Cerebral Visual Impairment

Working Within and Around the Limitations of Vision

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Note: the diagrams at the end of this paper may be helpful to refer to as you read the paper.

Introduction

The brain is a very complex structure. When it is damaged a wide range of effects are seen and every child with brain damage shows a combination of features unique to that child. We therefore need to have a system which identifies the full range of limitations caused by such damage, so that we can work within these limitations and capitalise on the abilities which are identified. This chapter outlines how the human visual system works and how spectacles may help to make best use of vision.

We all have limits to what we can see. Visual information is handled in the brain in a number of different ways. Like all sighted animals man has a reflex visual system, which initiates immediate evasive action when necessary, to avoid hazards. This is a subconscious system. At a higher level of processing, visual information is divided into two categories which are handled in different locations in the brain. One system is responsible for knowing where things are, so that we can move our bodies effectively through visual space. The other system is the 'what' system and allows us to recognise what we are looking at. Both of these high level visual systems can be damaged to varying degrees.

The difficulties caused by blurring of vision (due to disturbance of the input to the brain), are not difficult to imagine. One just has to think about what pictures look like when they are out of focus. A lot of the information is missing. However, the real situation can be much more complex. Exploration and play are important ways of gaining knowledge. If impaired vision interferes with exploration and play, then opportunities to learn fundamental information may have been missed. Vision is needed to gain knowledge and information, particularly in areas which are poorly communicated in other ways, such as knowledge of the anatomy of the opposite sex. We gain our ability to understand and express language by facial expression within the first few years of life. If facial expressions cannot be seen, then they can neither be interpreted nor copied, this can lead to permanent impairment in such communication skills including paucity of facial expression.

It is estimated that over 40% of the brain is devoted to visual function, so it is not surprising that a large proportion of children with damage to the brain have visual problems of one sort or another. These problems may be due to blurring of vision, or they may be due to difficulties making accurate eye movements, or analysing, understanding or moving through the visual world.

Experience during childhood provides the framework for what the child considers to be normality. Just as we have considerable difficulty understanding how a child with visual impairment sees, children with poor vision from an early age 'know' their vision to be normal and do not have a concept of how the world is visualised by people without visual disorders. It is only by careful assessment and continued observation of the visual behaviour of such children that we can gain a deeper understanding of how they see. This knowledge can in turn be used to structure communication, information and the environment to enhance the child's social skills, learning and mobility by ensuring that each element is designed to fall within the perceptual limitations of each child. Such an approach potentially makes best use of professional time and arguably will help to reap the greatest rewards.

The Visual System and How it Works (see diagram 1 & 2)

We take our vision for granted. Yet no one truly knows the answer to the question 'How do I know how other people see and if they see in the same way as I do?'
When you look at an apple, pick it up and eat it, the tasks you perform are extremely complex and nothing short of miraculous! We take such a mundane set of actions for granted, but it is worthwhile thinking about how the visual system is used to help carry out this action.

The eyes

The lens system at the front of the eye works in exactly the same way as the lens of a camera. An upside down and back to front picture of the apple is formed on the lining at the back of the eye (the retina) which, in principle, is very much like the film in a camera or the detection system inside a video camera.

If you look closely at a television screen you will see that it is made up of thousands of triplets of dots which are very closely spaced. The dots are red, green and blue. For seeing in daylight conditions the retina is made up in an analogous way. Millions of cells called cones (which are interspersed among rod cells for seeing in the dark) are arrayed in a single layer in the deep retina. The picture is registered by the cone cells, which detect red green or blue light and convert this into electrical impulses. These electrical signals are passed to an inner retinal layer of over one million cells in each eye (called ganglion cells), which carry the signal to the brain. The electrical signal to the brain is divided into two parts and is passed along two parallel wiring systems. One part is responsible for detecting motion and the other part is responsible for analysing detail.

The visual information about what the apple is passed to the brain by the detail analysis cells and nerve fibres, while the information about the moving hand is relayed to the appropriate parts of the brain by the movement detection cells and nerve fibres.

The optic nerves and visual pathways

While the eye functions in a way similar to a video camera, the optic nerves and visual pathways are analogous to the cable which runs between the video camera and the video recorder. Figure 1 (diagram of the visual pathways) shows how the visual system is wired up. The electrical signal which is formed at the back of the eye by the two different types of ganglion cells is passed to the brain along over a million fine threads which are layered like transparent silk over the back of the eye. They then exit the eye through a circular channel to become the optic nerve, which runs from the eye to the brain. The picture formed by each of the two eyes is slightly different and the two pictures are passed as electrical signals along both nerves into the brain.

The two nerves combine together in a cross (called the chiasm) in such a way that the picture seen on the right side by both eyes is passed to the left side of the brain and the picture seen on the left side is passed to the right side of the brain.

The electrical signals are then relayed to two locations. Most of the information is passed to the back of the brain, called the occipital lobes, but some of the information is passed to a lower central part of the brain called the brain stem. This can be can be thought of as the primitive visual brain.

The primitive visual brain

The primitive visual brain is an important structure which is present in most animals. It is the part of the brain responsible for protecting us from danger. We are not truly aware of this visual system until after it has worked, because it functions subconsciously. If you dodge a missile or you have a near miss when driving, it is your primitive visual brain which protects you. It detects a peripheral movement, and initiates movement of your body for you before you have a chance to be truly aware of what you are doing. It appears that this part of the brain is most sensitive to movement at the side and is less sensitive to movement detection straight ahead.

In children who have profound brain damage affecting vision there can be peripheral motion detection present which appears to be functioning at a subconscious level. In such children who are mobile they may be able to walk around objects in their path despite apparently having little if any detectable vision. Children who cannot move their four limbs may detect a moving spoon if it is at the side, and open their mouths more readily, than if the spoon comes from straight ahead. It appears that it is the primitive visual system which is functioning in these circumstances. In some such cases the system appears to be fatiguable because it may appear to work initially and then it doesn't work , but will work again after a rest.

The occipital lobes

The occipital lobes are at the back of the brain and they are analogous to the video recorder. They receive the electrical signals from the visual pathways and break the information up into its component parts. The detail of the visual scene is broken down and is analysed by tens of millions of cells which are responsible for independently handling colour, detail, orientation and movement. The left occipital lobe sees the right side of the visual scene and the right occipital lobe sees the left side of the visual scene. Moreover, the bottom of the occipital lobes sees the upper part of the scene and the top of the occipital lobes sees the bottom part of the scene.

Children with damage to the occipital lobes can therefore have a range of different visual field defects depending on which parts have been damaged. Damage to the right occipital lobe causes loss of vision on the left side (for both eyes), and damage to the upper part of the occipital lobes (or the incoming pathways to the occipital lobes) results in the lower visual field being impaired, so that an affected child is unable to see the ground when looking straight ahead and tends to trip over things.

(Loss of vision on one side is called homonymous hemianopia. This means loss of half vision in the same distribution in both eyes. It is very different to loss of vision of one eye. When vision is lost in one eye the whole visual scene can be observed with the remaining eye. Hemianopia on the other hand means that half the visual scene is missing for both eyes.)

The dorsal stream and the ventral stream (see diagram 3 & 4)

It takes about one-tenth of a second for information about the visual scene to reach the back of the brain or the occipital lobes. During the next tenth of a second, the visual information is analysed in two separate ways. Figure 2 shows the two pathways of the dorsal stream and the ventral stream. The dorsal stream runs from the occipital lobes to three locations, the back of the brain at the top (called the posterior parietal lobes), a vertical strip of brain in the centre (called the motor cortex) and the front of the brain (called the frontal cortex).

