Investigating Gaze Attraction to Bottom-Up Visual Features for Visual Aids in Games

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Abstract

Context. Video games usually have visual aids guiding the players in 3D-environments. The designers need to know which visual feature is the most effective in attracting a player’s gaze and what features are preferred by players as visual aid.

Objectives. This study investigates which feature of the bottom-up visual attention process attracts the gaze faster.

Methods. With the use of the Tobii T60 eye tracking system, a user study with 32 participants was conducted in a controlled environment. An experiment was created where each participant looked at a slideshow consisting of 18 pictures with 8 objects on each picture. One object per picture had a bottom-up visual feature applied that made it stand out as different. Video games often have a goal or a task and to connect the experiment to video games a goal was set. This goal was to find the object with the visual feature applied. The eye tracker measured the gaze while the participant was trying to find the object. A survey to determine which visual feature was preferred by the players was also made.

Results. The result showed that colour was the visual feature with the shortest time to attract attention. It was closely followed by intensity, motion and a pulsating highlight. Small size had the longest attraction time. Results also showed that the preferred visual feature for visual aid by the players was intensity and the least preferred was orientation.

Conclusions. The results show that visual features with contrast changes in the texture seems to draw attention faster, with colour the fastest, than changes on the object itself. These features were also the most preferred as visual aid by the players with intensity the most preferred. If this study was done on a larger scale within a 3D-environment, this experiment could show promise to help designers in decisions regarding visual aid in video games.

Keywords: Visual attention, Bottom-up visual features, Video games, Eye tracking.
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Chapter 1

Introduction

Video games of today often use some visual aid to help players perform tasks that should be done or to help find specific items in a 3D-environment. Visual aid is important because it can show players how to proceed in a game and could even be crucial for understanding how a task should be done. Knowing how to guide the players the best way possible could be difficult since there are many ways to attract the gaze, where gaze means looking intently at something of curiosity or interest for example. This could be connected to attention where according to James [1], it is what we consider as interesting that is the cause of our attention. He also points out that attention can be divided in different ways. Attention can be either passive, reflex, non-voluntary and effortless or it can be active and voluntary and these are called bottom-up and top-down processing. Hikosaka et al. [2] show that voluntary attention is top-down and reflexive attention is bottom-up. Bottom-up processing is when the direction of the gaze is automatically drawn to colourful and lively objects while top-down processing is consciously directed attention to goals or tasks [3]. Some bottom-up visual features include colour, brightness, contrast, orientation, shape, size, edges and motion [4].

When playing a game the players are most likely to have a goal or task which put video games in the top-down process category [5]. Task related attention has shown to be strong as Sundstedt et al. [6] found that when playing a game, where the goal was to guide a ball through a maze, the player focused on completing the task and ignored the most visually noticeable areas on the screen. When handed a task the players seem to focus so much on the task itself that many surrounding elements get ignored. In another study by Sundstedt et al. [7] it was investigated if participants noticed any difference of quality in pictures when handed a task, like counting the red balls in the picture. The study shows that a majority of the participants did not notice any quality difference between two, regarding quality, very different images. Based on these studies, where top-down processing was so strong, it is relevant to investigate which of the bottom-up visual features attract the gaze more and therefore could be more suitable as visual aid in a game.

Looking at games played today like God of War: Ascension (SCE Santa Monica
Chapter 1. Introduction

Studio (2013), Destiny (Bungie, High Moon Studios, 2014) and Diablo 3 (Blizzard Entertainment, 2012) all use colour and intensity as a main cue. This is understandable since, for a long time, colour has been seen as pre-attentive and a good coding method in experiments to improve visual search patterns [8, 9].

Another important visual feature is motion and research has found that it is a strong cue for attracting attention. According to Wolfe [10] motion is one the most effective pre-attentive features when it comes to guiding attention. He found that the search for moving objects surrounded by stationary objects was highly effective while the search for stationary objects among moving objects was not as effective.

This shows that there are visual features that effectively attract the gaze but the question of how the features compare against each other in terms of attraction speed, to the author’s knowledge, was yet to be answered.

1.1 Aim and Objectives

Based on the information above, the aim of this project was to investigate if any of the visual features identified in a bottom-up visual attention process, when applied to a game object, attract a player’s gaze faster. To be able to investigate this, an experiment had to be designed and participants would look at the different visual features. By tracking the gaze with an eye tracker, quantitative data could be collected of each feature and make it possible to compare each feature against each other. By doing this the result could show possibilities to improve visual aid in games in the future.

1.2 Research Questions and Hypothesis

Since the features chosen are a part of the bottom-up visual attention process they are non-voluntary and reflexive [2]. Therefore, people are not likely to think about which one draw the attention faster because it all comes naturally. In games, when it is likely that players have a task, it is important that the visual aid is able to attract the attention automatically as fast as possible. When designing a game, decisions about which feature to choose as visual aid has to be made and the players will most likely prefer some more than others. The preferred feature might not be the same as the fastest attracting feature. Based on this, the research questions of this study were:
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- Which of the bottom-up visual features colour, intensity, orientation, shape, size, highlight or motion, when applied to a 3D object, attract the gaze faster?

- Which of the bottom-up visual features colour, intensity, orientation, shape, size, highlight or motion is preferred by players as visual aids in games?

The null hypothesis for this study was that there will be no significant difference in attraction time between the chosen visual features and the scientific hypothesis was that there will be a significant difference in attraction time between the chosen visual features.

1.3 Methods

To answer the research questions, a user study was conducted using adult participants. Gathering quantitative data was crucial for this study since the need of comparing the attraction speed between different visual features was the main part of the analysis. To measure the gaze of the participants an eye tracker was used. By using an eye-tracker and creating Areas of Interest (AOI) on the screen it was possible to measure the time it took for the user to get a first fixation and where on the screen that was. It was also possible to measure the total duration of a fixation point to see for how long a user was looking at the different areas. This made it possible to gather important quantitative data about the gaze attraction that could be analysed.

