UNIVERSITY OF PADOVA

Department of General Psychology

Bachelor's Degree Course in Psychological Science

Final dissertation

The interaction between central and peripheral vision on shape.

Supervisor
Professor: Marco Bertamini

Candidate: Brittany Cecilia Rogers Bonilla
Student ID number: 1222238

Academic Year 2023/2024

Table of Contents

Abstract

Vision is an extraordinarily complex, yet fundamental aspect of human life. It is true that, due to its application and use in everyday life, the effort that is put into it is not appreciated. Vision contributes a great deal of information that allows humans to avoid dangerous situations, as well as conduct many tasks at once. These aspects are particularly beneficial to humans in order to thrive as a species and deal with an otherwise extremely complicated environment.

Asking questions about the functionality of the visual system is important for its understanding since it is one of the most prominent sensory systems that humans rely on in everyday life. Understanding the function and the neural pathways implicated in vision, allow not only to broaden the acknowledgment of it, but also allows to understand and study diseases that cause negative effects on it.

The study of vision provides valuable information to humans, in the sense that it allows to understand it, but it also provides the opportunity to understand the way in which reduced visibility, or the complete lack of it can have an effect on daily life, and people's interactions with their environment.

The goal of this review is to highlight the interaction between central and peripheral vision, in terms of functionality and structure, focusing particular attention on the way in which shape is perceived differently in each type of vision, and the advantages that each type of visibility has. An interesting phenomenon regarding the ways in which humans perceive shape and objects differently in central and peripheral vision is due to the lack of acknowledgement towards the interaction between both types. This can be clearly identified only when attention is focused on these shape differences, or in experimental tasks aimed at the study of it, otherwise, this aspect is overlooked or undetected, since one of the visual system's pursuits is to maintain stability throughout the visual field.

Chapter 1: Vision and the physical world

1.1 Introduction

The objective of this review is to highlight the difference between central and peripheral vision, specifically focusing on how things appear changed when they are only seen in the periphery, and in which ways. Upcoming sections talk about neuroanatomical, functional, and structural differences between the different types of vision, and of particular interest to this thesis is to highlight the way in which shape is perceived differently in peripheral vision, compared to central vision. On another note, the methods used to conduct this research are highlighted, as well as limitations related to the study of this field. Additionally, some propositions for future research are also included in the final sections of this review, which is important considering the limitations on the currently available information in the study of shape in vision.

1.2 Perceived world stability

The world appears to be stable throughout our interaction with it and it has been shown that this stability is maintained also at early stages of perception. The way in which this is accomplished is through constant recalibration, meaning that we are constantly adjusting the way objects are perceived when they are viewed in central vision, based on the way in which these appear in the periphery. (Valsecchi & Gegenfurtner, 2016) As a result, perception in everyday life is influenced by our eye movements, which allow new information to be processed in the sensitive region of the fovea, and consequently, the new information reaching access to awareness in a preferential manner. (Klein et al., 2019) There is neuropsychological evidence that even before a saccadic eye movement takes place, the neurons pertaining to the visual and parietal cortex that are tuned to the target location where the saccade will land, produce a firing rate that is predictive, causing the shift of neurons' receptive fields in both the visual and prefrontal cortex, towards the saccades' target location. (Kwak et al., 2023)

1.3 Visual stability through saccades

One of the most surprising aspects of vision is the way in which humans perceive the world as homogenous and stable throughout their interaction with it. However, due to the complex nature of this aspect, different disciplinary fields have attempted to find an explanation to it. (Vater et al., 2022). A recurring theme regarding this subject has to do with saccades. These are eye movements made rapidly with the objective of relocating visual fixation within the visual field, jumping from to a different location. (APA Dictionary, 2023) Fixation can be defined as, when viewing an object, the orientation of each eye for the image to fall in each fovea, which is located at the centre of the retina, and can be described as a small depression which contains the most concentrated amount of retinal cone cells, and where images are most clearly focused. (APA Dictionary, 2023) Although it only constitutes less than 1% of the retinas' total surface, it is the part where light focuses on the retina and has the highest density of photoreceptors. (Vater et al., 2022)

As we know, the world in which we live is not uniform, therefore, our visual system must find a way to represent the information we acquire in a functional and smooth manner. It has been profusely determined that across the visual field, there is a variation in the level of acuity, which may provide an explanation to the reason why, depending on the eccentricity of objects, these are perceived in an affected way. (Baldwin et al., 2016) *Acuity* can be defined as "sharpness of perception". (APA Dictionary, 2023) When visual acuity is mentioned in this review, what is meant is the perceived precision with which a stimulus is assessed.

There is a factor which is believed to have an effect on perceived world stability, called **transsaccadic learning**. This process is thought to help integrate the appearance of foveal and peripheral vision, although there are many studies which refute this proposal. The idea is that information obtained during a saccade from both foveal and peripheral vision is integrated. It is said that this interaction is likely to act in accordance with temporal order in which the stimuli are seen. Given the likelihood of this order, it could be that the stimuli are first perceived in the periphery, and in the fovea posteriorly after a saccade is made, indicating that foveal perception can be altered by the information present in the periphery. (Stewart at al. 2020) It is important to keep in mind that the input provided in the periphery is blurry in its presaccadic state, and the postsaccadic outcome will be that the information will be brought into high detail when a saccade is made, and therefore, placing the information onto the fovea. (Kwak et al., 2023)

