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Attention is a complex and poorly understood subject. It has been researched by many, and from this research numerous theories have evolved. This paper will review history of attentional theories and the present theories which are most prevalent. In addition, there will be an emphasis on visual perceptual tasks. Describing attention and explaining the concept in terms of function and use is much simpler than defining this intangible concept. Most people will agree that concentrating on a particular stimulus indicates attention was paid to the stimulus. Attention also encompasses concentrating on a mental task or being ready to accept information (Matlin, M., 1983).

In the optometric profession, there needs to be a working definition of attention. To achieve this, the subject matter must be understood by the clinician. How does attention relate to the visual system? If it does, how can optometry benefit from understanding the various concepts of attention? In order to solve some of the unexplained problems in Optometry with respect to visual dysfunctions it is necessary that the area of attention become stable and understandable. The area of attention has been well documented in the literature. Since most of the research done on attention has been in the field of psychology, many eye care practitioners have not read the literature and therefore may not have a clear understanding of attention and its relevance to the visual system and the practice of optometry. Common themes among the literature include that information is processed at the conscious level, attention selects some stimulus or sensory system to focus on, attention is controllable, and attention involves skill. This paper will discuss previous attentional theories with special emphasis on visual perceptual tasks.

The area of attention at the present time is a theoretical nightmare. Several theories have been developed and proposed. Each one contributes to the understanding of the attention process. In order to understand these theories, it is essential to understand how information is processed, therefore, an information processing model must be introduced first.

Attention is implicated in the processing of information. A general picture of human information processing is given by Norman (1970). As information enters, the first step is to transform the new information from the sensory system to a physiological representation which can then be briefly stored in the sensory storage system. Once storage has taken place, the material is identified and encoded into a different format, understandable by the observer. The material at this point may be retained temporarily in a different storage system usually called short term memory. If the material received extra attention or is rehearsed enough times, it may be organized and transferred to a more permanent system called long term memory. From the above description, information seems to go through three stages: 1) a sensory system or iconic memory, 2) short term memory, and 3) long term memory (Norman, 1969; Norman, 1970; Maggio, 1971; Keele, 1973). The role of the attention mechanism in information processing acts to select the interesting aspects of the physiological image to be further processed by the central system (Norman, 1969).

A visual information model is also described by Sperling (1970). In his model he attempts to describe a brief exposure in the processing of information. His conclusions came from a partial-report procedure in which the subject reported on small fractions of the trial, but did not know which parts he would be asked before hand. Sperling begins his theory with the visual-information storage, where visual information enters through the eyes. The signal is then transformed by way of the visual scan to the recognition buffer-memory. At this point, the visual information has been transformed into a motor address. Next, rehearsal takes place. The information is either subvocally or verbally rehearsed and eventually recognized. Once recognition takes place, the information goes into auditory memory and loops back to the recognition buffer-memory. The rehearsal loop retains information in auditory short term memory longer than decay time of the memory itself.

The sensory system is the first stage in which information is processed. According to Stern (1985), the term iconic memory was given for this stage of processing in the late 1950's. An icon refers to the visual stimulus presented to the observer (Stern, 1985). If information is to be processed, the subject must be able to see the object clearly. It is part of the optometrist's job to insure the patient is getting the best possible retinal image in order to obtain a clear view of the visual stimulus. Once the information enters the sense organs and registers briefly (a second or less) to allow selection of the information to be processed, the information is then transferred to short term memory (Daniels, 1984). Erdelyi (1974) sums up the description of short term memory from other investigators as a high-capacity, very brief-duration information buffer which is unselective with respect to meaning. In other words, the sensory system lets all stimuli through. Identification of the material comes later on as selected material undergoes processing. This was shown in an experiment cited by Stern (1985) in which subjects were asked to name symbols in a row versus letters or numbers. The results found that subjects reported close to 100 percent of the symbols correctly compared to reporting only 50 percent of the numbers or letters correctly. It was therefore concluded that iconic storage was strictly a visual stimulus: more processing was required to identify the stimulus as being a letter or a number.

