doesn’t help in distinguishing it unless it’s significantly larger. Making it 50% bigger in my VR test did help in reducing miss clicks, but not by much compared to several other easy levels like silhouette, value and color.

5.1.2 Silhouette

Changing the silhouette is usually easier than varying the size between units. It’s very useful because pushing the silhouette to be different shows great results even if it’s just by a little bit. Naturally this happens when you have different models or animations for your units. As you can see in my own units, it doesn’t have to be a completely different model. I did it by adding armor, accessories and pushing the model’s anatomy around.

5.1.3 Value

Variation in value is another great way to separate units but requires some more contrast than color to be as effective. Its hard level where I only made it slightly brighter gave a very slow result and the participants in my survey gave it a bad rating. There are only so many values that will create a contrast between each other, but by blocking out values differently, making use of gradients and varying the value compositions of your characters you may get many distinct variation. When creating more contrast in value it became one of the fastest levels to complete.

5.1.4 Texture

Changing the texture of a unit without altering the color or values too much really doesn’t help much unless you are really close up like in a third-person or first-person game. This seem to be even more true in VR where the time difference between the easy and hard level were less than half a second. Basically, however much you alter the texture it won’t help with separating units in
VR unless you start making color or value changes to the texture and consequently creating more contrast. The results for the easy level for non-VR was a lot better than VR and I believe that’s because you can see more details on a modern non-stereo monitor than with a Vive. Even though two units appear to be equally large in VR and non-VR, the resolution of the Vive was not enough to render the same details of a unit like on non-VR.

5.1.5 Color
Changing the color of a unit has given the best results overall making it fast and easy to distinguish on non-VR and VR. Among the other games I analyzed I saw they used color slightly differently. They all used color to separate the teams from each other, but Total War did not have the team color on the units themselves and instead show it on UI elements and banners. Therefore they can use color to distinguish teams and units at the same time. If it’s really important to distinguish I’d probably follow Valve’s recommendation on giving each character a unique color palette.

5.1.6 Animation
With the help of animation you can change a units silhouette, movement and rhythm which has shown a good way to make characters unique. Just like with silhouette you don’t need to change much of the animation to make a noticeable a difference. However, the results from the easier levels are quite average in the VR and non-VR test, indicating that it might not be important to make completely new animations for each unit and instead it may be enough to only take the animations you already have and modify those to make an improvement.

5.2 Additional observations
Here are some additional notes from observations and literature that may be connected to every visual property. First of all it’s the use of UI elements around units. By analyzing other games I came across markers below units on the ground, banners above units and multiple different health bars above units. They were used to display the directionality of units, associated team, strength and health.

Secondly I’d like to put some attention to my literature study and what Block wrote in his book about contrast and affinity, where he states that an image can become too intense or too monotonous for the viewer to look at. Consequently there also has to be something unifying the units on a battlefield. For example by making a limited amount of visual properties similar between units that play similarly.

5.3 Method critique
The group of participants in my user tests and web survey is very limited and therefore the results may not represent those who play or are interested in playing top-down VR games. Some of the participants of the VR test may never have tried VR before and that could have a largely negative effect on their performance as they might be distracted by the new VR environment they’ve recently entered, and they might not fully understand the controls and the ability to move around in the room and look closer on units.

When it comes to the units themselves and their variations. For some visual properties it’s impossible to change them without changing another one. For example, changing the animation will change the silhouette because the unit is posed differently, exactly as I found out by looking through literature by Bruce Block earlier. This is something I had to accept. And when changing the values in the texture, should I be adjusting the brightness only or should I also be adjusting the saturation to make it appear as if the unit has the same color as before? I wonder what would actually be the correct way to measure change in value.

Since I only used HTC’s VIVE for my VR test the results may not represent all VR head-mounted displays. Whichever VR HMD I chose the results may not be appropriate for long, considering VR hardware is rapidly evolving. Specifically their screen resolution may have a great impact on readability.
6 Conclusions

All in all there doesn’t seem to be any huge differences between designing good readability for non-VR versus VR. But when creating assets for your top-down VR game know that your users will to a certain point have it harder than non-VR users to distinguish between all assets regardless of what visual properties have changed between them. Slight changes that are visible in non-VR might not be visible in VR. That’s not very exciting, but it’s nice to know. Seeing what visual property made the biggest difference in readability was more exciting. Of course, make use of all visual properties; size, silhouette, value, texture, color and animation, and for VR push their contrast a step further and combine them in different ways to distinguish units from each other to make a better read of a battlefield. But don’t make too much contrast or it can become noisy. Different types of assets and unit classes can have similarities between some visual properties to create some sort of structure. Toggleable UI elements around units can also help a user to read the battlefield by showing essential information while giving each unit something in common with other units. Something that would benefit designers making these kinds of games would be to see more research of when an image becomes too hard to read because of too much contrast and noise.

Make use of color to separate assets that are the most important for the player to distinguish between. For example teams, or hero units. Colors are the best way to distinguish assets and there are plenty of colors to choose from. Saturated and unsaturated. But because there are a finite number of colors we can pick from, I’d like to get a better understanding of color contrast and when two colors are far enough apart from each other that they are easily distinctive.

The worst you can do is only making modifications to the texture that doesn’t affect much of its colors or values. You need to create more contrast over the whole unit and not only in the details of the texture because they will not be visible in a top-down VR game.

I would be interested to see someone taking various units and looking at them with and without VR, measure their size on screen and see how much bigger they approximately need to be in VR to reveal the same amount of detail as you can see without VR on a non-stereo display.
References


Figure 3 right: Creative Assembly (2016). Total War: WARHAMMER [PC game]. SEGA. From https://youtu.be/3k0x8msQxXa (15th December 2016). (Accessed 28th March 2017).
Readability in top-down games

Evaluating what makes units distinguishable from each other, and what visual component is more important.

*Obligatorisk

Notice:

You don’t have to play these kinds of games to answer the following questions. Please be honest as the results will be used in a paper about “Improving Asset Readability in Top-down VR Games”. At the same time you don’t have to put too much thought into each of your answers. Your answers are anonymous.

When you have completed this 2-page survey you will instantly be able to see diagrams of what other participants have answered, if you are interested.

The units below can vary in size, color, shape etc.

How easy is it to distinguish the two units in this image?

[Image of two units with a scale from 1 to 5 for difficulty]
How easy is it to distinguish the two units in this image?

[Image of two figures with a scale from 1 to 5, indicating difficulty.]

1 2 3 4 5

Difficult [ ] [ ] [ ] [ ] [ ] Easy

How easy is it to distinguish the two units in this image?

[Image of two figures with a scale from 1 to 5, indicating difficulty.]

1 2 3 4 5

Difficult [ ] [ ] [ ] [ ] [ ] Easy
How easy is it to distinguish the two units in this image?

1  2  3  4  5

Difficult □ □ □ □ □ Easy

How easy is it to distinguish the two units in this image?

1  2  3  4  5

Difficult □ □ □ □ □ Easy
How easy is it to distinguish the two units in this image?
Rank how distinguishable each unit is to the original unit 1. A low rank doesn't necessarily mean the readability is bad, it just means that it's the worst between these 6 images.

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[Images of two units, one difficult to distinguish, the other easy to distinguish]

How easy is it to distinguish the two units in this image?

[Images of two units, one difficult to distinguish, the other easy to distinguish]
Rank how distinguishable each unit is to the original unit 1.

Give the images a final ranking of how easy/fast it is to distinguish the two different units in each image (1 is the original). A low rank doesn’t necessarily mean the readability is bad, it just means that it’s the worst between these 6 images.

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