The ventral stream runs from the occipital lobes to the back of the brain at the bottom (called the temporal lobes).

The Dorsal Stream

The back of the brain at the top (or posterior parietal cortex), is responsible for handling a lot of information at the same time. It works in the same way as the RAM in a computer. It allows us to hold open lots of computer programmes at the same time. If you look at a complicated visual scene such as a group of school children, while looking at one child in the middle, you are able to select out another child and immediately change your gaze and attention to that second child. In order to do that, you have to maintain an awareness of the whole class. This is an enormously complex computing task. To make matters worse, you had to make this choice while all the children were trying to attract your attention and there was a lot of background noise. The posterior parietal lobes are responsible for achieving this for you. (But the choice of which child to look at is probably made by the frontal lobes.)

It there is damage to the dorsal stream, or to the posterior parietal lobes, the ability to handle a lot of information at the one time is decreased and a child with such damage probably sees the world in a way similar to a baby. Babies tend to do one thing at a time and that is why baby books present single large pictures, because it is known that infants respond to one or two pictures but not more. It is also known that babies are "one thing at a time" children, for example, when they are listening to music, they are less aware of other things happening.

The motor cortex is responsible for bringing about movement of the body. In an adult who has had a stroke and who cannot move the right side of the body, it is the left motor cortex or the pathways from the left motor cortex which have been damaged. The top of the motor cortex is responsible for moving the foot and the side of the motor cortex is responsible for moving the hand.

The task of picking up the apple involves both the visual system and the motor cortex. First, the apple has to be recognised, it then has to be mapped along with everything else in 3-dimensional space by the posterior parietal cortex.. This information is passed to the frontal cortex which is responsible for making the executive choice of attending to and picking up the apple. The information about where it is then passed to the motor cortex responsible for moving the hand, which reaches out accurately in 3-dimensions using the coordinates given to it by the parietal cortex, in order to pick up the apple. At the same time, the hand is being shaped so that the fingers are separated far enough to encompass the apple. Once the hand has reached the right position, the fingers grasp the apple and pick it up. Throughout this task, the visual system and the movement system are working in perfect harmony. The action of picking up the apple has been brought about by the interconnecting pathways of the dorsal stream. The picture was formed in the occipital lobes. It was mapped by the parietal lobes. The choice of the apple was made by the frontal lobes. The action was executed by the motor cortex and the whole system was interconnected by the dorsal stream.

When we cross a road and step up onto a kerb, a similar instruction has to be given to the feet. Children with damage to the dorsal stream may have difficulty accurately reaching for things and/or difficulty moving their feet to a correct location in visual space. This can mean that they have difficulty interpreting whether a line on the floor is a step and difficulty working out how far the foot has to be lifted up in order to navigate over a kerb. It is possible that dorsal stream fibres responsible for moving the feet through visual space are damaged while the dorsal stream fibres responsible for moving the hands are not. In which case reaching is accurate but movement of the legs is not.

The frontal cortex has many functions. One of these functions is to move the head and the eyes to look at a chosen new location. When the dorsal stream is damaged, the ability to accurately move the head and eyes to a new target location is decreased and such movements can be either inaccurate or it may not be possible to bring them about at all. This means that it can be difficult to follow and track moving objects because the dorsal stream pathway, which gives the head and eyes the new location to look at is not functioning properly. Another function is to scan the information about the visual scene presented by the posterior parietal lobes and to make executive choices about what to look at, and what to reach for.

One can now imagine how difficult it must be to read when there is damage to the dorsal stream. Not only can a lot of printed information on the same page not all be seen and appreciated at the same time, but it is not possible to move the head and eyes accurately to a new location in order to access the information. The obvious educational approach is to present small numbers of words at the same time, to enlarge them and to show them sequentially, for example on a computer screen. The amount of information which can be handled at any one time varies considerably and has to be determined for each child.

The Ventral Stream

The ventral stream runs from the occipital lobes into the temporal lobes on each side. The temporal lobes contain the visual library. This library contains a general store of objects and shapes which enables us to recognise one object from another. There is also a special store of people's faces and a library of route finding methods both of which are usually located in the right side of the brain. When you walk down a busy street and recognise someone, your brain has accomplished a fantastic computing task for you. First, you probably know where you are going. Then, for every person you do not recognise, you compare the facial appearance of that person with your personal store of hundreds if not thousands of faces. When it does not match, you walk past that person. When you meet the person you recognise, you have a matching comparison which allows you to greet your friend. You were then able to recognise the facial expressions of your friend and to communicate accordingly. Children who have damage to the ventral stream can have difficulty differentiating one object from another and in particular, may have great difficulty recognising people's faces and differentiating different types of animals, one from another. They may be unable to recognise the language within facial expressions. In addition, route finding can be particularly difficult. This applies on a large scale when out and about and on a small scale within the home where, for example, it can be particularly difficult to know which drawer items are kept in.

It is clear that the dorsal stream and ventral stream pathways work in harmony with one another because we see and recognise, with our temporal lobes, what we choose to reach out and pick up using the dorsal stream, posterior parietal lobes. and motor and frontal cortex. However, when brain damage takes place, specific parts of these tasks are deficient and it can be difficult to understand why a child with such damage is able to see one thing but not another.

Conscious and Subconscious Vision

The conscious visual system allows us to see and understand the world around us. Incoming visual information is processed, analysed, understood and acted upon. As a young child grows and develops the visual system is being programmed. New experiences are being progressively stored and the visual system is being built up. At birth the visual brain is rather like an empty library with different sections reserved for different sets of books. Face recognition is a good example. The back of the brain at the bottom on the right (the temporal lobe) is the principal storage area for people's faces. If this area is damaged in an adult, that person loses the ability to recognise faces. Equally it has been shown that children with brain damage in this territory may have very similar problems of varying degree.

"Look where you're going!" How often have you heard this expression? The fact is we do not look where we are going. Like all other sighted animals, we move through the visual world without giving it a thought, by using our subconscious visual systems. Most people, when they first learn how to drive a car find steering difficult until they look into the distance. It then becomes much easier. Although we check the view ahead to choose where we are going, we use our peripheral vision in a subconscious way to drive the car, to move through a crowd or over to walk over uneven ground.

We often need to take evasive action. Whether one is ducking one's head to avoid hitting a kitchen cupboard door or whether one has to dodge an assailant, it is our subconscious safety system which is coming into play. We probably use a similar system for catching balls.

Progressive improvement in driving skill shows that certain aspects of our subconscious visual system can be trained, whereas the remarkable systems that we and other animals have for self protection are reflex and develop spontaneously. From a practical point of view there are two subconscious visual systems; a high level system mediated by the dorsal stream which allows us to move effortlessly through the visual world while talking or thinking about something else, and an intermittently used subconscious visual system which makes us brake suddenly when a child runs out in front of the car. This second system recruits our adrenalin and makes us feel drained because of the amount of effort which goes into bringing about such subconscious action. It is only after the event that we recognise what our visual system and reflex evasive action has done for us.

The significance of these observations is that a child with brain damage may appear to have no vision but may respond (either reproducibly or intermittently) to a moving target, particularly if it is in the peripheral field of vision.

Spectacles. What are they for and when are they needed?

Many children with cerebral visual impairment wear glasses. Spectacles are worn for different reasons.