In order for an icon (the visual stimulus) to be identified, a match for the meaning must be retrieved from a place in memory. This process is described by Stern (1985). The first step is the direction of attention to the unidentified stimulus in iconic memory. This is where selection of the information takes place. The visual information is then matched with information in long term memory and, as this is done, the semantic information is also retrieved. As the process continues, the observer becomes aware of the existence of the icon and its identity. Another way of stating this is the information from the icon passes to the recognition buffer where it is recognized and the appropriate instructions for motor responses may be sent. At this time the item can be written down, spoken, or rehearsed (Sperling, 1970; Gregg, 1986). If rehearsal takes place, the identified icon can be put into short term or long term storage.

Short term memory is an active store that processes information from the sensory register (iconic memory) and from long term memory (Deutsch, 1973; Daniels, 1984). The duration of information in this store is said to be between 10-30 seconds (Deutsch, 1973). Any rehearsal of the information must take place within that durational range or the information will decay and be forgotten (Daniels, 1984). Information which is recognized and attended to can remain in this store from a few minutes to years, depending on the amount of rehearsal which has taken place (Loftus & Loftus, 1970; Klatzky, 1975; Erdelyi, 1974; Hoyt, 1987; Cofer, 1976; Norman, 1976; Gruneburg & Morris, 1978; Daniels, 1984). If anything interferes with the attended stimuli, there will be difficulty in recalling the information (Gruneburg & Morris, 1978). This was found in experiments in which subjects were instructed to listen for a tone while words were flashed on a screen (Stern, 1985). Interference occurs in the information process system due to the system being bombarded by two different stimuli entering through two different sense organs. If interference does occur, neither stimulus can be identified properly, therefore one of the stimuli has to be selected or attended to and rehearsed in order for identification of information to take place. Rehearsal serves to recycle the material over and over again in short term memory to ensure decay does not occur as in iconic memory (Klatzky, 1975).

In addition to being of short duration, Short Term Memory also has a small capacity (Baddely, 1976; Hintzman, 1978). Researchers seem to agree with Miller's statement that the maximum number of items which can be stored in short term memory is 7 ± 2 (Norman, 1969; Hintzman, 1978; Daniels, 1984; Stern, 1985). This specified number of chunks of information is known classically as the span of comprehension, immediate memory, or consciousness (Erdelyi, 1974).

In contrast to short term memory, long term memory has an apparent limitless capacity to hold information (Daniels, 1984; Hintzman, 1978). Materials are stored in a manner that enables a person to recall events, solve problems, recognize patterns - - in other words, to think (Klatzky, 1975). Long Term Memory is a storehouse for an individual's knowledge about the world and their experiences within it (Klatzky, 1984). These materials are not conscious, but are available to be brought into consciousness when needed (Loftus & Loftus, 1970).

The length in which long term memory stores information is not well understood. In a model described by Gruneburg and Morris (1978), as information enters long term memory new nodes are being made along with appropriate interconnections between the pre-existing nodes. When retrieval occurs the search includes all of the nodes, old and new. This model seems to indicate that information in long term memory is stored in an orderly fashion, but such is not always the case (Norman, 1970). Daniels (1984) found that the information which is retrieved may not always be accurate. This indicates that long term storage loses information (when being transferred) by means of decay, disruption by other information coming in, or by faulty or inadequate retrieval methods.

The role of attention at the various levels of information processing is not clear-cut: there are many variables involved. The definition of attention as it relates to the memory process is to pay attention to the task at hand or to tune in to it (Klatzky, 1975). If this is the case, the attended stimulus should be remembered or recalled as it was presented. As long as attention is not diverted, items in temporary storage may be retrieved (Primbram & Broadbent, 1970).