1.4 Physical space, visual space, and visual field.

When we talk about vision, it is fundamental to understand the differences between some key aspects of visual space and its differentiation with physical space. On one hand, **visual space** corresponds to "the subjective appearance of physical space" (Baldwin et al. 2016), meaning that our personal perspective, or experience has an effect on our perception of the physical space. At the same time, we can differ visual space from **visual field**, since the latter corresponds to the extent to which, during any fixation period, the visible world is present to both eyes. On the other hand, **physical space** corresponds to the actual three-dimensional realm in which material objects are physically located. (Farlex, 2023) Understanding the core differences between these concepts is important, since there is not a precise representation of the visual space with respect to the physical space, because the former is subjective, and therefore, highly interchangeable. (Baldwin et al., 2016)

1.5 Brightness, luminance, and reflectance

Scenes perceived in the real world are complex, and are affected by many factors, such as lighting conditions, the numerously different points of perspectives, and occlusions. There are some physical properties concerning vision, which have their perceptual counterpart. *Brightness* corresponds to the perceptual counterpart of *luminance* (Strasburger et al., 2011). The perceived brightness of an object or stimulus is in relation with the physical properties such as the amplitude of the wave and its wavelength. (APA Dictionary, 2023)

Surface luminance refers to the way in which the interaction between the retinal stimulus corresponding to the lightness of a surface, and the brightness that corresponds to the visual area, results from a coupled effect between illumination and reflectance. This distinction is important since it allows to understand the effect that the intensity of illumination a particular scene or an object has. (Strasburger et al., 2011)

Researchers Pöppel and Harvey found in 1973 that when targets reach threshold in the periphery, these appear brighter than targets at threshold in the fovea. This is due to the fact that when targets reach threshold in the periphery, these have more luminance than foveal targets reaching threshold. This is observed as a result of the sustained brightness constancy widespread along the visual field. (Pöppel & Harvey, 1973)

Chapter 2: Structural and functional differences of vision

2.1 The retina and the visual field

At the back of the eye, there is a structure called the retina, which is light sensitive, and oversees transmitting signals to the brain for vision to be possible. Figure 1 depicts where the retina is located. (American Academy of Ophthalmology, 2023) This layer in the eye is composed by glial cells, which keep the retina balanced and functioning properly (García-Bermúdez et al., 2021), and photoreceptor cells, which are made up of two types. One being cones, which control humans' capacity to differentiate colours by capturing different wavelengths, and they are most sensitive to daylight, also known as photopic vision. These photoreceptors are most abundant in the fovea, located at the centre of the retina. The other type are rods, which are more active during scotopic vision, meaning that they are more sensitive to faint illumination, and these are most abundant in the peripheral part of the retina. (Nguyen et al., 2022)

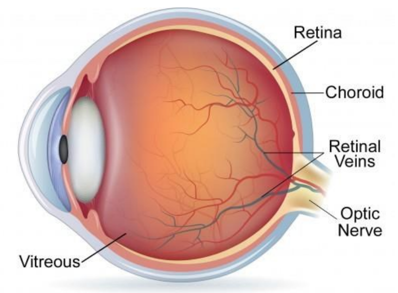

Figure 1: the retina (depiction of where the retina is located; VMR Institute, 2022)

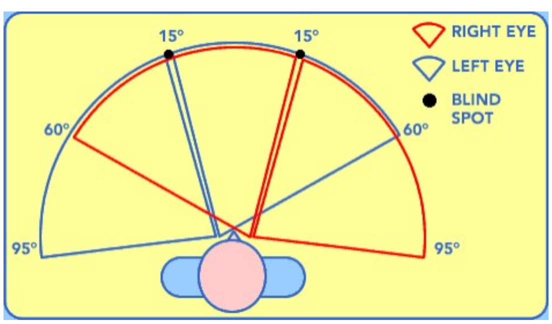

Figure 2: Visual Field (How far can the visual field see?; Vision and Eye Health, 2023)

The visual field corresponds to the extent to which the entire information provided by a scene is captured by the interaction and integration between central and peripheral vision. (Farlex, 2023) As figure 2 shows, each eye alone covers about 155 degrees of vision in a scene, given that each eye covers around 60 degrees from the centre of the eye towards the direction of the nose, and around 95 degrees of vision from the centre of the eye towards the direction of the ear. This means that the interaction between both central and peripheral vision allow humans to have a range of around 190 degrees across the scene they are in contact with, being the visual field. (Anne, 2021) Figure 2 also depicts a blind spot for each eye, which corresponds to the location of the optic nerve at the back of the eye. This region, located at about 15 degrees in relation from the centre of the eye and the nose, does not contain photoreceptors, and in consequence, light cannot be detected in this region, causing a blind spot in the visual field. (Vision and Eye Health, 2023)

2.2 Neuroanatomical explanations for visual perception

The study of visual perception has allowed to identify cortical areas in primates. The primary retinocortical pathway is responsible for most visual functions. This structure is made up of receptors, ganglion cells, the lateral geniculate nucleus, and the primary visual cortex. Moreover, the afferent visual pathway is responsible for the variation in performance, due to its' projection properties, for many visual functions across the visual field (Strasburger et al., 2011), since it is the structure responsible for the reception, transmission, and processing of visual information. (Wu et al., 2020)

The peripheral vision's ability to recognize the gist of a seen is believed to be a result of higher processing levels beyond the primary visual cortex. The region that is presumed to be responsible for this specialization is the parahippocampal place area (PPA). (Strasburger et al., 2011) This area is particularly category-selective in the processing of scenes (Baars & Gage, 2010), showing eccentric processing for structural and feature information in scenes and buildings. (Strasburger et al., 2011)

It is known from neuropsychological research that global information is integrated by the primary visual cortex as a result of spatial precision through feedback loops. Neurocomputational models provide evidence that cortical areas form reciprocal connections to integrate global information through local analysis. (Strasburger et al., 2011)

Another region of interest is the lateral occipital complex, characterised by being extended both dorsally and ventrally, located on the lateral part of the fusiform gyrus, which is located between the temporal and occipital lobes. (Grill-Spector et al., 2001) This region has been found to have a strong role in the representation of shape, therefore, it is believed that this area contributes to the feedback process of object information, as well as position-invariant object information, that takes place from higher cortical areas to the foveal retinotopic cortex.