Short sightedness is common in children born prematurely. A short sighted eye is s large eye and the picture is brought into focus in front of the retina. Glasses with concave lenses are used to move the image backwards onto the retina. The glasses make the eyes look smaller and one can see that the side of the face viewed through the glasses appears to be displaced inwards. Without glasses the child is in focus for near but distant objects are out of focus, hence the term short sight. For some children with reduced clarity of vision this means that the printed page can be seen better without glasses. The short sight means that the child can see the page when held close to the eyes. The magnification gained by proximity gives the same effect as a magnifying glass.

Long sightedness occurs when the eye is small. The picture is blurred because it reaches the retina before it has been brought into focus. In the majority of children the focusing system of the eye compensates for this and brings the picture into focus. However, in children with brain damage long sightedness can cause problems which are alleviated with glasses. The focusing system may not work well so that even a very small amount of long sightedness is not corrected for. This problem can affect over half of such children in special schools, and a small correction for what would otherwise be a 'normal' amount of long sightedness can make a significant difference to the child's ability to see and academic performance. Long sightedness can also be responsible for making the eyes squint by turning in and when glasses are worn the squint is reduced or eliminated. In children who are long sighted the spectacles magnify the eyes and ideally they need to be worn most of the time.

Astigmatism occurs when the front of the eye has a very slight rugby ball shape. The lens of the glass is shaped in a reciprocal way to compensate for this shaped anomaly.

Children with reduced vision due to brain damage commonly remove their glasses even when they definitely improve vision. One possible reason is visual fatigue. The clear picture requires more processing power than the blurred picture so it is more comfortable to have a blurred picture because it is less complicated and easier to handle. This is of course is only a working hypothesis, but when children remove their glasses after working hard for a while they may be giving their visual systems a well deserved rest.

In summary, short sightedness is corrected by glasses which make the eyes look smaller and children may remove their glasses to gain magnification by holding things up close. Long sightedness is corrected by glasses which make the eyes look bigger and children may remove their glasses to get a more comfortable blurry picture for a while.

Visual Thresholds

We are all limited by our vision but because we 'know' our vision to be normal we are not aware of these limitations. Telescopes and magnifying glasses allow us to see things which are otherwise too small to visualise. This highlights the limitations of the clarity of our vision. Society then chooses to present information in a way which the majority of people can see because it falls within these limitations. People with reduced vision are not able to always see within these limitations and just like the picture which is only revealed by magnification the information is not there to see and is not known about.

Children with poor vision from an early age also 'know' their vision to be normal and just like fully sighted people, they do not know what it is they do not see and they are not aware of their visual limitations. Unless we know in detail what these limitations are for each child information which is not seen will be presented to the child. The failure of the child to respond to this information can easily be misinterpreted as either lack of ability or even stubborness. It is very expensive to teach children with brain damage and the cost implications alone of using educational material and approaches, which are not actually seen by the children, are considerable. It is therefore important to try to get inside the mind of the child, and to understand as fully as possible what is seen and what is not seen and then to work inside all of these limitations or thresholds.

Clarity of vision

Look at this printed page and move it back until you can only just read it. You are now looking at the smallest text you can see when it is printed in black against a white background. This is your visual acuity or the limit of your clarity of vision.

Now try and read the text as fast as you can when held at this distance (and don't cheat by getting closer to it). You will find that it is something of a strain and that you quickly fatigue and get fed up with the task. Compare the time it took you to read a passage, with the time it takes you to read the same text when held at your normal reading distance. It is much quicker to read at the normal reading distance and much less tiring, This is because the text is now big enough to be seen clearly and comfortably.

The letter charts used to measure clarity of vision measure visual acuity. This is the main test used by doctors to make a diagnosis of reduced central vision and is measure of the smallest clear black target which can be seen against a white background. However, this is not a measure of functional vision (which is recorded with both eyes open), it is a measurement for medical reasons in order to help make a diagnosis or to provide information required for follow up.

For a child who has reduced vision what one wants to know is the size of target which can be seen with ease at maximum speed. The visual acuity which is a measure of the smallest target which can be seen is useful to know, as this is the limit of what can be seen, but neither children nor adults can work at the limit of their vision for very long.
Educational information therefore needs to be well within the limit set by the visual acuity so that it can be easily seen throughout the day even when the child is tired.

Colour and contrast

Imagine the rainbow. Red, orange, yellow, green, blue and purple all blending into one another. Purple can also blend into red. These colours can be arrayed in a circle in such a way that they blend into one another. This is known as the colour circle. If you take a can of grey paint and add red colouring little by little the paint will gradually become redder until it can get no more red because it is fully saturated. One can now imagine a central grey circle with surrounding colour circles which become progressively more colourful with the primary colours on the outside. Imagine now that the grey centre becomes progressively whiter vertically upwards and progressively blacker vertically downwards. This is what is known as the grey scale. Finally imagine the red becoming a progressively lighter shade of pink until it blends into the apex of white at the top and becoming progressively more brown as it blends into a black apex at the bottom. This imaginary concept is know as the colour solid made up of two circular cones base to base. Black and white are the furthest apart and show the greatest contrast while, for example, blue and slightly lighter blue are close together and show very little contrast.

In relative darkness it is easy to mix up such colours as green and brown, but black and white can still be differentiated from each other, as can very light blue and navy blue.

Many causes of visual impairment cause difficulties in differentiating contrast and colour. This of course imposes limitations on what can and what cannot be seen. As a rule of thumb the further apart colours are from each other across the colour solid the more likely they are to be differentiated from one another.

The degree to which brain damage impairs colour vision and contrast perception in children with damage to the brain is not known. As a general rule colour perception is maintained remarkably well in such children but from a practical point of view it is worth ensuring that pictures and toys are bright and clear, and that there are few colour boundaries in pictures which are very similar. For example a picture of a dark green frog against lighter green grass may not be seen because of the low colour contrast, but the same frog portrayed on yellow sand would be much more obvious. Information is often photocopied and re-photocopied. This results in grey text against a grey background. The contrast is therefore reduced so that someone with reduced vision may not be able to see it even if the size of the text falls within the visual acuity limits.

The visual world is made up of myriad colours in all sorts of juxtapositions. Visual impairment can degrade colour boundaries of low contrast, while not affecting boundaries with more contrasting colours and shades. This means that some things are seen and others are not and it is important to be vigilant to look out for what is seen when not expected and what is not seen when expected. It is by making mental notes about these observations while working or just being with the child that one can build up a mental picture of the colour boundaries which are seen and the ones which are not.

Visual fields

The visual field is the area over which one can see at any one time. The nerve fibres which run from the eyes to the brain are arranged in a very organised manner. This means that when damage takes place well recognised patterns of visual field loss can occur, and different patterns of loss have different functional consequences

<u>Hemianopia</u>
The wiring diagram of the brain is such that the back of the brain on the right is responsible for seeing on the left side of the visual scene (for both eyes), and the back of the brain on the left is responsible for seeing the right side of the visual scene. Brain damage can affect one side or the other and gives rise to left or right sided loss of vision.

The lack of vision in hemianopia can be thought of in the same way as the world behind you. It is not seen. Occasionally, however, some visual function may be retained such as the subconscious perception of movement so that an affected child may not appear to see on one side but is able to walk through a crowd without bumping into anyone.

From a practical point of view there are a number of issues which need to be considered when looking after a child with hemianopia.