Participants read instructions and signed a form of consent before starting the experiment. The experiment consisted of two parts. In the first part the participant’s eyes were calibrated to the eye tracker for measuring the gaze. They were then shown a total of 18 slides consisting of 18 pictures or video-clips on the computer screen. Two of the slides contained objects without any visual feature applied for measuring search patterns while 16 slides had a visual feature from the bottom-up visual attention process applied to an object. Each slide contained eight objects spread around the screen in an octagon shape. The participants looked at each slide for 10 seconds before moving on to the next. Meanwhile the eye tracker was measuring where the participant was looking so the time it took to find visually different objects could be analysed.

The second part consisted of a short survey that asked which one of the visual features the participant would prefer as visual aid in a game. A survey was chosen because it gave the participants a chance to express their own thoughts on the problem which could be useful knowledge for designers. The aim of the survey was to see if there was any difference between what visual feature the user preferred and which one of the features attracted the gaze faster. This could yield
interesting results if the visual feature least preferred by the players was found to be the one that attracted the gaze fastest.

1.4 Risks and Limitations

The result from tracking someone’s gaze could be invalid for a number of reasons. The eye tracker can have difficulties tracking the gaze and collecting gaze samples if the user is wearing glasses because of the additional reflections that can occur [11]. To get a valid result from the participants a limit of 95% gaze reading accuracy was set. If the participant had an eye deficiency such as colour blindness it would be a threat to the test’s validity since the experiment involves the difference in colours. If an eye deficiency was found, the participant’s result would not be analysed. By aiming for a higher number of participants than needed helped manage these risks.

There were limitations made to the user study where each participant only got to see 16 slides with random visual features instead of all 128 that was made. This could affect the outcome of the result and make it not as accurate but the choice was made to ensure that the amount of data was manageable to work with in the amount of time available. To make up for this, the design of the experiment made sure that all feature was seen equally many times on every position of the screen. Further, there were only one background colour in the user study and the result could differ if implemented in an actual game because of the large amount of different scenery in 3D environments.

The design of the features is also a limitation since there is only one design per feature. Each feature could have had a wider range of for example colours, sizes and shapes to make the study more comprehensive but due to the time limit only one design per feature was chosen.
Chapter 2

Background

The following chapter will explain the basic concept of visual attention and its processes as well as eye tracking technology. This offers the reader help to get a better understanding of the work, problems and decisions taken within this study.

2.1 Visual Attention

Visual attention can be split into two groups of processes: pre-attentive and attentive, also called distributed attention and focused attention by Palmer [12]. He explains the matter as follows: The difference between these processes is that pre-attentive processing is parallel while attentive processing is serial. This means that over the entire visual field, the distributed process takes place at the same time while the attentive process is a series of attentional fixations that cover an area restricted in size. Processes like finding areas of colour and motions are considered to be done in parallel.

The eye is presented with a large amount of information. However, the human brain is not able to process the amount of information that the visual system is gathering [13]. The visual process solves this by selecting parts of the information that is preferred and processes those in a serial manner [13].

2.1.1 Bottom-Up and Top-Down Processing

When talking about perceptual information processing, there are metaphorical directions to these called bottom-up and top-down [12]. These are ways of saying if the visual attention is going from a low-level input to a higher level or the opposite way around. Bottom-up processing, also called data-driven processing is when the direction of the gaze is automatically drawn to colourful and lively objects [12, 3]. Some examples of bottom-up visual features are colour, brightness, contrast, orientation, shape, size, edges and motion [4].

Top-down processing is known as hypothesis-driven or expectation-driven processing and can be seen as directed attention to goals or tasks [12, 3].
In this study, the focus will be on the bottom-up process since the goal is to define if any of the lower level features have a faster gaze attraction time.

2.1.2 Saliency

A salient area in a picture or scene is the point where the gaze is unconsciously drawn to [14]. It could be seen as the most noticeable area. Previous research has often focused on predicting what the observer will look at in a picture or a scene by computing a visual attention model to create a saliency map using bottom-up visual features. This means that a pre-attentive analysis is made on a scene which compares a local visual attribute to its surroundings to see if it differs in terms of colour, shape, size, etc. [15]. This shows the most salient elements in the scene. From this a saliency map can be created and then help predict where the observer will most likely look.

2.1.3 Inattentional Blindness

The phenomenon of Inattentional Blindness (IB), also called perception blindness, means that a person often are blind to stimuli when focused on performing a task [16]. This involves not only visual tasks but any task where the mind is focusing on something else. Talking on a cell phone while driving is a good example of this when the driver is looking at the road but might have the focus on the call itself thus being blind of what happens on the road [16].

IB has been described in a study by Cater et al. [3] as a major side effect of the top-down visual process. In that study it is shown that when performing a task while watching an animation, almost nobody of the 80 observers could realise when some areas outside of the task focus were rendered in low quality.

2.2 Eye tracking

Eye tracking is a procedure that identifies a specific point that is being looked at by the observer, in both space and time [17]. In order to capture eye movements, there are different ways to measure this and these can be split into two groups. There are measuring the eye position relative to the head and there are measuring, in space, the orientation of the eye [11]. To know where on the screen the eye tracker should measure, AOIs are defined. These are regions on the screen, defined by the examiner, that are of interest to measure. This can be done manually by the experimenter or being mapped to objects in a game, using segmentation algorithms as done in a study by Sundstedt et al. [18].
By using an eye tracker there are different kind of data that can be measured but only the ones relevant to this study will be mentioned. It is possible to measure *fixation* which is a pause, for at least 100ms, over an object of interest [19]. There are various data that can be collected from fixations [20]. Those relevant for this study are *Time to First Fixation*, *Total Fixation Duration* and *Visit Count*. Between two fixations there is a *saccade* [18]. A saccade is a fast eye movement to reposition the fovea to an object of interest. This is a ballistic movement which means that when it started, the destination cannot be changed [12]. During a saccade, the visual system does not gather any information [21].

Some different systems used for measuring this are as follows:

- **Electro-OculoGraphy (EOG):** This system is based on electrodes that are placed around the eye and measure the potential electric differences of the skin. This is used for the measuring movements of the eye relative to the head position [11].