2.3 Eye anatomy effects on visual perception

Possibly related to meridional differences, which will be explained in more detail in the next section, are some structural reasons due to eye shape. There is a possibility that compression observed in the peripheral visual field may be partially caused by the way in which the projection of light enters the cornea into the retina. The structure of the eye is spherical, which consequently results in the optical distortion of objects. This can be observed when objects on the horizontal axis, appear compressed horizontally, and objects on the vertical axis appear compressed vertically. (Baldwin et al., 2016) Additionally, the adult cortex in humans has anatomical restraints, mainly being that there is a greater cortical surface in which information from the horizontal meridian is processed, compared to the vertical meridian, as well as a higher processing of the lower vertical meridian, compared to the upper vertical meridian, consistent with the horizontal-vertical meridian, and the vertical meridian asymmetry of performance fields. (Kwak et al., 2023)

2.4 Structural differences between central and peripheral vision

The fovea is the part that makes up 1% or less of the retinas' total surface where light focuses, making it the retinal area containing the highest density of photoreceptors as it has previously been mentioned. Surprisingly, 50% of the visual cortex is accounted for by this very small surface occupation. (Vater et al., 2022) Due to the fact that the centre of gaze has the highest visual acuity, it should not be inferred that the information provided by the rest of the visual field is somehow inferior, this only means that it is useful and necessary for different purposes. As it is known, peripheral vision preferentially processes global information, particularly focusing on form and its spatial position, whereas local information is processed by central vision, which analyses the material that makes up the form. (Klein et al., 2019) Due to the division of labour between central and peripheral vision, it has been a subject of interest throughout the years for many disciplines. (Vater et al., 2022)

Visual feedback theories on visual perception propose that perception is affected by feedback processes through the modulation or anticipation of the representations that feedforward responses to stimuli generate. Particularly, the central-peripheral dichotomy theory states that feedback processes conducted from higher cortical areas to lower ones is weaker in the outer peripheral visual field. (Zhaoping & Liu, 2022) Due to the ample research made on the feedforward and feedback processes, it is known that there is a non-overlapping representation of each process in different parts of the retinotopic cortex, therefore, they can be separately studied and clearly distinguished. (Williams et al., 2008) An interesting phenomenon to keep in mind, is that recognition in peripheral vision mostly relies on feed-forward input, which in turn makes peripheral vision more prone and vulnerable to visual illusions than central vision. (Zhaoping & Liu, 2022) It is known that higher cortical areas feed object information back to the foveal retinotopic cortex. This is interesting, since it has been shown in various studies that object information located in the foveal retinotopic cortex is relevant when conducting a behavioural task. Stronger information in the foveal cortex regarding objects has been seen to be correlated with better object-discrimination task performance. (Williams et al., 2008) Therefore, it seems that information provided by the peripheral visual field can be misleading (as in visual illusions), due to insufficient feedback processes when the visual information is vague and unclear in the environment. (Zhaoping & Liu, 2022)

The neurons that are found in the foveal region of the retina have a higher sensitivity to spatial frequencies. (Kwak et al., 2023) Spatial frequency refers to the number of repeated elements in a particular pattern at a given distance. (APA Dictionary, 2023) At the same time, the fovea also has a higher proportion of orientation-tuned neurons, than the periphery. It is then possible that preparing a saccade causes the activation of these neurons in order to access a foveally similar representation of the target in the periphery. (Kwak et al., 2023) Therefore, predicting foveal perception could functionally be useful based on the information available in peripheral vision. (Stewart et al., 2020) On another note, ganglion cells distributed on the retina, causes an enlargement effect in foveal vision, which consequently causes objects of the same size to appear smaller in the periphery compared to how the objects are perceived in central vision. (Baldwin et al., 2016)

Another aspect that has an effect on the way in which shape is perceived and varies, is due to "performance fields" which are divided into two: on one hand, we have the horizontal-vertical anisotropy (HVA) in which visual performance located in iso-eccentric regions is better at the horizontal meridian, compared to the vertical one. On the contrary, due to the vertical meridian asymmetry (VMA), visual performance in the lower vertical meridian will be better than at the upper vertical one. (Kwak et al., 2023)

2.5 Location vs. Identification / Where vs. What

As humans interact with their environment, there are different visual mechanisms for different things. In particular, the processes of identification and location of objects in the surrounding area are achieved in different ways. For example, when humans want to conduct an action, like grasping an object, they perceive certain characteristics of the target object with respect to other objects found in the same scene, achieved using peripheral vision, such as location, size, shape and even the orientation of the object, this can be seen as the “where” or “location” process. To conduct the action, foveal vision is responsible for the “identification” or “what” process for the action to take place. Attention then is shifted to the object itself without taking into consideration the scene. (Goodale & Milner, 2013) It is interesting, having understood these different processes, to highlight the work of Gestalt psychologist Korte, who claimed that there are three consecutive phases that take place in recognition, stating that the first phase is in charge of absorbing the greatest number of common features perceived by vision, as a whole, such as shape, orientation, and so on. The second phase is the one in which detail starts to emerge. And finally, the third phase is the one in which “unequivocal identification” takes place. (Strasburger et al., 2011)