Eating food can be a problem because food can be left on the side of the plate, on the same side as the hemianopia. When this is recognised, turning the plate round so that the remaining food comes into view can be very effective. A policy of putting the favourite food on the hemianopic side of the plate can help a child to develop strategies of exploration because one never knows what pleasant surprises may be waiting round the corner.

Communication with a child with hemianopia needs to take into account that someone sitting or approaching from the visually impaired side may not be seen.

Mobility can be impaired due to hemianopia with the child bumping into things and people on the affected side.

Crossing roads is an important issue. Oncoming traffic can easily be missed, particularly if it is small and silent like a bicycle. When looking to the affected side the head and eyes need to be turned fully. This is perhaps best taught by example, particularly with the young child.

The position in the classroom needs to be selected so that the subject of interest is either straight ahead or on the unaffected side. If the child is sitting so that the teacher for example is on the affected side it can be difficult to attract the child's attention.

Access to information can be restricted by hemianopia because data presented on the affected side may be missed.

Reading in particular requires special attention with left and right hemianopia having different implications. As the eyes scan across the text the hemianopia moves with the eyes. For loss of vision on the right side each new word jumps into view and may not be anticipated because it cannot be seen when looking straight ahead, but once the end of the line has been reached the left hand end of the next line down is seen and the eyes can jump to the beginning. For a left hemianopia, on the other hand, as the text is read from left to right the text on the left progressively disappears so that it can be difficult to find the beginning of the next line. It can be helpful to have a system of progressively moving a finger down the left hand margin. Alternative approaches of reading text either vertically or obliquely can prove very helpful for some children, particularly those who have developed their visual impairment after having learned to read.

Quadrantic visual field loss

Brain damage can cause loss of vision in any of the four quadrants of the visual field affecting both eyes equally. While quadrantic visual field loss of this nature is less of a problem than hemianopia it can still cause significant problems in any of the areas outlined above,

Associated cognitive visual problems

Problems of recognition and orientation are quite frequently associated with hemianopia. This subject is discussed later in the chapter.

Lower visual field loss

The visual pathways, which lead from the eyes to the brain, run very close to the water spaces in the brain. In particular it is the fibres which serve the lower field of vision in both eyes which run over the top of the water spaces and lie closest to them which are most likely to be damaged. The commonest scenario is the child who has difficulty moving her legs due to spastic diplegia who has lower visual field impairment. When looking straight ahead she is unable to see the ground in front of her and when walking over irregular ground she has to walk with the head turned down to check whether there are any obstacles or pot holes. On top of all that there may also be problems in knowing exactly where the feet are.

Lower visual field defects can be very variable and range from being complete so that none of the ground ahead is visible, to being relatively minor so that only the ground one to two metres ahead is not seen. It is worth simulating a lower visual field defect for oneself by holding a piece of card below one's eyes so that the ground immediately ahead is not seen when looking straight ahead. It is remarkable how much we take for granted. When one can't see where one's feet are treading it is quite disabling. An approach, which encourages the child to regularly look at the ground ahead to check for safety can prove helpful.

Children with impaired walking due to spastic diplegia and lower visual field impairment can particularly enjoy horse or pony riding. The horse provides mobility over rough ground; it can see where it is going and the training in balance is also helpful. Horse riding can provide a new found freedom for such children.

Visual field constriction

There is a range of disorders of vision due to damage to the brain which are accompanied by constriction of the visual field. A central island of vision is present but peripheral vision is restricted. Visual field constriction is however, unusual. The commonest cause of apparent constriction of the visual field is difficulty in attending to a lot of information at the same time. This gives the impression that the visual field is narrow but when the visual scene is made less complicated, the apparent lack of attention to a target in the peripheral visual field is no longer present.

Central visual field loss

If the visual acuity is reduced then there is a reduction in central visual function overall which in turn represents a central visual field impairment. In such children the more peripheral visual field may provide more useful vision and the child appears to look past what he or she is looking at, when in fact the child has chosen the head and eye position which gives the clearest picture.

Combinations of visual field disorders

Poor central vision commonly accompanies hemianopia, and lower visual field impairment can also accompany hemianopia so that vision is only present in one upper outer quadrant of the visual field for both eyes. Under these circumstances all of the difficulties outlined above can be compounded because of the greater restriction of vision.

Seeing movement

We take for granted the fact that we can see moving targets. Not only are we able to see the moving object and to work out the speed and direction of the movement, but we can also see and interpret detail on the object as it is moving. We all, however, recognise that when objects move quickly we are first unable to see the detail, and as the object moves faster it becomes so blurred that it may not even be possible to see it at all. As the blades of a propeller rotate they eventually cannot be seen as the propeller speeds up, and we take it for granted that one cannot see a bullet as it emerges from a gun barrel. In both cases the moving object is not seen because it is moving faster than the detection system in our brains is able to cope with.

The 'computing system' in the brain, which enables us to cope with perception of movement, is complex and it is perhaps not surprising that it may not work so well in some children with brain damage. There are two types of condition which impair movement perception, namely impaired tracking and impaired movement perception.

In children in whom there is damage to the eye movement systems there can be difficulty in tracking moving objects. Careful observation shows that such children may be able to compensate by moving the head to follow a moving target if it is slow enough, but if the target moves quickly it may be missed, both because the eyes are unable to lock on to, and follow the moving target.

Impaired movement perception due to brain damage is rare. There is a small sector of the brain, which is at the back of the brain on both sides, which is responsible for seeing movement. In the majority of children with brain damage this part of the brain is preserved, and they are able to see moving targets even if brain damage is severe. However, in a small minority it is this sector of brain tissue which is selectively damaged and although an affected individual can see static targets, objects which move may be invisible unless they are moving very slowly. This problem tends to remain permanent and it is clearly very important to recognise it.

Children with impaired movement perception often choose to watch television programmes in which there is limited movement, such as the weather man or the news reader, but they have little or no interest in fast moving programmes such as cartoons.

A teaching approach which recognises impaired tracking involves slow movement and gesture, and avoids educational material such as videos or DVDs in which there is a lot of movement.

Moving through the 3D world

The picture of what we see is first processed at the back of the brain. It is then broken down into two components, vision for recognition which takes place at the bottom of the brain at the back, the temporal lobes and vision for action in which the picture of the visual world is passed to the part of the brain responsible for moving the body through the picture of what we see. In many children with brain damage and visual impairment there are profound problems in bringing about accurate movements through visual space because the pathways in the brain which pass the details of the picture to the part of the brain responsible for motion, the dorsal stream, has been damaged.

In some children it can the movement of the legs through visual space which is impaired, and in others it can be the movement of the arms and the hands or both can be impaired. These problems can compound the problems of weakness and stiffness or spasticity, or they may simply be visual but the outcome of inaccurate movement of the body through visual space is the common outcome.

One situation which is common is the child who has difficulty knowing whether a line in the floor is a step or not. When the child comes to a boundary between linoleum and carpet for example, the boundary has to be carefully explored before it can be crossed. Another typical problem is difficulty negotiating steps and kerbs. Going up stairs is often easier but going down stairs is a particular problem because it is particularly difficult to estimate the depth of each step. The same applies to kerbs. Typically the foot is lifted too high and it may be lifted before coming to the step.

Other children can have problems accurately reaching for things and manipulating them. It can of course be difficult to work out whether the problem is due to weakness, or to poor coordination, or for visual reasons, but the typical picture is one in which the reach is intermittently accurate. The hand is not accurately pre-configured to the shape or to the orientation of what is about to be picked up.