- **Scleral Contact Lens/Search Coil:** This is very precise method for measuring eye movement and is based on using a mechanical or optical object as reference attached to a contact lens. The contact lens can then be worn on the eye for measuring [11].

- **Video-OculoGraphy (VOG):** The video based eye tracking systems record the eye movements with a camera to get information of the eye features and then use that information to decide the Point of Regard or Line of Sight [21]. This method often use an active infra-red (IR) light to project a corneal reflection from the eyes for the camera to capture. One downside with this is that thick glasses can disturb the IR which can make the result not reliable [22]. There are both head mounted and remote eye trackers using this technique.

When using the remote VOG method, participants are not needed to wear anything and the method itself can be non-intrusive which is the reason this will be used in this study.
Chapter 3

Related Work

Many studies regarding visual attention in video games have been using FPS games as 3D application for their tests. Kenny et al. [23] created an FPS game and wanted to determine if a visual psycho-perceptual phenomenon existed. According to them, this could be used within the area of distributed interactive media compression algorithms and find information limits for this. They stated the possibilities to use the areas on the screen where users attended to determine render priority and limits for dead reckoning.

Sennersten et al. [24] investigated three different hypotheses when playing a self-created map using the BattleCraft editor for the FPS game Battlefield 1942 (EA DICE, 2002). They investigated if the gun’s graphic drew attention away from the player’s task in-game. This was not supported by the evidence. Further, they examined if players first looked at the opponent before shooting them and in 88% of the encounters this was true. Finally they investigated, if meeting more than one opponent, the closest one is targeted first. Results show that an average of 77% targeted the closest opponent.

In a study that El-Nasr et al. [25] made it was investigated if dynamic lighting on important elements of the game could help players improve their spotting time. The test was executed in a modification of the FPS game Unreal Tournament 2003 (Epic Games, Digital Extremes, 2002). They were mainly looking at the impact of colour and brightness of the light. Their results showed that spotting time improved significantly, especially for casual and non-gamers, when using their dynamic light.

In an earlier study by El-Nasr and Yan [26] they examined the players’ visual attention patterns while playing two games of different genres. The games were the action-adventure game Legacy of Kain: Blood Omen II (Crystal Dynamics, 2002) and the FPS game Halo II (Bungie, Microsoft Studios, Pi Studios, Hired Gun, 2004). The study showed that when playing the FPS game the attention is focused at the centre of the screen while in the action-adventure game it was spread out. They also found that both genres had patterns of both bottom-up
Chapter 3. Related Work

and top-down processes. Visual attention studies have also been used to find different ways of designing games. Jie and Clark [27] used eye movement data to decide level difficulties for a game. By placing important items in areas of high or low attention they showed that it changed the score and therefore the difficulty of the game.

Some studies have been done that show that inattentional blindness could be a problem when looking at 3D scenes. In a study by Bernhard et al. [28] they were investigating if increasing the saliency of advertisement in a scene, by sharing visual features of high attended objects, could break the inattentional blindness. They argue that with this method, participants remembered the advertisement better than with no attention manipulation implemented.

Sundstedt et al. [6] made a study where participants would play a game, where the goal was to guide a ball through a maze. They found that when playing the game the players focused on completing the task rather than focusing on the salient distractors on the screen.

Research in eye tracking and visual attention has also been applied to serious games. Kiili et al. [29] used four different serious games to see if eye tracking could be used as a way to evaluate a design of a game in order to better understand what attracts the players attention. They found that salient elements could distract players which made them miss important information. They suggest that objects like this could be removed but with caution since removing too much would decrease immersion and engagement.

Despite interesting research in visual attention in games and attention to bottom-up visual features, none were found where the bottom-up features were compared against each other for the fastest gaze attraction time. There was also no previous work that shows similar experiment design as the one in this study.
Chapter 4

Experimental Design

This chapter will cover the design of the experiment, how the content was created and information about decisions taken. Decisions about what data was collected are also explained.

4.1 Content

The objects used in this project were all created by the author using the software Autodesk Maya 2016 and textured with the software Quixel Suite 2.0. There were two types of objects created, one simple and one advanced. The simple object was the form of a cube and the advanced was a robot character as seen in Figure 4.1. Both objects got the same wooden texture to eliminate the risk that different base textures on each object would affect the result of the visual features.

![Example of the objects used in their natural state without any visual feature applied.](image)

Figure 4.1: Example of the objects used in their natural state without any visual feature applied.

4.2 Design

The experiment was designed so that the objects were spread out in an octagon shape as seen in Figure 4.2. The octagon shape was used because the objects would have the same distance to its centre-point from the centre of the picture regardless of which position in the octagon. This helped eliminate the risk of distance having an impact on the result. Note that depending on the type of
object the top left, top right, bottom left and bottom right positions had a slightly closer distance to the closest point of the object.

As mentioned in Chapter 1, the aim of this study was to investigate different bottom-up visual features. Eight different visual features were therefore applied, one at a time to the objects mentioned on each position. Two of these features (motion and highlight) required a video-clip to be created because of the moving nature of motion and pulsating light of highlight. A total of 96 pictures and 32 video-clips were made in order to cover every position and object individually. The participant’s task was to find the one object with a different visual feature applied on each slide. Every slide had the same background which was 50% grey. This choice was based on the idea that a dark background would make the objects seem brighter and a bright background would make them seem darker [30]. With a more neutral background such as 50% grey this could be avoided.

**Figure 4.2:** Cube objects without visual feature applied in octagon shape with positional naming convention visible.
4.2.1 Bottom-up Visual Features

As mentioned earlier in this chapter, eight visual features were applied. The choice of features was based on their ability to be implemented as visual aid within a 3D environment. Below is an explanation of the features that was chosen.

**Colour** - The object had areas of a salient colour applied. The colour red was chosen to this because of the high salient value \([31]\) as seen in Figure 4.3 (a).

