Development Of Human Visual Function

A person undergoes many changes within their eyes during infancy that are crucial for being able to have the best possible vision. At birth, a baby's vision is very inferior when compared to an adult. This is because most elements of the eye are very underdeveloped and need to undergo changes as the baby ages in order to mature and function as they would in an adult. When first born the infant's vision will be extremely vague and not contain any colour besides black and white. Although their vision at this point is very poor, they do still have the ability to see vaguely. This shows that most of the development of the eye takes place prenatally however most of the components of the eye are very immature at birth which is why during infancy a lot of changes take place allowing maturation of parts of the eye so they can function correctly. Without changes in axial length, cornea and lens shapes, an increase in the number of certain cells and many other factors the persons vision would remain unclear and without colour throughout their lives and therefore causing lots of problems with carrying out everyday tasks and having an intensely bad effect on their quality of life. Many experiments have taken place which has shown how the eyes develop during the first year of a child's life and correlating strongly to visual acuity, colour vision and contrast sensitivity improvement.

When a child is born its visual acuity will be at around 6/120, however, as the infant grows its visual system will develop and by 4 months will be at around 6/60. At 6 months the expected acuity will be around 6/36 and by 1 year will be 6/18. From this, we can see visual acuity improves very rapidly in the first year of a person's life. Visual acuity is very important as it shows how clearly a person can see and how well they can distinguish between more than one image, letter or number. At birth the ability to distinguish is not yet available, however, objects that are 8-10 inches away from them will be where the baby aims its focus towards. During this first month, their eyes will begin working as a team but every so often one eye may move out of sync with the other eye but this is normal and not a definite sign of amblyopia. Over the next few months, visual acuity will improve rapidly with infants being able to move their eyes together faster and having a sharper vision.

Experiments have taken place in the past that show this, for example in 1978 it was found that acuity increased from 1.5 cycles per degree at one month to 20 cycles per degree at 12 months. In a more recent experiment where swept spatial frequencies were used to measure acuity, there was an increase from 4.5 cycles per degree at one month to about 20 cycles per degree at 12 months. The development of visual acuity correlates with how the shape and systems within the eye mature. As we know that infants are usually hyperopic which can be due to their eyeballs being too long or the cornea and lens not having the correct shape and therefore not bending light rays so that they focus on the retina, but behind the retina instead.

The cornea is responsible for around 70% of the eyes refraction and around 42D of the eyes power (Sridhar, 2018). An evaluation in 2004 concluded that infants at birth have very curved corneas but they flatten rapidly up to the age of six months. (Isenberg et al, 2004) Hence, this may be a factor contributing to why there is a big increase in visual acuity from 6/120 to around 6/36. Cone cells are important for observing fine detail as they have a high visual acuity due to them being so close together so when light from two positions close together hit two cones in the fovea two separate action potentials are sent to the brain. An experiment in 2012 showed that at birth foveal cones are very immature and do not contain OCT bands that are usually seen in the photoreceptors of an adult fovea. The cones grow longer and pack together whilst moving to form the fovea in the middle of the retina. Cone cells provide a system that has a high spatial resolution which helps give a high visual acuity, for example, each cone cells connects to one ganglion cell. Therefore, this is another factor contributing to why visual acuity increases over the first year of an infant's life. The axial length has been shown to increase by an average of 1.2mm from three months to nine which improves visual acuity as it helps the eye to focus images on its retina as it is likely images were being focused behind the eye before the eye grew.

Contrast sensitivity is nowhere near being perfect at birth due to an underdeveloped visual system. By the age of twelve months, components of the eye will have become more mature and therefore give a much higher contrast sensitivity compared to when firstborn. Contrast sensitivity is very important as it helps distinguish an item from its background. When light is a limiting factor or there is a situation where it is difficult to see, such as a foggy day, contrast sensitivity will help to continue doing tasks without being hindered by the inability to identify where an object is. High spatial frequency channels give the finer details of an object or image whereas low spatial frequency channels give information regarding the overall structure and how intensity gradually changes across it. Both frequency channels are very important in order to make up the full image.