This does not always seem to be the case in the study done by Norman (1969). He reported that when a person was asked to recall objects he had just seen, only a handful of items were mentioned. This reverts back to the temporary store and the limit to it's capacity. Waugh (from Primbram & Broadbent, 1970) explains that the temporary store (short term memory) is limited to the most recent few items that were attended to. The physiological traces of these items apparently do not decay autonomously in time. Instead, they are completely disrupted by other traces of items that may be perceived later on, or by subsequent shifts of attention. Restated, the items in short term memory undergo a change each time attention changes unless something is done to keep the present information there, such as rehearsal. Since the attentional shifts are ongoing, the information coming in may disrupt what is already there. Hence, only a few items are recalled.

A study by Grossberg and Stone (1986) has also shown that attention switching influenced the initial storage of items in short term memory. They found competitive interactions occurred between representations of stored items. This controlled the further evolution of temporal-order information of stored items as they are processed. The paradigm of Reeves and Sperling (1984), mentioned in this study, showed that re-ordering of items in short term memory occurred prior to conscious awareness. When short lists were presented, the items were recalled immediately in the correct order, but when long lists were presented, the beginning and the end were reported before the middle of the list. This showed that temporal-order information was not always stored exactly as it was perceived.

This information processing model provides the background to discuss the various theories that surround attention. Each theory describes how information is processed and where attention seems to play a role in order to select the information that needs further processing.

In order to achieve a full appreciation for the subject matter of attention and how it relates to the visual system, it is essential that background information be presented. Many authors have presented theories regarding how attention works and its role in the gathering of information. Several theories which have been cited repeatedly in the literature will be presented here.

In 1955, E. Colin Cherry introduced a theory which was later called the "cocktail party theory". This theory suggests that information can be selectively processed. Cherry described a situation in which many conversations are taking place, but a person is able to listen to a specific conversation. Some form of filter was suggested to cause such an occurance. This would indicate that a selective processing of information was taking place in order to keep the unwanted information, the background noise and other voices, from being processed.

In one of the experiments, two messages were presented simultaneously to either ear of a subject. Cherry used a technique, now referred to as a shadowing technique, in which the subject was instructed to repeat one of the messages as he listened to it. After the test, the subject was asked what message or sound was played to the other ear, the rejected ear. Subjects were able to recognize some properties of the rejected ear such as if it was speech, the voice changed from male to female or a tone was played, but the subject was unable to repeat any of the words spoken. One of the possible explanations for this was that the nonshadowed channel was masked, and there is a limited ability to process the material.

According to James (in Norman, 1969), a stimulus which is attended to will remain in memory, but a stimulus that is ignored will not leave any trace in memory. Norman tested this by interrupting the subject during the shadowing task, and asking him/her to recall the unshadowed message. (Cherry had waited until the shadowing task was complete before asking for recall of the nonshadowed message.) Norman found a temporary memory for the unattended message, but no long term memory.

In 1956, Donald Broadbent presented his first model of how information is filtered, which resembled a Y-shaped tube. Information from the senses was allowed to pass through either of two passages, but when this information reached a certain stage only one message was allowed through at a time. If the two messages did go through at the same time, they would not emerge properly. Instead, information could be selected from one area to go through first, and allow any other information to come through later.

Broadbent (1958), further modified his filtering model to what has been referred to as his Filter Theory of Attention. Information enters this system through a number of parallel sensory channels. In parallel channels, more than one message is allowed to enter at the same time. Information is then stored in short-term memory for approximately 2-3 seconds. This information is passed along to some neural representation called a filter. The filter's purpose is to allow specific messages to pass to the limited capacity channel. The selection process is done by pitch, loudness, spatial position characteristics, intensity, etc. The filter will allow the selected information to pass to the limited capacity channel by automatically blocking, or at least attenuating any channel of information not specifically selected for further processing. Information from the selected channels are allowed to pass to higher processing levels, unimpeded. The ability to focus attention on a particular class of stimuli is determined by the stimulus set or the response set. The stimulus set is defined by physical characteristics, and the response set may restrict the stimuli as a certain response has to be made (Kahneman, 1973). The limited capacity channel can not carry all the information that the filter receives. Signals (Inputs) that are stored in short term memory (STM) degrade and when allowed to pass, assuming that the signal does not degrade all together, are interpreted as an erroneous signal. To evade the problems of constricted space, the limited capacity channel can funnel information back to STM. This provides storage of unlimited time, meaning it can go back through the filter, through the limited capacity channel, return back to STM, and around this circle again. The capacity load of the channel is reduced in this way, and the signal is given another chance to go through the limited capacity channel. Long-term storage does not affect the capacity of the channel, but rather is the means for adjusting the internal coding to the probabilities of external events such that the limit on the channel is an informational one and not simply one of a number of simultaneous stimuli. Restated, this means that LTM does not process the input, but rather determines the possible output from previous experiences.