Practical approaches to these problems require practise, practise and more practise. Soft play areas which are quiet with not many children around and which provide a stimulating opportunity to learn to move through 3 D space without injury can be very helpful, both in providing the opportunity to learn skills and in helping confidence to develop.

Crowding and complexity

If one opens too many programmes in a computer to run at the same time the computer gets slower and if one more programme is opened the computer stops working. This is because there isn't enough active memory to cope with all the tasks which need to be done at the same time. Our minds function in a similar way. Watching television whilst doing homework usually means that it takes longer to do the homework. If there is a conversation going on in the room at the same time, the homework may never get done because all the 'programmes' cannot be held open at the same time.

The visual system has to handle a very large amount of information at the same time and it succeeds in doing this by using a double system which is located at the top of the brain at the back, the posterior parietal lobes. All the incoming information is processed simultaneously but the conscious mind cannot cope with this, so there is a second selection system probably located in the frontal lobes which selects out which information to attend to at any one time, and allows the rest to be ignored until it is chosen for attention.

Damage to the posterior parietal lobes or to the pathways which link them to the visual system, the dorsal stream, means that the mind can't cope with a lot of information at the same time. Children with such problems show a number of different features related to the complexity of the visual scene. Both the background and the foreground can be detailed and difficult to appreciate fully. Young children can find it difficult to locate a toy when it is on a patterned carpet but have much less difficulty finding the same toy on a plain carpet. If the same toy is in amongst other toys on a plain carpet it may not be possible to find it. The practical approach is to regularly investigate how clear the background and the foreground have to be in order to allow the child to function optimally. Older children who are learning to read may only be able to access a small number of words at the some time. The approach to take in this situation is analogous to reading brail in which the information is broken down and presented sequentially. For example when learning to read, a computer can be used to show one word at a time. When the condition is less severe, enlargement of text reduces crowding and can help significantly. Magnifying aids can also help because they too diminish crowding. A spectacle correction which corrects long sightedness may not normally be given because of the ability of the brain to compensate for the long sightedness by focussing. However such a correction can have the advantage of magnification which also reduces crowding.

Impaired simultaneous perception can give the impression that the child has tunnel vision because it is not possible to attend to a visual stimulus at the side at the same time as attending to something of interest in the centre of the field of vision. The visual acuity can be normal for single letters but reduced for words. This is called crowding and is brought about because the more information is present the bigger it has to be to create less crowding of the central visual scene so that less is being presented for analysis at any one time.

Gradual spontaneous improvement over a number of years takes place in the majority of children, and the ability to handle increasing amounts of visual information gradually improves. This means that the condition needs to be kept under regular review so that the educational approaches employed are matched to ability.

Limitations imposed by disorders of eye movement

Disorders of eye movement which can impair vision can be divided into squint, impaired tracking, and to and fro oscillation of the eyes or nystagmus.

Squint is a condition in which the eyes are not aligned correctly and one of the eyes is turned in, out, up or down. The brain adapts to squint in children by ignoring the image formed by the squinting eye. Our ability to see in three dimensions relies on the differences between the two pictures presented by the eyes. These differences are interpreted as a sense of depth. If you close one eye as you reach for something you will find that your reach becomes slightly less accurate. If you play a racket sport with one eye closed you will find it more difficult to hit the ball because the two eyes act in harmony to allow you to judge speed and distance in real time. If one eye is squinting the facility of such 3D vision is absent.

Many children with cerebral palsy have difficulty controlling the movement of their eyes. Our eye movements can be divided into two types, fast and slow. Fast eye movements are used to look from one object of interest to another while slow eye movements are used to track a moving target. Either or both can be impaired. In addition to degrading the ability to see detail on moving targets, there can be difficulty in accessing information on static targets as well. In order to read we have to move our eyes in a very regular way. The eyes make four or five jerking movements to the left as we read a line and at the end of the line they jump back to the beginning of the next line. In children with impaired tracking these movements are inaccurate and reading is difficult. It is not surprising that some children appear to miss words out or jump to the wrong line when reading. An approach which recognises this is to enlarge the text. This means that even if the successive eye movements are irregular, the next word is seen because the enlarged words compensate for the inaccuracy of the eye movements.

To and fro movements of the eyes sometimes accompany cerebral palsy and may be seen in children with cerebral visual impairment without movement difficulties. One might expect that the children would see everything oscillating to and fro, but they do not because the brain smooths out the picture. The outcome is that the visual acuity is diminished because of 'camera shake'. Many children discover that they get clearer vision if they hold their eyes in the position in which the eye movements are least. This results in the child adopting a head posture, particularly when concentrating on small print for example. Head posturing can be diminished in many children by enlarging the print so that there is no longer a need to enhance vision in this way.

Visual fatigue

There are many jobs which entail detailed inspection. For example, looking down microscopes, reading X rays and quality control. It is well recognised that because these tasks involve a lot of mental effort the workers become tired and inaccuracies creep in. Regular well earned breaks are therefore scheduled in order to enhance performance. Children with visual impairment due to brain damage become fatigued in like manner and their performance drops off when they have worked hard. In particular the visual system can be fatigued especially in children who have very limited vision. In these children there can be periods of remarkable lucidity when the visual system appears to be working well, interspersed with periods during which the child does not appear to see. The exact reasons for this behaviour are unknown.

On a lesser scale children get tired much more easily if what they are being shown is a struggle to see because it is at the limit of their perception, for any of the reasons already described. For all children who fatigue quickly the first thing to do is to simplify the visual information by enlargement and removing clutter. This can often give gratifying results,which can often be enhanced by ensuring that all forms of communication are clear and paced at the speed at which attention is maintained. By diminishing the amount of information a child has to handle, both in space and in time, and ensuring that everyone working with the child is aware of the limits of detail, complexity and speed of communication which the child can cope with, the periods during which the child becomes inattentive can be diminished.

Recognition

The human brain is designed so that we can rapidly see, know and understand what we are looking at. When a baby is born and looks around for the first time, the brain, which is a remarkably active self-programming computer is turned on. The brain of the newborn infant is rather like a brand new library without many books in it. There are however a number of rooms in the library which are destined for book collections about different subjects. The room for face recognition already has one or two books in it. The infant will spend more time looking at a face than a jumbled pattern of the same complexity. As each new face is seen, the picture is stored for subsequent recognition. Seeing the same face many times means that the young child begins to recognise close family members. As time goes by and the baby explores, the information about what is experienced is given meaning and is progressively stored. If there is an impaired visual input then the visual information which is stored can only be as good as the quality of the input which is provided. The mind can only learn to see as well as the information it is provided with. In most cases in which there is simply impaired clarity of visual input the young child compensates by getting much closer to see things. The magnification which is obtained by proximity compensates for the impairment in the anterior visual pathways. In contrast, when there is brain damage present the 'computing units' which are responsible for knowing and understanding what is seen may be dysfunctional. It is therefore important to be able to identify visual disorders due to brain damage so that the problems can be both circumvented and dealt with directly.

Recognition of people

When you walk down a busy street and recognise and greet a friend the amount of computing being done by your brain is phenomenal. The act of not recognising someone needs a lot of processing. Each person is compared with the whole stored image bank of the hundreds of people you already know and an almost instant conclusion is reached that you haven't met that person before. When you come to the person you do know, a match is made and you are able to greet your friend.

When you then have a conversation you are able to respond to a wide range of nuances of facial expression and reciprocate with appropriate facial expressions of your own. Although we take facial expression for granted, this too needs a lot of computing power in the brain.