**Intensity** - The object kept the base colour but the intensity value were increased as seen in Figure 4.3 (b).

**Orientation** - The rotation of the object was mirrored along the x-axis. The x-axis was chosen because both objects were positioned in a way that they seemed to be standing naturally on the ground in a video game and rotating along another axis would change that as seen in Figure 4.3 (c).

**Shape** - The object was squashed making it shorter and wider. The volume of the object remained the same as seen in Figure 4.3 (d).

**Size** - This feature was split into two parts. One part had the object’s scale value decreased and the other had it increased by the same amount which was 0.2. Shape remained the same as seen in Figure 4.3 (e) and 4.3 (f).

**Highlight** - Closely related to intensity but pulsating intensity changes was used instead of static. A total of 30 frames were used with a frame rate of 30 frames per second. The intensity peak was set on frame 15 to ensure that a visible intensity change was seen fast enough to compete with the other features as seen in Figure 4.4.

**Motion** - The object was moving in place. The cube had a total of 40 frames with a frame rate of 30 frames per second. During that time it was rotating 360 degrees as seen in Figure 4.5. The character had a total of 20 frames with the same frame rate and consisted of a "walk cycle".
Figure 4.3: A collection of the static visual features at bottom position with mixed cube and character objects. The upper row shows (a) colour, (b) intensity and (c) orientation. The lower row shows (d) shape, (e) size small and (f) size large.

Figure 4.4: Character object with visual feature motion at bottom position. Image (a) shows object on frame 4 in the animation, (b) shows frame 7 and (c) shows frame 15.
Chapter 4. Experimental Design

Figure 4.5: Cube object with visual feature motion at bottom position. Image (a) shows object on frame 14 in the animation, (b) shows frame 29 and (c) shows frame 36.

4.3 Eye Tracking and Tobii Studio

To create an experiment from the pictures and video-clips, the application Tobii Studio was used which is Tobii’s own application made for their eye trackers. A test which consisted of a slideshow of pictures and video-clips was created for each participant. Each participant had their own test and each test needed to be unique to rule out that learning had an effect on finding the object. At first, eight tests were created. The reason for this was that there were eight visual features for each object that would be placed on eight different positions, see positions in Figure 4.2. The positions of each feature were randomly distributed among the first eight tests filling each test with one picture or video per object and feature. When a test had all the media inserted, it was randomised to give it a unique order to show the participant. This way, since the order of media appearing was completely random, the participants could not know which feature would be shown next or what position the feature would show up on. This could then be repeated as many times as needed depending on the number of participants. To make sure that every feature was shown the same amount of times, the number of participants had to be of an even eight. An alternative to using the eye tracker as the data collector for the experiment was creating an application where participants would see the same pictures but instead mouse click on the object with the visual feature when found. Then it would have been possible to extract the time it took to find the visual features. This alternative was not chosen because reaction time between noticing the feature and moving the mouse would have been a factor in the result. The eye tracking alternative suited better with the aim of the study in terms of gaze attraction. Both methods could have been made together but the time limit of the project was a factor in choosing only one.
4.4 Measurements

As mentioned in Chapter 2, there are much data that can be collected using fixations and eye tracking. The main data collected in this study was chosen with the research questions in mind and additional data was collected mainly to strengthen the reliability of the main data but also to see if other variables could have affected the result. Below is an explanation of the data that was chosen to be collected.

**Time to First Fixation** - The first part of main data collected in order to find out which visual feature attracted the gaze faster. The mean time to first fixation was analysed for each bottom-up feature. AOIs were created around all objects for measuring fixations within the area. A picture of the AOIs can be seen under Figure 4.6.

**Fixation Duration** - Additional data for Time to First Fixation. Measuring how long the participant was focusing on the same area to help decide if the first fixation was a conscious find. A high value means that the participant started to fixate early on the area.

**Re-visits** - Another additional data for Time to First Fixation. Checking how many times the participant visits an area after the initial visit. Leaving and entering an area multiple times could mean that the participant was still searching for the correct area to fixate on. A high number indicates that the first fixation was not a conscious find of the feature.

**Time to Fixation, Object** - A separate and smaller investigation to see if there was any difference in the mean first fixation time of a simple object (cube) and an advanced object (character).

**Areas of First Fixation** - Another separate investigation to see if participants had a search pattern when looking at a picture with objects without any visual feature applied. This was done to get an understanding if a search pattern could affect the result in any way. Data was gathered from first fixation to the AOIs to see where the participants started their search.

**Time to Fixation, Areas** - Additional data for Areas of First Fixation. Investigated the mean time to find a visual feature within the different AOIs. Data was gathered to see if there could be a connection between search patterns and time to find a visual feature.

**Preferred Visual Feature** - Second part of main data collected to answer research question two. The data were collected from a survey to establish if players
preferred visual features were the same as the ones that attracted the gaze faster. Score was counted from 1 to 5 where 1 was strongly disagree and 5 was strongly agree. The mean value was analysed.

*Figure 4.6: AOIs used for measuring.*
Chapter 5

Experimental Procedure

This chapter will present information about the execution of the experiment. Information about preparations and participants will be covered as well as the whole experiment session.

5.1 Pilot Test

Four pilot tests were made before the real experiment could begin. This was made to find any flaws in the experiment design and see if the eye tracker settings were correct. The tests showed that all participants had similar search pattern and the decision to have two neutral images in the final test to measure each participant's search pattern was made. The duration each slide was shown was increased from 7 to 10 seconds to make sure that it was enough time to find the visual feature.

5.2 Experimental Set-Up

The experiment was held in a private laboratory room at Blekinge Institute of Technology. The room required a key card to enter to ensure that no disturbance would affect the participant. The test was set up on a computer with the following specifications:

- Win10 x64 Education OS.
- Intel®Core™ i7-6700k CPU@4.00GHz.
- 16GB RAM memory.
- Nvidia GeForce GTX980 with 4096MB GDDR5 graphics memory.