With time, Broadbent's theory was found to be unrealistic for it did not disclose a representation of processing strategies. It seems that there were massive top-down influences in perception. This means that higher-level information affects lower-level recognition. There also seemed to be an excessive burden upon feedback loops from long-term storage to earlier stages, in this model.

Although Broadbent's model was found to have flaws, it has been modified many times and was the basis for many new theories on the filtering of attention. Almost every book and article on attention will make some reference to Broadbent and the work he has done.

Anne Treisman (1964) proposed a modification of Broadbent's original filter theory based on her research with auditory stimuli. In this theory, information enters through parallel channels. A series of tests is then performed on the incoming messages. The first set of tests involve distinguishing among the inputs on the basis of sensory or physical cues, later among syllabic patterns, specific sounds, individual words, and finally, grammatical structure and meaning. This sequence of tests was compared to a tree, with incoming sensory information starting at the bottom or trunk and working its way up to a specific end point. There are tests at various levels where a choice may be made. The point where each test is given, in the model of a tree, is the point at which it would branch off, with each new branch representing a new test. These tests can be flexible. An example of this is if a word is expected: all of the tests will have a lower threshold for the expected word, making it easier for the word to get through.

If distinctions between stimuli can be made at an early stage, then it becomes possible to separate them from each other by attenuating the irrelevant channel to decrease its interfere with later testing. If a word on the irrelevant channel however, fits within the context of the material just processed, it may be detected anyway as the tests were pre-sensitized toward the expected event. An expected event will cancel out the effects of attenuation. It is in this way that mistakes can be made, and why we often claim to have heard something when we haven't. If a signal has been associated in the past with a signal that was allowed through, then the system will be more sensitized to that signal, and it will have a lowered decision criterion. An example is the word hospital. The doctor may have a lower threshold to cross as it may have been associated with the hospital before.

Though Treisman's research was done primarily with respect to auditory stimuli, it has been applied to sensory systems in general (Moray, 1969 ; Norman, 1969). Moray (1969), felt that at each test point in Treisman's diagram, there were thresholds. The stimuli with the thresholds lower than the test criterion were allowed to pass through, with the threshold value which testing takes place allowed to vary for each test. The dictionary units (i.e. one of the sets of tests) which respond to the occurrence of biologically (or emotionally) important signals have permanently lowered thresholds (Moray, 1969, p. 32). Examples are breathing or the sound of your name being called. Signals which would normally be attenuated may have a lowered threshold and cause a triggering if the subject now 'pays attention to' that message.

The processing of information from two separate sources was first introduced by Cherry (1953) and Broadbent (1954). According to Deutsch & Deutsch (1963) two problems were noted from these experiments: (1) how different streams of information are kept distinct by the nervous system and how noise or babel is avoided and (2) why only one of the messages is dealt with at any one time. A more radical conclusion by Deutsch & Deutsch came about after Treisman made a moderate revision of Broadbent's theory : "a message will reach the same perceptual and discriminatory mechanisms whether attention is paid to it or not" (Kahneman, 1973).