Children who have poor vision due to brain damage can have impairment of both face recognition and the ability to interpret facial expression. It is very important too recognise these disabilities for obvious reasons. An inability or disability in recognising one's friends is socially disabling. If this is compounded by not being able to react to facial expressions a significant degree of alienation can result. When teaching a child with these problems one has to be aware that one is recognised by the tone of the voice and that the language component of facial expression may not be apparent. The voice therefore needs to convey all the language.

Recognition of shape and form

In order to recognise the differences between different types of car the brain has to do the same job as it does for faces but a different part of the brain is used. This means that brain damage can result in problems in differentiating shapes from one another but with an intact ability to recognise faces. This can be relevant to maths for example where such a child may have numeric skills but be unable to comprehend geometry.

Damage to the temporal lobes can impair the ability to read text resulting in alexia (inability to read) or dyslexia (selective impairment in reading in the context of normal intelligence in other aspects of intellectual function). The part of the brain responsible for interpreting the written word into language comprises the language centre, which is on the left side in most people. If there is damage to the back of the brain on the left combined with damage to the pathway between the back of the brain on the right and the language centre, alexia is the result. The damage on the left causes inability to see on the right side or hemianopia. There is intact visual function in the right brain, but because the pathway (the posterior corpus callosum), which conveys this information to the reading centre is damaged, text information cannot be interpreted linguistically. There is some evidence that phonetic reading is particularly impaired in these individuals and that the 'look and say' method of reading may be the best way of teaching individuals with this rare disorder.

Orientation

Orientation is not truly a visual skill because people with no vision can be fully orientated by virtue of their other senses. However, in general, vision and visual memory play a large part. We need to be orientated to find our way about from one place to another, and within buildings. The same skills are needed to know where to find things in cupboards and drawers, both at home and at school and orientation is needed to know where one has put things down. If the part of the brain which is used for orientation is not functioning well there may be problems and difficulties both on the large scale of fining one's way around and on the small scale within the home and at school.

Like the skill of face recognition orientation requires an ability to retain a store of information which is compared with the current scene. If there is a match one is orientated if not the new scene needs to be learnt and memorised for future reference.

The part of the brain which is used for finding one's way around is close to the part for recognising faces and close to the part for seeing on the left hand side. This means that children with impaired orientation may or may not have problems recognising people and seeing on the left hand side as well.

Orientation when outside

It can be difficult to know whether a child with brain damage has difficulty finding his way around outside because such children rarely have the opportunity to get out and about on their own. There can therefore be two factors which lead to problems with route finding, an intrinsic disability and lack of opportunity to learn the strategies which come naturally to children who are given their independence. When possible the child should be asked to be the guide and take the lead.

There are a number of approaches which can be very helpful for people who have difficulties finding their way about.

1. Talking about where one is going in a consistent way for all important routes helps each route to be remembered.
2. Looking out for landmarks and talking about them.
3. Learning where the sun is at different times of day and learning how to use the sun as a reference point so that one doesn't lose one's sense of direction.
4. Writing short songs or poems about important routes can prove very helpful to some.
5. Playing hide and seek.
6. Getting out and about regularly

Orientation when inside

Have you ever had difficulty remembering which drawer or cupboard something is in? Imagine what it is like to have this as a permanent problem, but you know that you are normal because you have always had the problem and you do not know what it is to have the skill. You develop a system of leaving things in specific locations which you have spent ages remembering. Then someone moves them! Imagine how frustrating this is. It takes ages to find them despite a huge amount of effort and then you are told that you're stupid if you can't find things. Not surprisingly your frustration boils over. You then develop a system of marking each drawer and each cupboard and your mum comes into the room, gets angry that the furniture has been defaced and removes all your carefully designed labels. Your rage boils over and you are thought to have behavioural problems! This is a true story of a child with problems due to previously undiagnosed problems with orientation. As soon as the problem was recognised and everyone was informed of the cause and nature of the problem the drawers were re-labelled, the position of everything was respected and all the 'behavioural problems' disappeared.

The same children have tremendous problems when they change schools and need intensive orientation training in such new environments. The degree of the problem can vary from occasionally getting lost in school to never being able to find the classroom without help. Identifiers which are ideally designed and put up by the child can be very helpful.

Younger children need to be given every opportunity to act as the messenger in the school, while children in secondary school may need intensive training about the school ideally in advance. Parents may need help in developing methods of teaching particularly when visiting hotels and other large public buildings. Some children can be taught to develop a discipline of making up alternative ways of remembering such as mnemonics.

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Knowing where things are

Children with profound problems with orientation can have difficulty knowing where they have put things. To the observer it is obvious that the felt tip pen is just on the right hand side but to the child someone may have stolen the pen because it is nowhere to be found.

Children with this degree of orientational difficulty need to have a dedicated work station in which the location for the pen is clearly shown. To begin with a place mat with the patterns of the cutlery can help at meal times. With a lot of hard work these difficulties can be overcome and it is then only when the child is rushed or stressed that the problems become evident.

Visual Memory

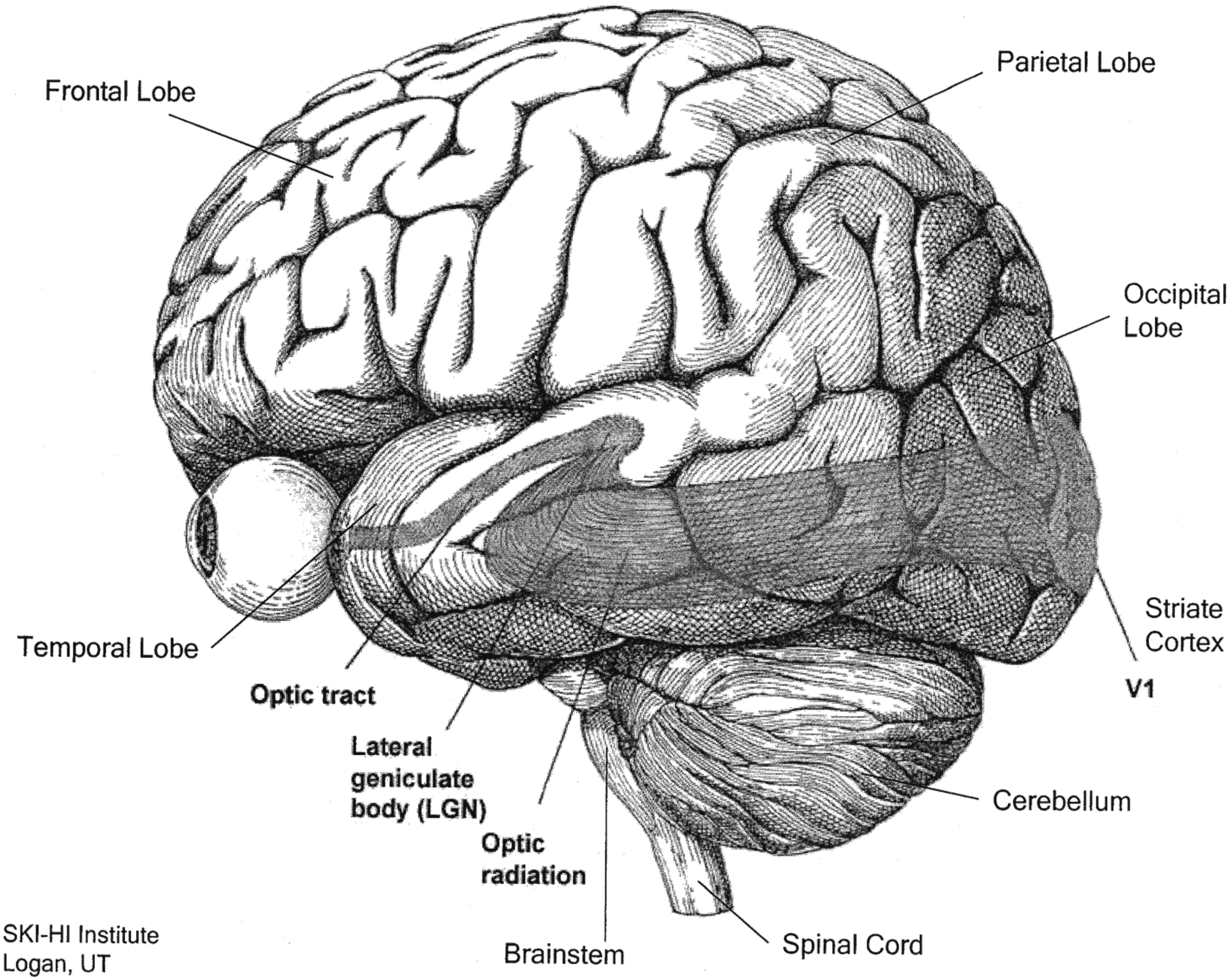
Our ability to remember what we have seen is very important. The initial part of the process is carried out by the inner parts of the temporal lobes of the brain. If visual memory is impaired due to damage to the temporal lobes and adjacent areas where visual memories are formed it is not surprising that such tasks as copying are difficult. One strategy which is worth considering is to encourage the child with a poor visual memory to speak out loud (initially and then to speak in memory) what has been seen so that auditory memories are formed instead, which can in turn help such activities as copying down information.