Chapter 3: Components in studying vision

3.1 Endogenous and exogenous covert attention

Covert attention can be understood as, when we fixate on a location, our attention is diverted or focused on a different location. (APA Dictionary, 2023) There are two types of covert attention, and what differentiates them is the way in which spatial resolution is modulated. The first one is called endogenous attention which can both increase and decrease resolution in accordance with the demands of the task. Whereas exogenous attention simply enhances resolution in an automatic fashion, even if this has a negative effect on the task at hand. (Kwak et al., 2023) One way of illustrating the main difference between peripheral and central vision, is by saying that the former is for looking, and the latter is for seeing. Looking consists in choosing attentively a visual location which we want to analyse in detail, which will be possible once we convey our attention to it. Of course the manipulation of the two kinds of covert attention have been studied, which can be observed, for example for endogenous attention, by implementing horizontal bars in order to allow the identification of the next location in which the target will be presented, whereas for exogenous guidance, when the mask onset occurs, and simultaneously an exogenous flash appears at the targets' expected location, this will positively impact the discrimination performance of the target, as a cueing effect of exogenous attention. (Zhaoping & Liu, 2022)

3.2 Visual crowding

The most characteristic aspect of peripheral vision is a phenomenon called crowding. It clearly distinguishes peripheral and foveal vision since it is distinctively peripheral. (Strasburger et al., 2011) Visual crowding is when it becomes difficult to identify objects that are located close to each other in the peripheral visual field. (Vater et al., 2022) This has been an interesting subject to study in visual perception, since it is much more complex than simply analysing concepts about pattern recognition. It has been proposed that the crowding effect is partially due to a vague focus of attention. The interaction between flankers and target patterns as lateral interactions in a spatial range, seem to depend more on the eccentricity in which the target is in the visual field, meaning where the target is located, rather than the content of the target in the scene. This proves that there is a loss in the interrelation between actual features and parts of patterns. (Strasburger et al., 2011) Throughout many different studies, it has been found that crowded objects can be improvingly recognised when the context of the scene is paired with perceptual grouping, allowing the resolution of peripheral information which is otherwise difficult to identify. This can be observed in tasks in which the gist of a scene is picked up from a glance and multiple objects must be tracked at once, showing that there is a preservation of enough information in crowding. (Vater et al., 2022)

3.3 Masking

Using masks is a common phenomenon used in visual perception. The purpose of it is to reduce the visibility of a targets' image by adding another image, which is itself the mask. (Breitmeyer & Ogmen, 2010) Therefore, metacontrast masking consists of producing reduced visibility of a briefly presented object by additionally presenting a mask that is spatially adjacent, specifically when the mask is presented after the target, rather than before it. It has been found that masking effects are predominantly strongest in the range between 40 and 100 ms after a target has been presented. Metacontrast masking seems to only work when the contour of the target is surprisingly near the target's contour, since it has been found that the effect of masking is reduced drastically when the distance is increased between the target and the mask contours. (Zhaoping & Liu, 2022)

Increasing mask size causes a disruption in form and material processing, since the size of the mask causes a greater occlusion of the peripheral visual field, however, it has been found that form disruption is more affected than material processing. The importance of this effect on both material and form is important because it provides additional information to the different roles central and peripheral vision have with respect to this information, since it is difficult to study directly. Particularly, these findings provide evidence for the contingent idea that peripheral vision is specialised in the processing of global form, whereas central vision primarily focuses on local material information. (Klein et al., 2019) Metacontrast masking, therefore, causes disruption in the identification of information as a result of the interference of feedback processes when a target is to be recognised.

Furthermore, active V1 and V2 neuropsychological scalp recordings in monkeys have shown that evoked potentials in these visual areas have similar responses to both masked and unmasked targets suddenly after the onset of the target, suggesting that early visual cortical responses are affected in a limited way by masking, and it seems as if there is no marked distinction between masked and unmasked situations in early visual cortical responses. (Zhaoping& Liu, 2022)

3.4 Visual perception evidence

As it has been thoroughly explained throughout this review, a recurring phenomenon in vision is the fact that humans are not consciously aware of perceived shape differences, since both central and peripheral vision work in conjunction to make the world and the scenes they are looking at appear stable. It is only when humans actively pay attention to these differences that it becomes apparent. This phenomenon is usually only noticed when a particular task requires to focus more attention on shapes in the peripheral visual field, or because of experimental research studying this subject of interest. Objects in the periphery appear differently than when they are located on the fovea. They may be distorted in both size and shape, in particular they appear smaller and compressed. As French painter Roger de Piles stated in 1708, "Bodies decrease in both force and colour in proportion as they recede from the straight line, which is the centre of vision". (Baldwin et al., 2016) The following section highlights the way in which objects are perceived differently, and some functional explanations for these differences.