The Tobii T60 eye tracker with a data rate of 60Hz was used during the experiment. See Figure 5.1 for a picture of the set-up.
Chapter 5. Experimental Procedure

5.3 Participants

A total of 43 participants, 37 men and 6 women, volunteered to be a part of the experiment. The age span ranged between 20 - 40 years old with an average of 23.20 years old. Since the eye tracker was continuously checking for gaze samples from the participants during the experiment, the reliability of the experiment could vary if the percentage of gaze samples was too low. After talking to a representative of Tobii a limit was set to at least have received gaze samples 95% of the time to get reliable data. As said earlier in this chapter, the experiment needed the number of participants to be an even eight to ensure that all of the visual features and all positions were used equally many times. Due to the limit of 95% gaze samples and the participants have to be of an even eight, 11 participants were excluded from the result making it 32 participants in the final experiment analysis. The way this was done was to start excluding the participant with the lowest percentage and continue like that until the number of an even eight was reached. In the end there were 28 men and 4 women with an age span ranging between 20-40 years old and an average of 23.44 years old. Nine of the participants had glasses, three used contact lenses, one had corrected to normal vision and 17 had normal vision. No other eye deficiencies were reported. The participants could all be considered to be players since everyone had experience in playing video games as seen in table 5.1. For the survey, the data of all 43 participants was collected to be able to see if a larger group of people showed any difference in the result compared to only the smaller group with 32 approved participants.
Chapter 5. Experimental Procedure

<table>
<thead>
<tr>
<th>Level of Game Experience</th>
<th>No. of Participants (32 Approved, All 43)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0, 0</td>
</tr>
<tr>
<td>2</td>
<td>0, 0</td>
</tr>
<tr>
<td>3</td>
<td>1,2</td>
</tr>
<tr>
<td>4</td>
<td>1, 1</td>
</tr>
<tr>
<td>5</td>
<td>5, 8</td>
</tr>
<tr>
<td>6</td>
<td>6, 7</td>
</tr>
<tr>
<td>7</td>
<td>19, 25</td>
</tr>
</tbody>
</table>

*Table 5.1: Game experience data of participants collected from questionnaire*

5.4 Procedure

Before the experiment could begin, the participant had to sign a form of consent. The form stated that the experiment was voluntary and that there was no financial compensation for participating. The form also stated that all personal information was to be confidential and no result would be linked to the participant in any way. The data collected would only be used for scientific purposes. A short description of the study, aim and time required were also stated.

After signing the form of consent, the participant was led to a computer where a task description, see Appendix A, was handed out which stated details about what to do in the test. To avoid bias, no information about the experiment other than what was written in the form of consent and task description was revealed. When understood what to do, the calibration of the eye tracker began. To ensure that the eye tracker could read the gaze of the participants properly, the distance between the eyes and the screen had to be set to around 60cm. A calibration of the eyes when following a red dot on the screen was also made. After the calibration, the experiment commenced where the participant was looking at the slideshow consisting of 18 slides with pictures and video-clips. Each slide was shown for 10 seconds as a result from the pilot tests.

When done with the experiment, the participant was handed a questionnaire, see Appendix B, to fill and also a survey based on the visual features in the experiment as seen in Appendix C. If the participant was interested, questions could now be asked about the purpose of the experiment.
Chapter 6

Results

This chapter presents the results from the experiment sessions. It is split up in two parts where the first part consists of the results from the experiment and the second part consists of the results from the survey.

6.1 Experiment Data

The result of time to first fixation shows that colour had the fastest fixation time (mean = 0.408 seconds) followed by intensity, motion and highlight. The most difficult one to find was size small (mean = 2.247 seconds) followed by orientation, size large and shape. After applying a two-way ANOVA test it could be seen that this result was significantly different ($F(7, 217) = 24.8, p < .001$). The two-way ANOVA test was chosen because the data consisted of two factors, different visual features and different objects, which the two-way ANOVA can measure correctly [32, 33]. As seen in Figure 6.1 there was a difference between the top four and bottom four with a difference of more than 0.5 seconds. It can also be seen that the cube object was more difficult to find than the character when the features size large or orientation was applied. A detailed list comparing the features against each other can be seen in Figure D.1 located in Appendix D.

The two-way ANOVA test on fixation duration showed a significant difference between features ($F(7, 217) = 33.9, p < .001$). It can be seen in Figure 6.2 that size large, size small and orientation had the shortest fixation duration while colour, intensity, highlight and motion all had long duration. Orientation showed a difference between the cube and the character of over one second and size small almost one second difference. Figure D.2 in Appendix D displays the comparison between features of fixation duration.

Figure 6.3 shows that orientation and size large had the highest amount of revisits while highlight and colour had the lowest. Orientation and size small showed difference between object with more than 0.5 visits each.
Chapter 6. Results

Figure 6.1: The mean time to first fixation to the visual features. Error bars show standard error of the mean ($SE_x$).

Figure 6.2: The mean fixation duration to the visual features. Error bars show $SE_x$. 
Chapter 6. Results

Figure 6.3: The mean number of re-visits to the area of an object with the visual features applied. Error bars show SE₂.

There was no significant difference in first fixation time between objects when a feature was applied \( (F(1, 31) = 1.37, p = .250) \). The difference between the objects was 143ms as seen in Figure 6.4.

Figure 6.4: The mean time of first fixation to the objects. Error bars show SE₂.

A chi-square test [34] was made on the result from areas of first fixation on slides without any visual feature applied to the object. This showed a significant difference between areas \( (X^2 = 30.25, df = 7, p < .001) \). With 21 first fixations, the top area was the area with highest number of first fixations as seen in Figure
6.5. The areas with the second highest count of first fixations were the left and right area with 9 times each. The least looked area was bottom right with 2 first fixations.

Figure 6.6 shows that the top left area had the shortest mean time to find an object with a visual feature applied within that area (mean = 0.831 seconds) followed by top, top right and right. The area with longest time to first fixation was bottom left (mean = 1.413 seconds). However, this result did not show a significant difference ($F(7, 217) = 1.36, p = .223$).