Conclusion

Cerebral visual impairment is complex. The input to the brain can be impaired due to damage to the visual pathways. The information processing can be disturbed in such a way that recognition is impaired (damage to the 'what' pathway or ventral stream) or in such a way that analysis of the complexity of the visual scene and movement through 3D space is impaired (damage to the 'where' pathway or dorsal stream). The pathways serving eye movements can be damaged and this means that rapidly moving information may not be seen. The control of focussing by the eye can also be deficient so that an affected child has difficulty bringing things into focus particularly if long sighted. This can lead to significant blurring of vision. Children known to have poor vision associated with known damage to the brain need to be evaluated in a structured way which identifies all the problems. The educational approach which is adopted must ensure that all information which is presented can be seen, appreciated and understood. The information therefore needs to be designed to fall within the perceptual limitations of each child.

Diagram 1

Visual Pathway and the Brain



SKI-HI Institute
Logan, UT

Diagram 2

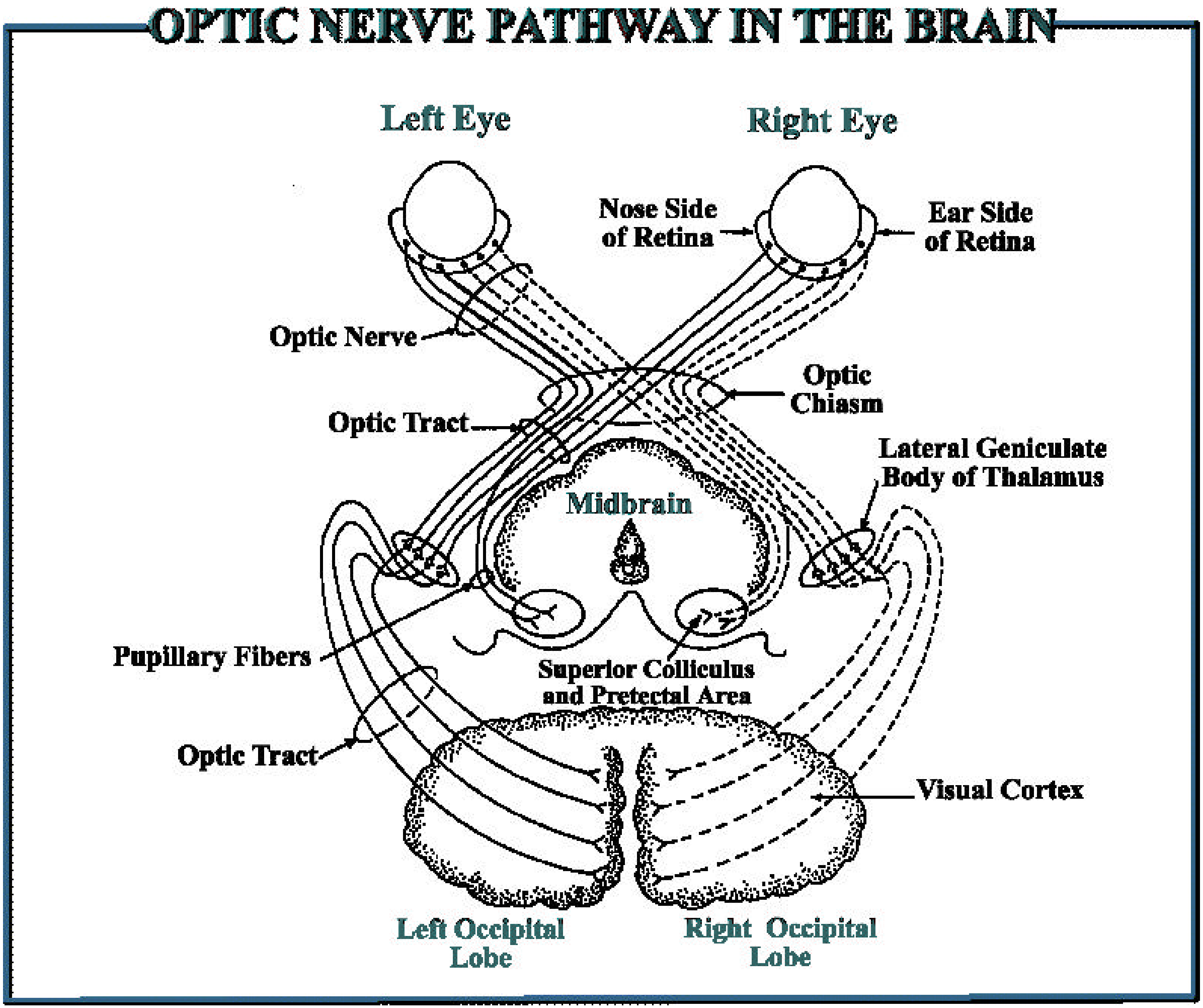
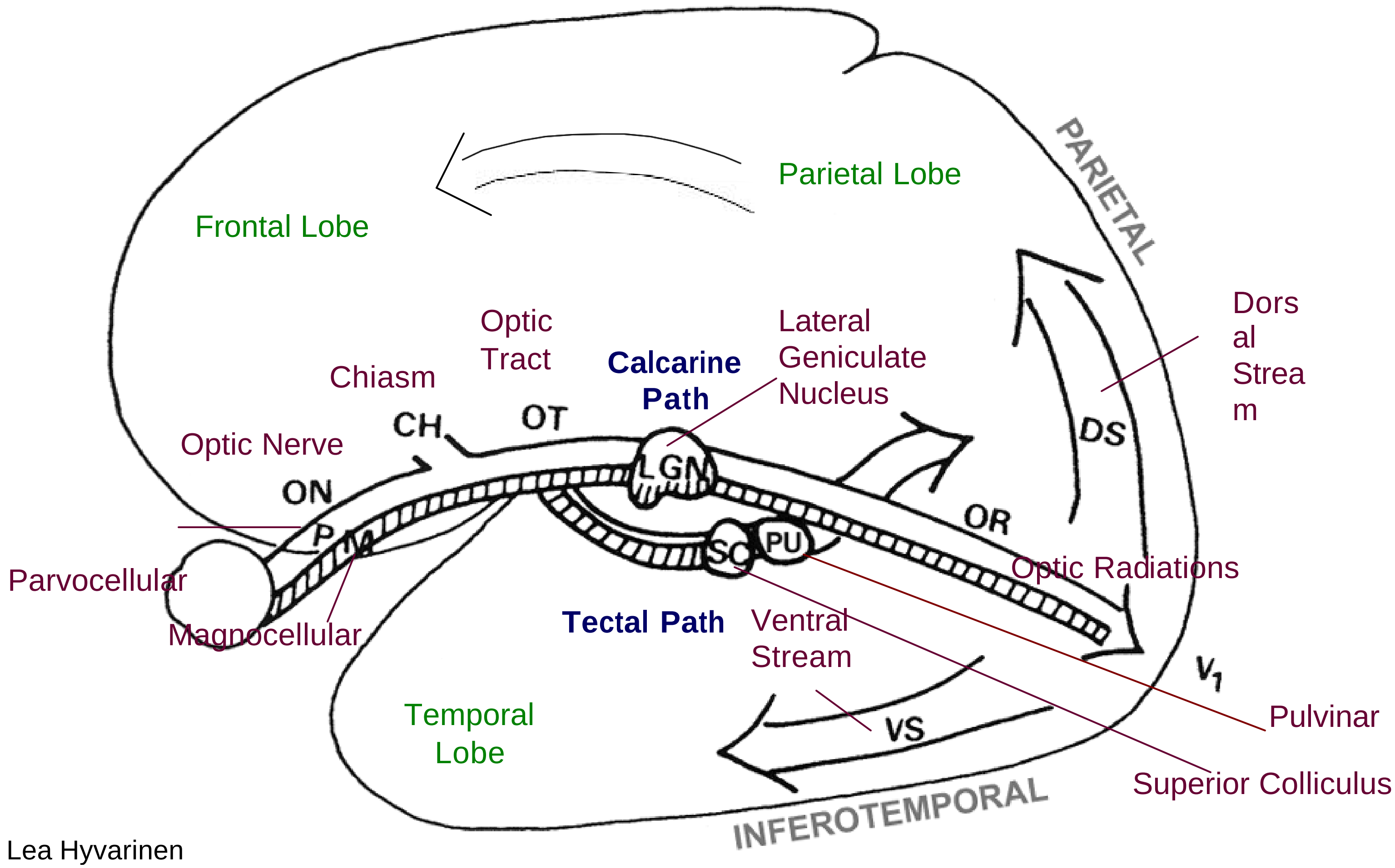