The theory of Deutsch & Deutsch (1963) is based on the importance of a signal as it arrives for processing. The mechanism whereby the weighting of importance of messages is carried out is given by Deutsch's (1953,1956,1960) theory of learning and motivation. This theory (Deutsch & Deutsch, 1963) introduced link-analyzers that responded to stimuli. Excitation of these link-analyzers depend on which primary links are connected and the resistance of these connections. It was assumed that the amount of excitation was determined by the link-analyzer's threshold of excitability and the ranking of importance of the stimulus. The theory implies that detection of a relevant signal should be easy whether or not the observer is currently attending to the channel in which the signal is presented (Kahneman, 1973). On a neurological basis, Deutsch & Deutsch (1963) speculate that some diffuse and nonspecific system is necessary as a part of the mechanism sub-serving selective attention. The afferent connections are from discriminatory and perceptual systems influenced to take as the"highest" afferent messages and the efferent connections which are also connected to discriminatory and perceptual systems would be signalled at their own levels. If the level of the nonspecific system was above that of a particular discriminatory mechanism, no registration in memory or motor adjustment would take place. Therefore, only that discriminatory mechanism being activated whose level equalled that of the diffuse system would not be affected. This indicates the more important message would be selected. All of this suggests that their treatment of focused attention assumes that parallel processing normally occurs at all levels of perceptual analysis, with a bottleneck that controls entry to awareness, response selection, and permanent memory (Kahneman, 1973).

While the allocation of attention is flexible and highly responsive to the intentions of the moment, there are pre-attentive mechanisms that operate autonomously, outside voluntary control (Neisser, 1967). These mechanisms provide a preliminary organization to perception by a process of grouping and segmentation whereby the objects are defined and subsequent processes of selective attention take place (Kahneman, 1973). According to Kahneman (1973), the general rule from Neisser's theory is attention is easily focused among several objects.

At simple levels, several distinct processes of recognition can function simultaneously in the analysis of a single stimulus-configuration (Neisser, 1963). There are many levels a stimulus must go through in order to be picked out as the stimulus on which attention will be placed. Many subsystems for processing visual information can operate in parallel, at least in situations where a high degree of accuracy is not required (Neisser, 1963).

According to Neisser's theory (1967), perception is an active constructive process, and the role of attention is to select the percepts that will be constructed or synthesized (Kahneman, 1973). Whatever percepts that are chosen, these will be analyzed by a synthesis process while all other objects of perception are excluded. In addition to the process of analysis by synthesis, Neisser assumes the existence of passive or "silent" systems which perform preliminary sorting and organization of sensory data and whose operation is not represented in awareness (Kahneman, 1973). Any innate response, such as responding to the sudden motion of object, describes this system. According to Kahneman (1973), Neisser's theory provides for focused attention as it implies a process which selects the relevant stimuli that deserve the effort of perceptual synthesis. A selected stimulus attracts more attention than do other stimuli, therefore a stimulus for which one is prepared will "jump" from the background (Kahneman, 1973).

There are many questions as to the effect of dividing attention. Neisser and Becklen (1975) performed an experiment to show this. In their experiment, subjects were shown games on television. They could easily follow one game, however, when two games were displayed at the same time, subjects made eight times as many errors than when viewing only one game. Other researchers have also showed a decrease in performance when attention is divided (Cherry, E.C.; Francolini, C.M. and Egeth, H.E., 1979; Somberg, B.L. and Salthouse, T.A., 1982).

Eriksen and Eriksen (1974) performed an experiment in which subjects were instructed to attend to the center of a row of letters, and ignore the nontarget letters. There were two responses, depending upon the identity of the target letter, and to what group or subset it belonged. The results showed a faster response time when the nontarget belonged to the same subset as the target, but a slower response time if the nontarget belonged to another subset. Even when the nontarget letters did not belong to either subset, a correlation between target and nontarget produced a faster response (Miller, 1987). The authors conclude that unattended stimuli influence performance.