![Figure 6.5](image1.png)

**Figure 6.5:** The result of first fixation to the different areas on objects without a visual feature applied.

![Figure 6.6](image2.png)

**Figure 6.6:** The mean time of first fixation to object applied with a visual feature in the eight areas. Error bars show SE$_x$. 
Chapter 6. Results

6.2 Survey Data

The result from the survey shows that among the 32 participants approved for the main experiment result, intensity was the most preferred visual feature to use as visual aid in video games. This was closely followed by highlight, colour and motion were result indicates that it is agreeable to use as visual aid in games. Shape, size large and size small was considered disagreeable to neutral while orientation leaned more to disagreeable as seen in Figure 6.7.

![Figure 6.7: Result of preferred visual feature by the 32 approved participants. Error bars show SE_δ.](image)

In Figure 6.8 it can be seen that for all 43 participants, not much changed except colour which was less preferred and dropped under the agreeable mark.

![Figure 6.8: Result of preferred visual feature by all 43 participants. Error bars show SE_δ.](image)
Chapter 7

Analysis and Discussion

The findings in this study show that the visual feature colour attracted the gaze fastest. However, there was not much difference between the four visual features colour, intensity, motion and highlight. Between colour, which had the shortest mean time to first fixation, and highlight, which had the fourth shortest time, it only differed 115ms as seen in Figure 6.1. Since these features had a high fixation duration time and a low number of re-visits it indicates that the result of first fixation time was accurate and these features might be a good choice for visual aid. The feature with the shortest time to first fixation was size small. The difference between size small and size large was about 0.9 seconds and the reason for this could be that large objects appear to be closer than smaller objects and therefore more noticeable. As the study by Sennersten et al. [24] show, the closest opponent was targeted first by a majority of the players. This could have been a factor when seeing the objects with size as visual feature.

Noticeable was the big difference between the four features with shortest time to first fixation and the four with longest time. The four with the shortest time, all include some contrast changes in the texture except for motion where the texture does not change but instead move with the object. For both intensity and highlight, the intensity in the texture changes and the addition of a different colour to the texture makes the feature colour. This indicates that, design wise, contrast in texture could be the better choice when it comes to attracting attention than changes in the object itself. Looking at the different objects, cube and character, there was not a big difference in first fixation time on motion and the three with texture changes. These features showed almost the same time to first fixation regardless of what object that had the visual feature applied. The rest however, show noticeable difference. This further strengthen the idea of the contrast in textures could play a bigger part than the object since only when the contrast in textures did not change, noticeable changes in first fixation time between objects appeared. These results show similarity to the ones in the study by El-Nasr et al. [25], where players spotting time to enemies improved when adding colour and brightness to a surrounding light. A future research with these two findings combined in a 3D environment where lighting complements visual features applied
to objects as visual aid could show interesting results.

These results were completely based on the fact that there was only one design per feature. If each feature had many different designs the results could have turned out different as well. The feature colour for example included only one colour which was red. This colour could change to a less salient choice and the result might be different. Smaller and larger size is a good example as well. In this study the difference between the size features and the rest of the objects was a scale value of 0.2 but if that value was increased to an extreme level like 0.9 it could turn out to have as short attraction time as those that had the shortest in this study. This can be applied to all features in this test and future work on that would be necessary to be able to generalise the result.

Situations that could have affected the result and needed to be addressed was that participants had a search pattern where first fixation occurred in different areas. The area that had most first fixations was top. It can be seen in Figure 6.6 that top also was the area with second shortest mean first fixation time. Since the participants had different search patterns, this poses a threat to the time to first fixation result. To clarify, it could be possible that the feature with shortest time to first fixation was placed on a position that the particular participant started the search pattern thus giving the feature a shorter fixation time. Since it could not be predicted what search pattern each participant would have it poses a threat to the result’s validity. These findings of search patterns show slightly different results than previous search pattern research. In a study on search patterns for a visuospatial attention test, Huang and Wang [35] found that over 90% started their search to the left side and moved in a horizontal manner like when reading. A possible reason for the different result in this study could be that the participants were affected by the position of the feature on the previous slide thus starting on the same side as the feature before. The search pattern findings leads to the fact that a majority of the participants in this study had their origin in northern Europe which could have affected the outcome. If the experiment was performed on people from other parts of the world, where daily visual events like reading differs from here, the result might have differed as well.

To keep the analysis manageable, each participant got to see 16 slides of visual features instead of all 128. This could have affected the result but the design of the experiment made sure that every feature and position was shown equally many times in total to make up for this.

When comparing the results from the survey, the same four features with the shortest time to first fixation were also the most preferred as visual aid in games. Intensity changes were most popular as visual aid where the intensity feature had the best rating and the highlight feature had the second best rating. The result
between the 32 approved participants and all 43 participants was that colour was less preferred in the test with all 43 which could mean that if asked to even more people, colour might be even less preferred. Comparing the result of preferred visual aid and time to first fixation showed that colour, which was the feature easiest to find, was not the most preferred feature as visual aid. A possible reason for this might be that it could make the visual aid too obvious and might remove the challenging part of a game if not applied thoughtfully. Since the majority of the participants considered themselves highly experienced in games, they could be experience challenging scenarios in a different manner than a less experienced player. A study involving only casual players with little or even no experience in games might show different results.
Chapter 8
Conclusions and Future Work

This study investigated which visual feature from a bottom-up visual attention process attracted the gaze faster in order to find the feature best suited as visual aid in video games. By using an eye tracker, a user study could be conducted to gain the quantitative data needed for analysing gaze fixations.

The result for answering the first research question, *Which of the bottom-up visual features colour, intensity, orientation, shape, size, highlight or motion, when applied to a game object, attract the gaze faster?*, showed that the visual feature colour attracted the gaze in the shortest time, closely followed by intensity, motion and highlight. An important finding was that texture changes on objects seem to attract the gaze more than changes in the object itself. For the second research question, *Which of the bottom-up visual features colour, intensity, orientation, shape, size, highlight or motion is preferred by players as visual aids in games?*, results showed that intensity was most preferred by players meaning that the visual feature that most effectively attracted the gaze was not the most preferred.