OPTIC NERVE PATHWAY IN THE BRAIN
Left Eye
Right Eye
Nose Side of Retina
Ear Side of Retina
Optic Nerve
Optic Chiasm
Optic Tract
Lateral Geniculate Body of Thalamus
Midbrain
Pupillary Fibers
Superior Colliculus and Pretectal Area
Optic Tract
Visual Cortex
Left Occipital Lobe
Right Occipital Lobe

Diagram 3

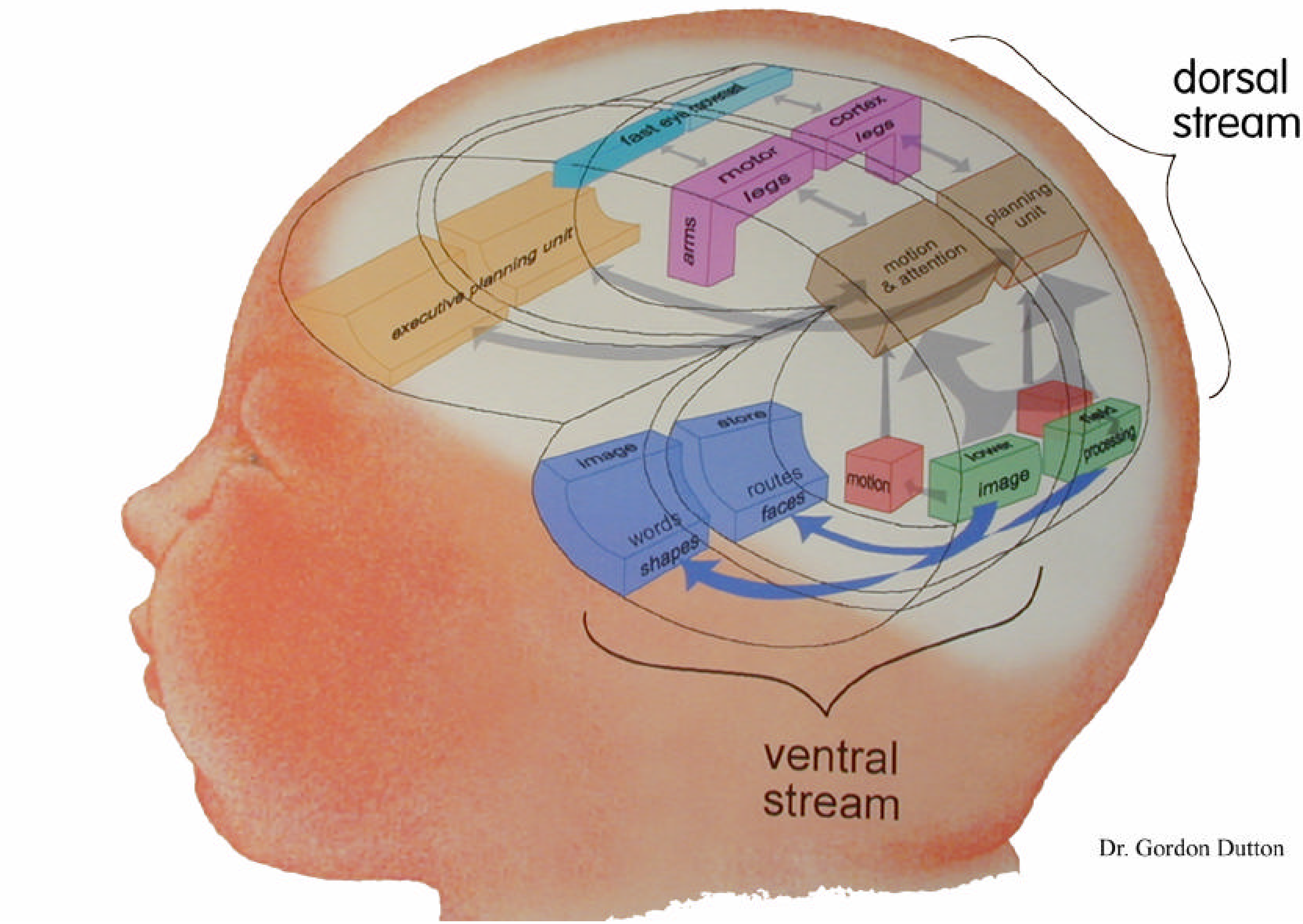
Pathways for Visual Information in the Brain



Dr. Lea Hyvarinen
Helsinki, Finland

Diagram 4

Visual Processing Centers in the Brain



Dr. Gordon Dutton