- **Faces**

  An aspect of everyday life consists in seeing faces, which are made up of different classes of objects, and as with other objects, they are constantly going through several modifications that constantly create changes among their configurational features. (Beale & Keil, 1995) Humans acquire expertise at a very early age to analyse them. Faces convey important information about identity to humans, but they also cue information regarding emotions. Many studies have found that identifying faces and the process of emotional expression are carried out in different neural pathways due to the nature of their functionality, however, these separate mechanisms seem to rely on akin analyses of facial configuration components. One way in which facial expression greatly differs from face identification is due to the fact that the former is highly influenced by categorical perception. (Strasburger et al., 2011) Categorizing facial expressions is particularly useful for humans due to the wide range of emotions they exhibit. (Beale & Keil, 1995) As a result of this categorical perception, it is believed that peripheral vision is particularly enhanced to decipher emotions, which may prompt the recognition of relevant behaviour in the environment, suggesting that complexly distributed features provided in the peripheral visual field are useful to humans. (Strasburger et al., 2011)

- **Letters vs. Non-letter strings**

  Reading is not innate to human nature, it can be considered one of the most convoluted skills they can acquire, and it has been widely studied due to its complexity. There is a rather unanimous understanding around the process of reading. Initially, there is a parallel processing of all the elements composing a word, meaning the letters contained in it. This parallel processing leads to the identification of each letter in the word, and their position within it. (Chanceaux & Grainger, 2010) A considerable number of studies have been conducted in order to understand this process, and it a well-known fact that the smaller the size of letters are, there is a significant need for there to be higher contrast in order for the recognition to be possible, as in comparison to larger letters, particularly but not specifically to letters presented in the periphery. (Strasburger et al., 2011) There are other characteristics in reading which are also of interest to researchers, like the effect that letters have on position, when they are presented in a string-like manner, particularly when they are viewed in the peripheral visual field. It has been determined that there is an advantage to the letters present in the outer part of the string, either positioned at the beginning or at the end, in comparison to the characters that are present in the inner part of the of the string. (Bouma, 1973) Researchers have also analysed the way in which recognition in the peripheral visual field may be different when comparing simple geometrics shapes and letters in a string-like manner. Although the geometric shapes used for these experiments are highly familiar, it has been found that strings of letters tend to be more familiar at the moment of recognition than strings of shapes. When both types of stimuli (letter vs. non-letter shape) are respectively presented at the same degrees of eccentricity, there is a higher degree of recognition for letter stimuli. These results show that the visual field processes letter and shape strings in a qualitatively different fashion. (Chanceaux & Grainger, 2010)

- **Shapes**

  It is interesting to pose the question of whether time constraint has an effect on the way in which objects in peripheral vision are perceived. A sophisticated study by Baldwin, Burleigh and Pepperell was conducted to answer this question. When the task is to compare the appearance of peripherally viewed objects with identical objects in central vision, those in the periphery will be perceived as smaller in size, and their shape will be compressed. When subjects analyse a circular object, particularly a round disk, without any time constraints, it appears smaller in size in the periphery when it is directly compared to the same object in central vision, and additionally, the circular object will appear to have a more elliptical shape, sometimes it may even seem to acquire a polygonal shape. (Baldwin et al., 2016) This phenomenon is hypothesized to surface as a result in the V1 area in the visual cortex, which is composed by a large number of orientation-tuned cells. The way in which this could have an effect on the perceived polygonal shape in peripheral vision, is that circles may be processed as a series of connected straight lines. (Ito, 2012) On another note, it is also interesting to observe what happens when there are time constraints, and targets are presented briefly. The same authors, therefore, took on the task, and found that shapes observed in the peripheral visual field appear remarkably smaller across the periphery when compared with the same sized objects in the central visual field. Whereas objects briefly presented in the peripheral visual field in shape discrimination tasks tend to be reported accurately, except when they are presented in the far region of peripheral vision. These researchers found that perceiving shape at 30° of eccentricity, has no negative effects on the recognition of the shape, however further eccentricities begin to approach chance levels of recognition. (Baldwin et al., 2016) These findings are consistent with the idea that there are a lot less peripheral receptive fields, which at the same time are greater in size, as compared with foveal receptive fields. They are also consistent with the fact that peripheral regions are far less attended to than the foveal regions. (Kirsch et al., 2020)

3.5 Multitasking and tradeoffs

The integration of visual perception is due to the combination of central and peripheral vision, allowing a more reliable understanding of the world, which most likely would not be possible if we used the perceptual information of each system individually. (Stewart et al. 2020) Both types of vision are used to interact with the environment and monitor it, since foveal vision allows us to focus on specific targets, and peripheral vision provides information regarding objects in the world and compares it with the body's position in relation to them.

Multitasking is a predominantly complex factor of human life which benefits from the active interaction of foveal and peripheral vision. Peripheral vision provides useful information, even though it is degraded in comparison to foveal vision. As a result, tradeoffs are actively being made, in order to decide if one should move their gaze towards a particular location with eye movements, or if it is possible to rely on peripheral vision. (Vater et al., 2022) These tradeoffs are strongly influenced by factors which have systematic effects on whether to rely on peripheral vision or to conduct a saccade. Some of these factors have to do with physical properties of the objects such as luminance, eccentricity and size, others have to do with visual factors, such as monocular or binocular viewing, and whether the objects are in the temporal or nasal side (Strasburger et al., 2011), and personal properties of the subject interacting with the environment, such as age, the subject's current emotional state, degree of concentration or distraction coupled with the subjective importance of the task at hand, and expertise. In general, humans tend to rely on their peripheral vision when they are familiar with particular situations, meaning that expertise is an important factor which reduces saccade onset, since it is likely advantageous for the task at hand to depend on peripheral vision instead. (Vater et al., 2022)

3.6 Costs of looking away

As mentioned previously, the world changes in unpredictable ways, and it is highly unlikely that all relevant information can be found at a singular location in the environment, hence, it is not possible to fixate on the most important information present in the visual field at the specific time when it is needed. Humans are constantly, yet usually unaware of the fact that they are multitasking due to the complexity of the world surrounding them, since it is an automatic process most of the times. (Vater et al., 2022) As a result of this, visual information is constantly being processed, both centrally and peripherally to different degrees, and depending on the complexity of the task at hand, one can depend on the information provided by the periphery or redirect their gaze to another location in order to process this information in the fovea, which in turn will allow the new acquired information to have favoured awareness access. (Klein et al., 2019)