For future work, to get a more accurate result, this experiment could involve participants from different parts of the world to see if other search patterns get introduced and the effects from that. With a larger group of participants the results would probably be more accurate and showing all 128 slides of visual features would give a more reliable result. At the same time, multiple designs per features could be introduced to see different aspects of the same features would get the same results.

This study could also be used in other fields. For example it could be applied to a newspaper or magazine in order to attract the reader to important articles and make sure that no areas are missed. The design behind advertisement could also benefit from this study to attract the viewers’ attention. As Bernhard et al. [28] showed in their study, advertisement that shared visual features with high attended objects were remembered better. By using the visual features investigated in this study in a commercial setting it could help to see what feature
attracts the attention to their products more.

The field of game design could benefit if this study was done in a larger scale within a 3D-environment where combinations of studies could find the best way of delivering visual aid to players. There would be many aspects that could be looked into if done in a 3D-environment. Search patterns could be looked into to see if players find it easier to locate items on the upper and left part of the screen. An area with high importance and relevance when beginning this study was to find a suitable visual feature that could possibly break the IB when playing a game. Taking the visual features from this study and applying them on partially hidden objects in a video game could make it possible to find out if the IB could be broken by any of these features. Combined with lighting a more subtle approach could show interesting results and possibly a positive reaction from the players.
Appendix A

Task Description

Task Description
You will be asked to look at 18 different pictures and video-clips filled with objects. Your task is to find the odd one out in each picture/video-clip. When found, please keep your eyes focused on that object. Before and in between each image, please focus on the cross in the middle of the screen. When done, you will be asked to fill in a short survey. If anything is unclear please ask any questions you might have before the study starts.

Figure A.1: The task description handed to participants before starting the experiment.
Appendix B

Questionnaire

Please, tick the appropriate box/ies:

Gender: Female □ Male □

Age: ___________

How often do you play video games?
Never □ A few times a year □ Every month □ Every week □ Daily □

How would you rate your experience in playing video games?
Give a rating between 1 and 7. 1 being very low and 7 being very high.
1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 □

Vision: Normal □ Corrected-to-normal □ Contact lenses □ Glasses □

Figure B.1: The questionnaire handed to participants before the survey.
Appendix C

Survey

Figure C.1: First page of the survey handed to participants after the experiment.
Figure C.2: Second page of the survey handed to participants after the experiment.
Figure C.3: Third page of the survey handed to participants after the experiment.
## Appendix D

### Feature Comparisons

**Figure D.1:** Statistics for the time to first fixation. Features with a significant difference from the two-way ANOVA test are shown in yellow boxes.

<table>
<thead>
<tr>
<th>Feature (A)</th>
<th>Feature (B)</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>P-value</th>
<th>95% Confidence Interval for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Intensity</td>
<td>-0.025</td>
<td>0.027</td>
<td>1.000</td>
<td>-0.116, -0.065</td>
</tr>
<tr>
<td>Colour</td>
<td>Orientation</td>
<td>-1.087</td>
<td>0.226</td>
<td>0.001</td>
<td>-1.858, -0.307</td>
</tr>
<tr>
<td>Colour</td>
<td>Shape</td>
<td>-0.787</td>
<td>0.147</td>
<td>0.000</td>
<td>-1.290, -0.280</td>
</tr>
<tr>
<td>Colour</td>
<td>Size Large</td>
<td>-0.965</td>
<td>0.161</td>
<td>0.000</td>
<td>-1.519, -0.414</td>
</tr>
<tr>
<td>Colour</td>
<td>Size Small</td>
<td>-1.939</td>
<td>0.261</td>
<td>0.000</td>
<td>-3.732, -0.146</td>
</tr>
<tr>
<td>Colour</td>
<td>Highlight</td>
<td>-0.115</td>
<td>0.029</td>
<td>0.008</td>
<td>-0.210, -0.015</td>
</tr>
<tr>
<td>Colour</td>
<td>Motion</td>
<td>-0.071</td>
<td>0.027</td>
<td>1.000</td>
<td>-0.197, 0.055</td>
</tr>
<tr>
<td>Intensity</td>
<td>Orientation</td>
<td>-1.062</td>
<td>0.224</td>
<td>0.001</td>
<td>-1.627, -0.507</td>
</tr>
<tr>
<td>Intensity</td>
<td>Shape</td>
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<td>0.140</td>
<td>0.000</td>
<td>-1.420, -0.104</td>
</tr>
<tr>
<td>Intensity</td>
<td>Size Large</td>
<td>-0.943</td>
<td>0.159</td>
<td>0.000</td>
<td>-1.497, -0.409</td>
</tr>
<tr>
<td>Intensity</td>
<td>Size Small</td>
<td>-1.814</td>
<td>0.259</td>
<td>0.000</td>
<td>-3.696, -0.922</td>
</tr>
<tr>
<td>Intensity</td>
<td>Highlight</td>
<td>-0.069</td>
<td>0.024</td>
<td>0.019</td>
<td>-0.170, -0.009</td>
</tr>
<tr>
<td>Intensity</td>
<td>Motion</td>
<td>-0.045</td>
<td>0.029</td>
<td>1.000</td>
<td>-0.145, 0.055</td>
</tr>
<tr>
<td>Orientation</td>
<td>Shape</td>
<td>0.300</td>
<td>0.212</td>
<td>1.000</td>
<td>-0.424, 1.024</td>
</tr>
<tr>
<td>Orientation</td>
<td>Size Large</td>
<td>0.119</td>
<td>0.270</td>
<td>1.000</td>
<td>-0.060, 1.042</td>
</tr>
<tr>
<td>Orientation</td>
<td>Size Small</td>
<td>-0.752</td>
<td>0.247</td>
<td>0.131</td>
<td>-1.595, 0.091</td>
</tr>
<tr>
<td>Orientation</td>
<td>Highlight</td>
<td>0.973</td>
<td>0.225</td>
<td>0.004</td>
<td>0.204, 1.741</td>
</tr>
<tr>
<td>Orientation</td>
<td>Motion</td>
<td>1.017</td>
<td>0.222</td>
<td>0.002</td>
<td>0.256, 1.775</td>
</tr>
<tr>
<td>Shape</td>
<td>Size Large</td>
<td>-0.161</td>
<td>0.174</td>
<td>1.000</td>
<td>-0.777, 0.455</td>
</tr>
<tr>
<td>Shape</td>
<td>Size Small</td>
<td>-1.052</td>
<td>0.254</td>
<td>0.011</td>
<td>-1.953, -0.151</td>
</tr>
<tr>
<td>Shape</td>
<td>Highlight</td>
<td>0.673</td>
<td>0.141</td>
<td>0.004</td>
<td>0.190, 1.156</td>
</tr>
<tr>
<td>Shape</td>
<td>Motion</td>
<td>0.711</td>
<td>0.138</td>
<td>0.000</td>
<td>0.245, 1.189</td>
</tr>
<tr>
<td>Size Large</td>
<td>Size Small</td>
<td>-0.870</td>
<td>0.284</td>
<td>0.012</td>
<td>-1.842, 0.010</td>
</tr>
<tr>
<td>Size Large</td>
<td>Highlight</td>
<td>0.854</td>
<td>0.155</td>
<td>0.000</td>
<td>0.237, 1.472</td>
</tr>
<tr>
<td>Size Large</td>
<td>Motion</td>
<td>0.898</td>
<td>0.159</td>
<td>0.000</td>
<td>0.353, 1.442</td>
</tr>
<tr>
<td>Size Small</td>
<td>Highlight</td>
<td>1.725</td>
<td>0.256</td>
<td>0.000</td>
<td>0.851, 2.598</td>
</tr>
<tr>
<td>Size Small</td>
<td>Motion</td>
<td>1.768</td>
<td>0.256</td>
<td>0.000</td>
<td>0.894, 2.643</td>
</tr>
<tr>
<td>Highlight</td>
<td>Motion</td>
<td>0.044</td>
<td>0.030</td>
<td>1.000</td>
<td>-0.056, 0.146</td>
</tr>
</tbody>
</table>
## Appendix D. Feature Comparisons

