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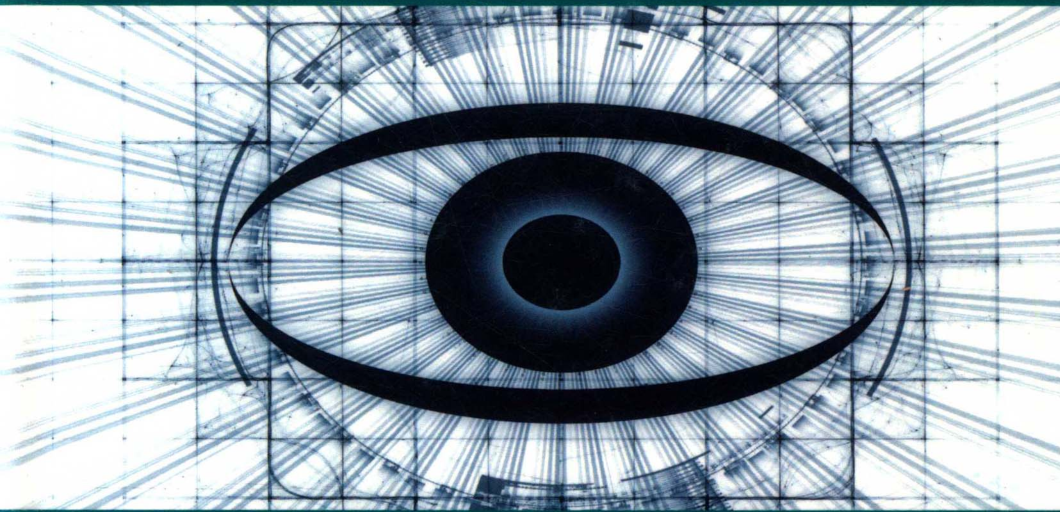

Eyestrain Reduction in Stereoscopy

Laure Leroy

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Eyestrain Reduction in Stereoscopy

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Introduction

Devices offering stereoscopic vision are becoming more and more frequent in everyday life. We are offered films to watch with depth perception – the famous “3D Cinema” – we are offered games consoles including small three-dimensional (3D) screens, the video game industry assures us that virtual reality helmets will be all the rage tomorrow, the first smartphones with 3D screens have begun to appear, etc. Even if television screens are showing a decline in sales, 3D vision, or stereoscopic vision, is slowly becoming part of our everyday lives.

On the other hand, some professionals have already long been using stereoscopic vision for extended periods of time. For example, the review of virtual car prototypes is carried out in immersive rooms with 3D vision, some training methods are also performed in stereoscopy, scientists observe the molecules that they create immersively and in 3D, etc. For all these people, 3D vision is an important element of their professional life.

Despite this enthusiasm, more and more people report having headaches coming out of a 3D film, de-activating the 3D feature on their console or not using their stereoscopic TV screen. Some professionals reduce the use of 3D in their applications from time to time to rest their eyes. All these signs show that there are questions to answer about these techniques.

This book does not intend to explain how and why we should ban artificial stereoscopy from our lives, nor, on the contrary, to affirm that stereoscopy is not at all tiring for the eyes, and that this miracle of technology has no secondary effects. It intends to explain why it can be tiring, and to offer some paths for content creators to reduce visual fatigue among users, yet without insisting that technological advances will be able to resolve all the psychological problems linked to 3D technology.

Chapter 1 will explain the main principles of 3D vision in general and of stereoscopic vision in particular. In fact, we will see that stereoscopy cannot be studied on its own, outside the context given by all the other indicators of depth. Our visual system uses all the information at its disposal and the problems begin to appear when conflicts arise between pieces of information.

Chapter 2 discusses the elements of technology currently used to achieve artificial stereoscopy. It will allow us to familiarize ourselves with the technological terms and to be able to understand the ins and outs of each technology.

Chapter 3 will explain the known causes of visual fatigue in stereoscopy. It gives a description of the current research in this area. It is important to be able to differentiate between causes of fatigue to know which are those over which we can have some influence and which are those for which an in-depth revision of the content is necessary.

Chapter 4 quickly explains the consequences of long and sometimes uncontrolled stereoscopic viewing. Unfortunately, we do not yet have sufficient hindsight to be able to understand the long-term effects, but some short-term effects have already been measured.

Chapter 5 presents methods that might be used to measure visual fatigue, those preferred by certain researchers, those that have proved effective in certain cases and why.

Chapter 6 is a result of my doctoral work. It contains one of the two proposals which I make to reduce visual fatigue. It consists of applying blur to some parts of the image. This chapter thus explains how to do it, the algorithms used, the experiments carried out to verify the impact of this treatment as well as the results obtained.

Chapter 7 presents another proposal. It is the outcome of research that I carried out with another researcher on the subject of reducing the depth of image at the right moment to reduce visual fatigue, while allowing users to not lose the benefits of stereoscopic vision, depending on the task being carried out.

Contents

1

Principles of Depth and Shape Perception

1.1. Function of the eye

Before speaking about depth, it is interesting to quickly describe how the human eye and the visual system function as a whole (Figure 1.1).