Humans are constantly evaluating their environment in order to avoid dangerous situations. It has been found that humans tend to feel more threatened by sharp edges, since this may pose a threat to their well-being, and it is believed that the human cortex contains low-level sensory information that is particularly influential in the detection of harmful features in the environment. (Bar & Neta, 2006) Foveating on a new location resulting from a saccade causes the previously foveated information to fall into the periphery, which can have detrimental effects, and it is important to keep in mind that foveating back to the initial location takes time. This is the reason why tradeoffs are such an important component in vision, in order to decide whether it is necessary to change gaze direction through a saccade or not. (Vater et al., 2022)

3.7 Problems in vision can cause difficulty in daily life.

Due to the importance of the information that is conveyed by peripheral vision, deteriorations of it can cause problems in human everyday life, and their interaction with the environment. There are a series of visual disorders and lesions that can contribute to the loss of peripheral vision; however, a particular disease will be mentioned here. Retinitis pigmentosa is a visual disorder that progressively makes people lose input conveyed in the periphery. (Vater et al., 2022) The loss of peripheral vision is commonly known as “tunnel vision”, a very accurate name for this condition, since patients suffering from it can only perceive what is available in the foveal region. This means that they need to move their head to register the information available in the environment. (Dean McGee Eye Institute, 2022) Of course this implies a reduction in performance for many tasks, including the safe navigation in the world. (Vater et al., 2022) Loss in peripheral vision can be detrimental to humans because a large portion of the visual field is represented in it, containing elements in the environment that could be crucial to task performance, and something as basic as survival. (Stewart et al., 2020)

Chapter 4: Research results

4.1 Methodology

The investigation for this literature review was mostly conducted on a search engine called Scopus. Preference was given to scientific articles containing keywords such as “peripheral vision”, “central vision”, “shape”, “form”, among others. Books specialized on vision and neuroscience were also used to retrieve information not presented in the scientific articles, but that was important for the understanding of this review. During the screening process of scientific articles, only those which contained information about shape and peripheral and central vision were used, excluding those focusing more on colour or other aspects not closely related to the subject of shape. It became clear that, although the literature found in the field of visual research is abundant, much exploration in this discipline is yet to be made. Something that stood out was the need to conduct more research on the effects of perception on shape, both in central and peripheral vision, due to the very high quality, yet surprisingly low number of studies conducted in this regard. There is a higher demand in the study of colour perception in visual research, than for shape perception, which of course is not the main concern of this thesis, and therefore were not included in the review. Many systematic reviews and particularly interesting studies related to vision were consulted, in order to have a better understanding of the neuroanatomical pathways present in vision perception, focusing primarily on cortical areas specialised in vision and the processing of shape. Major functional differences between both types of vision, such as one being useful for obtaining detailed information from specific locations or objects in a scene, and the other providing more general and less detailed information such as shape orientation, distance, and even provides emotionally relevant information and awareness towards objects that may present a threat to wellbeing. Studies which focused their attention on experimental tools and techniques were also included, since they provide insight into the understanding of the way in which visual experiments are conducted, and studies that focused on visual crowding were also consulted, since crowding is characteristic only for peripheral vision, representing characteristic aspects that differentiate peripheral from foveal vision. Another aspect that was included in this review, were the negative effects that poor peripheral vision can have on human experience in everyday life. A particular condition called retinitis pigmentosa, commonly know as “tunnel vision” was included to highlight the way in which the lack of access to peripheral information can cause difficulty in many tasks.

4.2 Results

This review has highlighted the general differences between central and peripheral vision, both in structure, and functionality. It is clear that foveal vision requires a great more deal of attention, and it allows to fixate on particular locations at a time, whereas peripheral vision corresponds to the rest of the visual field, and although the information provided by the periphery may be distorted and be less attended to, the input provided by this visual field is extremely valuable for humans while they interact with the complex world in which they live. Peripheral vision is important for survival, which is why there are trade-off processes that allow to discriminate whether it is necessary to change the location of gaze towards a currently peripheral location, or to rely on the information provided by peripheral vision. These processes are important, because conducting a saccade can have detrimental effects in dangerous and unpredictable situations. In general, humans are not consciously aware of the different way in which objects are perceived differently in peripheral and central vision. The acknowledgement of this phenomenon only becomes apparent when attention is shifted to perceived shape differences in the periphery, which can be beneficial for a number of reasons, one reason may be to conduct a particular task that requires focusing greater attention to objects in the periphery while foveating on a particular location, another reason may be related to shifting one's attention to peripheral objects that could pose a threat to their wellbeing, or because experiments are conducted in this field of interest and the differences become apparent.

The objective of this review is to focus on how shape appears differently in the peripheral visual field in comparison to the central visual field. When it comes to size, objects will appear smaller than when they are seen in the fovea, even in situations in which people are aware of the size of the object. Whereas when it comes to shape, it has been found that shape in the periphery does seem to be perceived in a different way when the objects are briefly shown. However, prolonged presentation of objects in the peripheral visual field seem to cause the perception of a distorted or different shape. There is an important aspect that must be taken into consideration when talking about shape deformation, which is *eccentricity* of the object. It has been found that objects at low eccentricities seem to preserve their shape, meaning that objects located close to, but not on the fovea, are still perceived without distortions. However, as the objects continue to fall further onto the far periphery, objects appear to change shape, with objects on the horizontal axis looking compressed in length, and objects on the vertical axis looking compressed in height.