### Figure D.2: Statistics for the fixation duration. Features with a significant difference from the two-way ANOVA test are shown in yellow boxes.

<table>
<thead>
<tr>
<th>Feature (A)</th>
<th>Feature (B)</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>P-value</th>
<th>95% Confidence Interval for Difference</th>
</tr>
</thead>
<tbody>
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<td>Intensity</td>
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<td>0.075</td>
<td>1.000</td>
<td>-0.232 - 0.262</td>
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<td>2.494</td>
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<td>0.000</td>
<td>1.163 - 3.825</td>
</tr>
<tr>
<td>Colour</td>
<td>Shape</td>
<td>1.163</td>
<td>0.259</td>
<td>0.003</td>
<td>0.276 - 2.048</td>
</tr>
<tr>
<td>Colour</td>
<td>Size Large</td>
<td>2.697</td>
<td>0.315</td>
<td>0.000</td>
<td>1.621 - 3.772</td>
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<td>Colour</td>
<td>Size Small</td>
<td>2.533</td>
<td>0.348</td>
<td>0.000</td>
<td>1.345 - 3.722</td>
</tr>
<tr>
<td>Colour</td>
<td>Highlight</td>
<td>0.052</td>
<td>0.072</td>
<td>1.000</td>
<td>-0.155 - 0.305</td>
</tr>
<tr>
<td>Colour</td>
<td>Motion</td>
<td>0.197</td>
<td>0.062</td>
<td>1.000</td>
<td>-0.119 - 0.513</td>
</tr>
<tr>
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<td>Orientation</td>
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<td>0.375</td>
<td>0.000</td>
<td>1.198 - 3.760</td>
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<tr>
<td>Intensity</td>
<td>Shape</td>
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<td>0.231</td>
<td>0.001</td>
<td>0.350 - 1.928</td>
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<td>1.650 - 3.693</td>
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<td>Intensity</td>
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<td>0.000</td>
<td>1.401 - 3.818</td>
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<tr>
<td>Intensity</td>
<td>Highlight</td>
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<td>0.057</td>
<td>1.000</td>
<td>-0.120 - 0.262</td>
</tr>
<tr>
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<td>Motion</td>
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<td>-0.090 - 0.444</td>
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<td>0.011</td>
<td>-2.471 - 0.191</td>
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<td>0.475</td>
<td>1.000</td>
<td>-1.424 - 1.830</td>
</tr>
<tr>
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<td>0.040</td>
<td>0.439</td>
<td>1.000</td>
<td>-1.452 - 1.541</td>
</tr>
<tr>
<td>Orientation</td>
<td>Highlight</td>
<td>-2.403</td>
<td>0.381</td>
<td>0.000</td>
<td>-3.706 - 1.999</td>
</tr>
<tr>
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<td>Motion</td>
<td>-2.297</td>
<td>0.373</td>
<td>0.000</td>
<td>-3.572 - 1.022</td>
</tr>
<tr>
<td>Shape</td>
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<td>1.534</td>
<td>0.329</td>
<td>0.002</td>
<td>0.410 - 2.657</td>
</tr>
<tr>
<td>Shape</td>
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<td>1.370</td>
<td>0.308</td>
<td>0.003</td>
<td>0.316 - 2.422</td>
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<td>-1.699 - 0.244</td>
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<td>-1.796 - 0.003</td>
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<td>Size Large</td>
<td>Size Small</td>
<td>-0.163</td>
<td>0.341</td>
<td>1.000</td>
<td>-1.328 - 1.001</td>
</tr>
<tr>
<td>Size Large</td>
<td>Highlight</td>
<td>-2.605</td>
<td>0.370</td>
<td>0.000</td>
<td>-3.683 - 1.527</td>
</tr>
<tr>
<td>Size Large</td>
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**First Fixation to Areas**

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**Figure D.3:** Statistics for the areas of first fixation. Features with a significant difference from the Chi-square test are shown in yellow boxes.
References