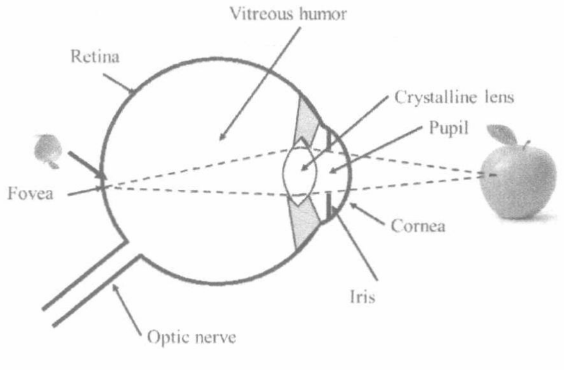

Figure 1.1. *Diagram of eye function*

When a ray of light is emitted or reflected by an object and captured by our eye, it first passes through the cornea: a transparent membrane that serves to protect the eye. It then passes through the pupil: the hole in the iris that allows the light rays to arrive on the crystalline lens. The latter is a kind of flexible lens that redirects rays of light (see section 1.2.2.2) toward the fovea through the vitreous humor, a transparent and gelatinous substance that fills the eye. On the retina, the wall at the back of the eye lined with photoreceptors, the fovea is the place with the highest concentration of these receptors. When the rays arrive at this location, they are considered to be perceived in central vision. The photoreceptors of the retina are divided into two categories: the cones, which capture colors, more numerous on the fovea; and the rods, which capture brightness, concentrated mainly on the remainder of the retina. All the photoreceptors transmit their information via the optic nerve and the optic chiasm to be processed in the parts of the brain called the lateral geniculate nucleus, the occipital cortex and the visual cortex.

1.2. Depth perception without stereoscopy

1.2.1. *Monocular cues*

Monocular cues are all those visual cues perceptible with a single eye. You do not need three-dimensional (3D) glasses to understand that, in the key scene of your favorite film, the heroes are standing in front of the background. Similarly, when you look at a photo you see immediately that such-and-such an object is closer to the lens than such-and-such a person, and vice versa. You are capable of making these deductions due to monocular depth cues.

We must not overlook the influence of these cues in our perception of depth. Indeed, it is estimated that between 3 and 10% of the population do not use stereopsis in their day-to-day vision. You might be one of them without even knowing it. Your depth vision would be based only on monocular cues. Also note that these cues are so strong that, when monocular and binocular cues conflict, your brain will follow the monocular cues.

1.2.1.1. *Static monocular cues*

Among the monocular or monoscopic cues, there are the static cues: shadows, superposition, perspective, apparent size of objects, variation of texture, etc. We use these cues when we look at a photo or a drawing or any other fixed image.

1.2.1.1.1. Light and shadows

Through its reflection on surfaces, light will influence the perception of the orientation of planes and the distance between these and the light source.

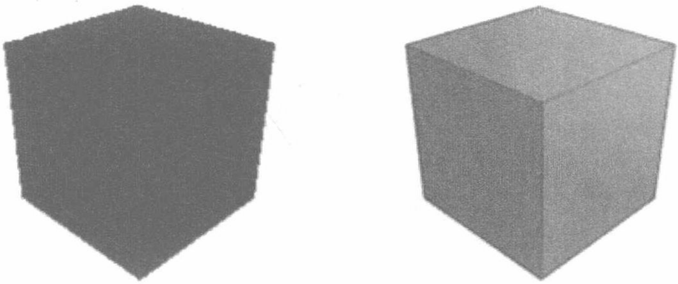

Figure 1.2. *Light and shadows completely change depth perception*

1.2.1.1.2. Interposition

When an object partially hides another, the brain interprets the hidden part of the object as being further away than the object that hides it.

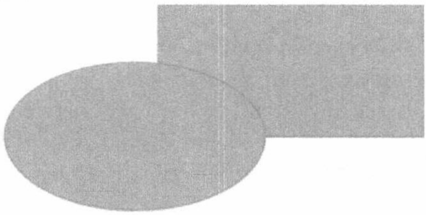

Figure 1.3. *Interposition between a rectangle and an ellipse. The brain interprets the rectangle as being behind the ellipse*

Thus, in Figure 1.3, we see an ellipse in front of a rectangle. Note that we perceive a rectangle, part of which is hidden, whereas we might have equally seen a shape with one concave edge, next to an ellipse. But it is easier to perceive a shape with symmetries than a shape with no symmetry.

1.2.1.1.3. Relative size

When objects produce a smaller retinal image when they are supposed to be of the same type, we interpret this difference as being due to the fact that the objects with a smaller retinal image are further away. Thus, in Figure 1.4, we see several flowers of different sizes, and the smallest flower will be perceived as being furthest away.

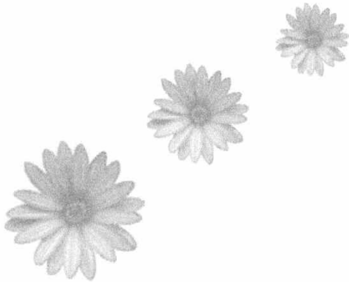

Figure 1.4. *Relative size (as well as height) gives the impression that the smallest flower is also the furthest away*

1.2.1.1.4. Variations in texture

The brain interprets regular textures more rapidly and easily, when the retinal image presents gradients of texture (in fact, gradients in the spatial frequencies of texture; see section 3.3). It interprets this as a difference in depth rather than a difference in texture. Thus, in Figure 1.5, we see that the paving stone that is closest is much more clear than those further away. In fact, it is possible to see the grain of the joins between the paving stones when they are close, but when they are distant, this is no longer possible. Similarly, we see that, in the image, the joins between the paving stones are becoming narrower and narrower. Now, we know that generally this is not the case, and we conclude from this that they are not getting narrower, but that they are getting further away.

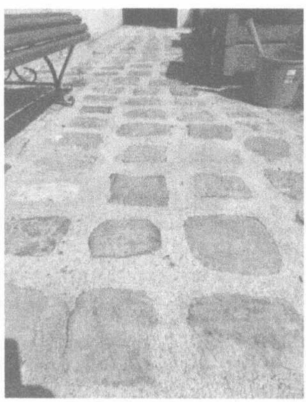

Figure 1.5. *The further away an object, the less clear its texture*