The experimental development in vision has provided useful information that has allowed to better understand the way in which the visual field is perceived, and the different roles that central and peripheral vision have respectively, and the conjunct interaction between both types. A characteristic aspect of peripheral vision is crowding, which is when objects that are placed close together become difficult to identify, an phenomenon which is not present in central vision, and that clearly distinguishes them.

Even though the two visual fields differ among themselves, humans have a rather stable representation of the world surrounding them. This is believed to result from the active interaction between the two, since information from only one of the sources could be less beneficial to humans and their interaction with the world. A particularly interesting aspect in this field of research is the fact that both types of vision work together, permitting the observer to perceive scenes in a stable manner, until particular attention is focused on the actual perceived differences of shape in peripheral vision, in comparison to central vision. This shift in attention to highlight the differences may be useful to the observer during tasks or activities in everyday life, and may have survival benefits, and it is actively studied in vision sciences, to understand the characteristics and uses that these differences have.

Some aspects of vision research were also included to understand the way in which studies are conducted to acquire information in this field. Masking and different periods of presentation of stimuli used in various studies were also pointed out, showing that masking effects decrease when target and mask contours are placed further away from each other, and that stimuli presented in the periphery for longer periods of time seem to be perceived as deformed, or appear to be a different shape.

The term “tunnel vision” was also mentioned, with the objective of providing an insight into the way in which peripheral information is crucial for humans and their interaction with the world surrounding them and their performance on everyday tasks. Not having the ability to see anything other than objects located on the fovea clearly poses a threat to wellbeing, since all the information provided in the periphery cannot be accessed, and indirect emotional cues and body language, or objects that may be harmful will not be perceived, unless one is able to perceive them through foveal vision. This limited access to visual information is likely to have an impact on multitasking, which is a characteristic component of human life.

4.3 Discussion

Overall, vision is a sensory process which is fundamental for humans in their everyday lives, however, since it is an automatic process for most people, it is not perceived as complex as it actually is. Over the centuries, people have raised questions regarding the visual system and trying to find explanations that answer them. Many theories have been proposed, some of which have been refuted with increasing knowledge, for example, considering the eye to have a similar mechanism to a camera used to be a widespread belief, which does not hold true in modern standards. The increasingly more sophisticated technology today is a great instrument that can be taken advantage of to study vision, continuously updating and improving previously used tools which opened the door to many discoveries. A milestone in the study of vision was the access to eye-tracking devices in visual tasks, which has of course been modernized since it first came out.
Due to its complexity, there are still many open questions in vision research, which encourages professionals from different fields to continue studying it, opening the possibility for interdisciplinary research to be conducted, which can be more beneficial to widening the knowledge in this matter. There are many aspects that need to be considered in the study of vision. Crowding is distinctive characteristic of peripheral vision, since central vision does not have it. Such considerations allow to pose new questions regarding the different functions that central and peripheral vision have among each other, and characteristics that distinguish and affect both types, such as the study of visual illusions as well, which tend to be more prone in the periphery, than in central vision.
Understanding the negative effects that visual disorders have is also particularly interesting in the study of vision. It is useful to perform experimental research on people that have normal vision and others who have visual difficulties, since the understanding of one can provide useful information for the other in different aspects.

4.4 Conclusions

There is still much that is unknown about the visual field due to its complexity. Although a lot of progress has been made, it is important that scientist come together to conduct research in both central and peripheral vision. It is an advantage that there is a growing consensus on the way in which the visual system is understood, and on the models that have been proposed and confirmed regarding the neural pathways that are responsible for visual perception. As it has been previously discussed, shape is perceived differently in peripheral vision, with regard to central vision. However, it is important to remember that even though the information may be more prone to appear blurry, and humans do not seem to be aware at all times that they are processing information in the peripheral visual system, this does not mean that the information is less valuable. On the contrary, the periphery provides humans with important information that allows them to coordinate their body in relation to the world and facilitates them to register information in the environment which can be harmful to their well-being, meaning that peripheral vision is an important aspect for survival in many real-life situations. On another note, peripheral vision is an important aspect in human everyday life since it enables them to multitask in an otherwise unsustainably complex world.

The main objective of this review was to clearly present the different ways in which shape is perceived in central and peripheral vision, understanding that shape is heavily influenced by the eccentricity to which objects are presented. When they are close to the fovea, shape does not seem to be distorted, however, as the objects are perceived further away in the periphery, shape tends to be distorted, sometimes being perceived as a similar but somewhat different shape, usually distorted in length when presented on the horizontal axis and distorted in height when presented on the vertical axis. As shapes are perceived further away into the periphery, shape seems to become deformed and hard to identify, sometimes even looking like a completely different shape than it originally is.

Interdisciplinary research in the field of vision perception can be extremely useful and should be pursued in the near future, in order to better understand the visual system and the particular characteristics of both central and peripheral vision. As mentioned before, much progress has been accomplished in its understanding, but there is still much to be discovered.

References

American Academy of Ophthalmology. (2023). *Retina*. Https://Www.Aao.Org/Eye-Health/Anatomy/Retina-103.

American Psychological Association. (2023). *APA Dictionary of Psychology*. Https://Dictionary.Apa.Org/.

Anne, Kellie. (2021). *Monocular Vision – Sight With Only One Eye*. Https://Www.Uccellodesigns.Com.Au/Blog/Monocular-Vision-Sight-with-Only-One-Eye/.

Baars, B. J., & Gage, N. M. (2010). Chapter 6 - Vision. In *Cognition, Brain, and Consciousness.* (Second, pp. 156–193).