In another type of target search, subjects were to count the number of red items present (Francolini and Egeth, 1979). Black distractors in the area had no effect on the mean response time, suggesting "perfect selectivity". The lack of interference from the distractors led the authors to argue that unattended stimuli were not identified (Francolini, C.M. and Egeth, H.E., 1980). Tipper (1985) produced evidence to counter these claims. Subjects were presented with two overlapping line drawings of a certain color. Response times was slower when the drawing was related to the previous unattended drawing. It is suggested that this effect shows an inhibitory mechanism for selective attention (Tipper & Cranston, 1985). A slowed response time has been found when as attended word relates to an unattended drawing from the previous trial (Tipper & Driver, 1988), and this implies that the effect is "operating at an abstract level of representation, because there is no physical resemblance between a related drawing and word" (Driver & Tipper, 1989). Driver and Tipper (1989) argue that noninterfering distractors may be processed more slowly than interfering distractors, and if the distractors are not processed until after a response is given, one would not expect an increase in response time. It also follows that if the distractor is identified by the time the next stimulus appears, it may interfere with the following response (Driver & Tipper, 1989).

There is a relationship between reaction time and where attention is focused. As a target to be detected is shifted further into peripheral vision, there is a characteristic increase in reaction time (Eriksen & Hoffman, 1973; Hoffman, 1975; LaBerge, 1983; Posner, Nissen, & Ogden, 1978). This increase in reaction time is proportionate to the distance into the periphery, and has been termed the V-shaped reaction time curve. The shortest reaction time is centrally located on this curve, and begins increasing as a target is moved away from the center. LaBerge & Brown (1976) regarded this characteristic increase in reaction time as the marker of attentional processing.

Two theories are used to explain this increase in reaction time: a shifting focus theory and a gradient theory. The shifting-focus theory (Eriksen & Hoffman, 1972; Eriksen & Yeh, 1985; LaBerge, 1973; Posner, 1980; Posner et al., 1978; Tsal, 1983) uses the premise that attention is focused centrally, and as the target or cue is deviated from the center, this focus of attention must shift to that area. A corresponding increase in reaction time results the further the focus of attention must be shifted from the center.

The gradient theory (LaBerge & Brown, 1986) of attention utilizes the spotlight model. The center of this spotlight of attention receives the greatest priority for processing, with decreasing priority the further the stimulus is away from the center (but still within the spotlight). "Thus the allocation of attention can be viewed as a gradient of processing" (LaBerge & Brown, 1989).

Eriksen and Yeh (1985) have modified the zoom lens model, a model very similar to the spotlight model. There is a continuum of attention in this modified model in which the two modes proposed by Jonides are the extreme ends. One end can be widely and evenly distributed while the other is a sharply, narrow focused area which is the zoom lens model. There is a wide field of view with little or no magnification at one end, and a highly magnified, constricted field with a high degree of detail discrimination at the other. In the wide field of view or parallel processing channel, the rate of processing would be slow, however, if the subject allocates a lot of attention to one small area, this would result in faster information extraction.

Spatial cues have a direct influence on the reaction time to stimuli in peripheral vision, even when eye movements are not necessary (Posner, 1980; Posner, Snyder, & Davidson, 1980). Reaction time will decrease at cued locations, but if incorrectly cued, there will be an increase in reaction time. These studies show that attention may be shifted within the visual field even without an associated eye movement. If nontarget stimuli are presented to a location other than where attention is focused, there may be an increase in reaction time (Eriksen and Eriksen, 1974). This effect occured when the nontarget appeared within one degree visual angle, however if a stimulus was presented outside this area, the identity had no effect. Eriksen & Hoffman (1973) and Humphreys (1981) agree that the attended area in this situation is about one degree. Tsal & Lavie (1988) used color and shape to further test selective visual processing. Subjects were instructed to report a target, by color or shape, and then any other letters they might have seen. Whether the target was a color or a shape, the nontargets most reported were those spatially closest to the target, suggesting the importance of location in selective processing. Order of presentation will also have an effect on reaction time. Nontargets appearing after presentation of the target have no effect at all, however, nontargets presented prior to the target, even beyond one degree, has an effect upon reaction time (Gathercole & Broadbent, 1987).