An experiment took place which examined the change in contrast sensitivity in human infants. It was found that in low spatial frequencies the contrast sensitivity increased at a very fast rate up to ten weeks of age but then began to level off and remain fairly constant up to around 40 weeks. The contrast sensitivity values found ranged from 4.7 to 30 between the ages of 2 and 4 weeks. Results were also obtained which showed acuity increase from the first 8 weeks where it was 2.5 to 9 c/degree and increased to between 10 and 20 c/degree at 30 weeks. High spatial frequency development and grating acuity develop until around 30 weeks as well. (Norcia, Tyler, Hamer, 1987) In another experiment where infants provided a sweep VEP estimate of contrast sensitivity, it was shown that contrast sensitivity developed very fast in younger infants and then increased at a slower rate after around 16 weeks. Contrast sensitivity for a higher cycle per degree grating followed the same pattern but the initial sensitivity was smaller. (Allen, Tyler, Anthony) When the sweep VEP method was used in infants the contrast threshold advanced from a 7% contrast in the first month to around 0.5% at 2 months when low spatial frequencies were used. There was also a slow increase in spatial frequency when using grating acuity as in the first month there was around 5 c/degree but by 8 months spatial frequency had reached 16.3 c/degree. At all spatial frequencies, there had been a major increase from birth to nine weeks, however, after nine weeks contrast sensitivity remained fairly constant at low spatial frequencies but continued to increase at high spatial frequencies.

All experiments that have been tested to see the development of contrast sensitivity usually give results showing an increase in contrast sensitivity as the infant ages. This will be due to the infant's eye changing and becoming more advantageous. At one month an infant usually has very short dendrites and unmyelinated cells which can both contribute to low contrast sensitivity. Rods in the eye are quite mature by two months which allows the infant to distinguish between black and white. By 10 weeks the amount of rhodopsin present is around 50% of adult levels. (Fulton et al, 1999)

Colour vision allows images or objects to be distinguished depending on their wavelengths. It is fairly crucial as it helps identify objects from their backgrounds as colour aids in seeing their borders. It also makes it much easier to recognise an object you may be looking for in a place full of other similar looking objects, therefore saving a lot of time and energy. Visible light is part of the electromagnetic spectrum and is made up of a stream of photons that all travel at the speed of light. Around 75% of the light that reached the eye actually get to the fovea which is where visual acuity is best, the highest light intensities are responded to and where the highest population of cone cells is found. Around 25% is responded to by the inner region and the rest are taken by the cones in the outer region.

At birth infants can only see in black, grey and white, they do not possess the ability to see any other colours yet. Red is the first colour that will be seen by an infant as their eyes mature, and eventually, by five months, it is believed that an infant can see the full spectrum of colours. It has been shown that two-month-old infants can discriminate varying intensities of red from a white backdrop proving that by two months infants are dichromatic. Following experiments showed that at least L and M cones are present and functioning by three months of age. This means long and medium wavelengths can be responded to and allows colour discrimination. This explains why red is the first colour to be seen by infants as it has the longest wavelength in the colour spectrum. Data has been provided which gives evidence to show short-wavelength cone cells are present at four to six weeks of being born, but for reasons such as the retina still developing, the immature dendrites and the optic nerve not being completely myelinated, the cone cells sensitivities are suppressed in the majority of infants. In a small proportion of infants, however, there is supporting the idea that functioning short-wavelength cones which show very little sensitivity but are still functional. As the majority don’t have functioning S cone cells at 2 months, we can assume this is why infants are dichromatic until around five months of age.

There is a maximum of three different cones present in a human eye, each is responsible for either red, blue or green by working over a spectrum of wavelengths and light intensities. In order to recognise a specific colour, the brain must receive information from two or more cones at the same time. The reason for being able to see colour at 2 months is a result of the colour pathway beginning to operate at two or three months of age. As the fovea develops the foveal cones continue to lengthen and cell bodies are piled up in order to have the densest layer of cells it can. (Provis, Dubis, Maddess, Carroll) This is important as cones contain pigments and other transduction elements which allow photons to be converted into the form of electrical signals which can be sent to the brain through the optic nerve. In an experiment, it is shown that maximum saturated photoreceptor responses had an increase of approximately 0.18 log units from six weeks to four months. This will also be a key factor why infant vision is almost mature by four months.

Through all the research I have done I can conclude that infancy is a very important period for a person as it is when the eye undergoes the most rapid changes. A baby advances from having no colour vision at birth to being trichromatic within four to five months, having a visual acuity of 6/120 to 6/18 with twelve months and contrast sensitivity also showed a rapid increase within the year. We can also see which parts of the eyes are most responsible for the development of vision by seeing the correlations from previous experiments that have taken place.