Baldwin, J., Burleigh, A., Pepperell, R., & Ruta, N. (2016). The perceived size and shape of objects in peripheral vision. *I-Perception*, *7*(4), 1–23. https://doi.org/10.1177/2041669516661900

Bar, M., & Neta, M. (2006). Humans prefer curved visual objects. *Psychological Science*, *17*(8), 645–648. https://doi.org/10.1111/j.1467-9280.2006.01759.x

Beale, J. M., & Keil, F. C. (1995). Categorical effects in the perception of faces. *Cognition*, *57*(3), 217–239. https://doi.org/10.1016/0010-0277(95)00669-X

Bouma, H. (1973). Visual interference in the parafoveal recognition of initial and final letters of words. *Vision Research*, *13*(4), 767–782. https://doi.org/10.1016/0042-6989(73)90041-2

Breitmeyer, B., & Ogmen, H. (2010). Visual Masking: Time Slices Through Conscious and Unconscious Vision. In *Visual Masking: Time Slices Through Conscious and Unconscious Vision*. https://doi.org/10.1093/acprof:oso/9780198530671.001.0001

Chanceaux, M., & Grainger, J. (2012). Serial position effects in the identification of letters, digits, symbols, and shapes in peripheral vision. *Acta Psychologica*, *141*(2), 149–158. https://doi.org/10.1016/j.actpsy.2012.08.001

Dean McGee Eye Institute. (2022). *Peripheral Vision Loss: What Is It and How Is It Treated?* Https://Dmei.Org/Blog/Peripheral-Vision-Loss-What-Is-It-and-How-to-Treat-It/.

Farlex. (2023). *The free dictionary.* . Https://Www.Thefreedictionary.Com/.

García-Bermúdez, M. Y., Freude, K. K., Mouhammad, Z. A., van Wijngaarden, P., Martin, K. K., & Kolko, Miriam. (2021). *Glial Cells in Glaucoma: Friends, Foes, and Potential Therapeutic Targets*. Https://Www.Frontiersin.Org/Articles/10.3389/Fneur.2021.624983/Full#:~:Text=Glial%20cells%20serve%20to%20maintain,BDNF%2C%20NT3%2C%20and%20NGF.

Goodale, M., & Milner, D. (2013). *Sight unseen: an exploration of conscious and unconscious vision.* (Second).

Grill-Spector, K., Kourtzi, Z., & Kanwisher, N. (2001). The lateral occipital complex and its role in object recognition. In *Vision Research* (Vol. 41). www.elsevier.com

Ito, H. (2012). Cortical shape adaptation transforms a circle into a hexagon: A novel afterimage illusion. *Psychological Science*, *23*(2), 126–132. https://doi.org/10.1177/0956797611422236

Kirsch, W., Pfister, R., & Kunde, W. (2020). On Why Objects Appear Smaller in the Visual Periphery. *Psychological Science*, *31*(1), 88–96. https://doi.org/10.1177/0956797619892624

Klein, R. M., Reichertz, M., Christie, J., Wong, J., & Maycock, B. (2019). On the roles of central and peripheral vision in the extraction of material and form from a scene. *Attention, Perception, and Psychophysics*, *81*(5), 1209–1219. https://doi.org/10.3758/s13414-019-01731-6

Kwak, Y., Hanning, N. M., & Carrasco, M. (2023). Presaccadic attention sharpens visual acuity. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-29990-2

Nguyen, K. H., Patel, B. C., & Tadi, P. (2022, August 8). *Anatomy, Head and Neck: Eye Retina*. Https://Www.Ncbi.Nlm.Nih.Gov/Books/NBK542332/.

Pöppel, E., & Harvey Jr., L. O. (1973). Light-difference threshold and subjective brightness in the periphery of the visual field. *Psychologische Forschung*, *36*(2), 145–161. https://doi.org/10.1007/BF00424967

Strasburger, H., Rentschler, I., & Jüttner, M. (2011). Peripheral vision and pattern recognition: A review. *Journal of Vision*, *11*(5). https://doi.org/10.1167/11.5.13

Valsecchi, M., & Gegenfurtner, K. R. (2016). Dynamic Re-calibration of Perceived Size in Fovea and Periphery through Predictable Size Changes. *Current Biology*, *26*(1), 59–63. https://doi.org/10.1016/j.cub.2015.10.067

Vater, C., Wolfe, B., & Rosenholtz, R. (2022). Peripheral vision in real-world tasks: A systematic review. *Psychonomic Bulletin and Review*, *29*(5), 1531–1557. https://doi.org/10.3758/s13423-022-02117-w

Vision and Eye Health. (2023). *Visual Field.* Https://Www.Vision-and-Eye-Health.Com/Visual-Field.Html.

VMR Institute. (2022). *What is the retina?* Https://Www.Vmrinstitute.Com/What-Is-the-Retina/.

Williams, M. A., Baker, C. I., op de Beeck, H. P., Mok Shim, W., Dang, S., Triantafyllou, C., & Kanwisher, N. (2008). Feedback of visual object information to foveal retinotopic cortex. *Nature Neuroscience*, *11*(12), 1439–1445. https://doi.org/10.1038/nn.2218

Wu, S. Z., Masurkar, A. v., & Balcer, L. J. (2020). Afferent and Efferent Visual Markers of Alzheimer's Disease: A Review and Update in Early Stage Disease. In *Frontiers in Aging Neuroscience* (Vol. 12). Frontiers Media S.A. https://doi.org/10.3389/fnagi.2020.572337

Zhaoping, L., & Liu, Y. (2022). The central-peripheral dichotomy and metacontrast masking. *Perception*, *51*(8), 549–564. https://doi.org/10.1177/03010066221108281