There is generally a reduction of performance with divided attention, but this isn't always the case. A typist was found who was able to recite nursery rhymes while typing (Shaffer, 1975). This appears that she could perform two tasks at the same time, however there may be another explanation. Automatic processing may control information flow without requiring attention (Schneider & Shiffrin, 1977). Matlin (1983) used driving as an example of automatic processing. Learning to drive requires a lot of attention, however once the process of driving is learned, one may drive and carry on a conversation at the same time. There may be implications of automatic processing in reading.

The act of reading is a complex process. The functional components involve an integration of eye movements along with higher cognitive processes such as attention, memory, and the utilization of the perceived visual attention (Garzia, et.al., 1990).

There are two different eye movements used in reading: fixations and saccades. Fixations are reflexive, and allow any image to be held stationary on the retina while information is extracted from the text. Up to ninety percent of the total reading time can be spent on fixations alone (Larsen, 1990).

Saccades are high velocity eye movements which move the eyes to the next area of fixation where new information may be extracted and sequential visual input about the text may be continued. When a peripheral signal is the target of a saccade, attention will move to the signal before the saccade (Posner and Cohon, 1980).

During reading, approximately eighteen letters can be seen during one fixation, and only five to eight of those are seen clearly as they are on the foveal "cone" of clear vision (Rayner, 1983). These letters are directly processed by parafoveal vision, being analyzed for shape and length. Parafoveal vision is used to pre-process upcoming information (Underwood, 1988). Attention is not only on the letters currently being processed, but on the future text as well. Future letters, words and phrases may be primed or expected by preceeding context (LaBerge, 1972). LaBerge and Samuels (1974) suggest that the skill of reading is complex, and in order to read rapidly, many aspects of reading become automatic. Rather than looking at the different parts or shapes that make up individual letters, attention may be directed to the content of the words and future context. There is a significant difference in the perceptual grouping of good and poor readers (Williams & Bologna, 1985). Perceptual grouping separates the areas into "figures and regions". Williams and Bologna (1985) suggest that poor readers, with a larger grouping of elements, are less efficient at selective attention.

There are several ways to measure attention. Commonly, response or reaction time is used to measure attention as well as divided attention (Driver & Tipper, 1989; Eriksen & Eriksen, 1974; Eriksen & Yeh, 1985; Francolini & Egeth, 1979; LaBerge & Brown, 1976; and Miller, 1987). It assumes that the longer the response time, the more attentional processing that is required.

Another method which has been used to measure attention is the blink reflex. By using a puff of air or an intense auditory tone, Hackley and Graham (1983, 1987) reported that when attention was directed toward a stimulus, blink reflexes were found to be larger and faster than when attention was directed away from a stimulus. When there was a pulse for the subjects to selectively attend to prior onset of the stimulus, there was a reduced magnitude of the blink response (Hackley & Graham, 1987).

Attention can also be measured through event-related potentials or P300. In recent years, event-related potentials (ERP) have been found to be the key to recording activity in the brain without much harm to the patient. ERPs are a transient series of voltage oscillations in the brain that can be recorded from the scalp in response to the occurrence of a discrete event (Kramer). The EEG recordings come from midline electrodes at Cz, Pz, Oz, and Fz (Israel, et.al., 1980; Holcomb, et.al., 1985). These oscillations reflect a phasic change that is related to the processing of specific events (Kramer). ERPs have been found to be linked to certain types of stimuli as well as psychological constructs like task relevance, attention, and memory (Kramer; Johnson, 1986).

ERPs have been studied to determine the components. It has been found that electronic potentials recorded from the scalp represent a small subset of the neuronal transactions of the brain that summate to form the ERP wave (Kramer). The P300 is part of the ERP and that it's amplitude and latency could be used to indicate the nature and timing of a subject's cognitive response to a stimulus (Johnson, 1986; Ruchkin, et.al., 1990). In 1978, Posner et.al, proposed that a higher level of response was responsible for the generation of the P300, conscious attention (Holcomb, et.al., 1985). Therefore, using his framework, a large P300 would indicate that the subject was focusing a substantial amount of available attention resources on the stimulus event, while a small or nonexistent P300 would indicate that the resources were unavailable, or diverted elsewhere.

There have been studies done to see what affects the amplitude of the P300. The pattern of variation of the P300 amplitude with sequential structures of a series of tones depended on the category to which the events were assigned, rather than on the individual stimuli eliciting the P300 (Brown, 1982). An example of this is to present the subject with two tones, one high and one low. Both tones are presented in random order, but with a certain probability of the number of times each will occur. When the subject is asked to count only the high tones, a P300 will be elicited. Both tones will not produce a P300, as the P300 is only elicited in response to new information, or different information. If a stimulus is continuous, the P300 will not be elicited except for the first time. The random trials of tones (high and low) will produce P300's as the stimulus is random rather than continuous. In experiments involving two tasks like visual tracking and counting tasks, the P300 amplitude was reduced (Pitman & Herzog, 1983; Ruchkin, et.al., 1990). This indicates that the subject must "attend" to the stimuli in order to elicit a P300 (Israel, et.al.; Israel, et.al., 1980).

In a review done by Pritchard (1981), the P300 was found to reflect only the general informational properties of the stimuli; that is, it indicated if the stimulus was task relevant and of low probability, but did not reveal any specific sensory information. The information that elicits a response must be used by the subject.

A P300 model proposed by Johnson (1986), explains that variations of the P300 amplitudes are due to three dimensions: 1) subjective probability, 2) stimulus meaning, and 3) information transmission. Subjective probability refers to the amplitude related to the probability of the stimulus categories rather than probabilities of the individual stimuli. It was found that the P300 amplitude is directly related to unexpected events (Brown, 1982; Johnson, 1986; Jasiukaitis & Hakerem, 1988). Stimulus meaning refers to the stimulus used in the experiment. The P300 amplitude was found to be sensitive to experimental variables that are independent of those affecting the formulation of subjective probability. Information transmission refers to that proportion of stimulus information received by a person relative to the total amount of information originally contained in the stimulus. The amount of attention given to the stimulus and how much was lost in the transmission will affect the amplitude of the P300. This means that a P300 will not be elicited if the subject is distracted or not attending to the stimulus (Israel, et.al.; Pitman & Herzog, 1983). Since all these dimensions affect the amplitude of the P300, great care must be taken to make sure the stimulus is right and the subject understands the task at hand.

P300s have been elicited using somatosensory, auditory, and visual modalities (Pitman & Herzog, 1983). The P300 is recorded within 300 to 800 msecs following the presentation of a task relevant stimulus or oddball paradigm (Kramer; Pritchard, 1981). There is some evidence that suggests that P300s invoked by visual stimuli may be larger than those invoked by the other modalities which may be reflecting the dominance of the visual system in humans (2). The same parameters can be followed as the tone experiment mentioned earlier.

Since many variables can influence the P300 amplitude, it could be used to differentiate normal children from those that have attention and reading deficits. A study done by Holcomb, et. al.

(1985), compared a control group of children to three other groups which were classified as attention deficit with hyperactivity, attention deficit without hyperactivity, and reading disabled. These children were referred for classroom behavior problems or having academic problems. The results of this study showed the same results as previous findings by others in that attentional and reading disabled children have smaller P300 than normal controls. This study also found a longer latency of the P300 than the normal control. A number of studies cited by Holcomb, et. al. (1985) noted that the latency of the P300 component corresponds with the evaluation or decision time of the stimulus and that the more difficult the decision or task is for the subject, the longer the P300 latency. Shorter latencies indicate a fine tuned speed of attentional resources to the task relevant stimuli, while longer latencies indicate a breakdown in the efficiency of allocating attentional resources. This was found in the attention deficit groups.

Several problems may be encountered that may affect attention. These may include general binocular dysfunctions, vestibular problems, Down's syndrome, attention deficit disorder, aging and reading problems (prism reader effect). Some of these will be addressed here.

It has been suggested that there be a correlation between Down's syndrome children and attention deficit (Green, et.al. 1989). Green st.al. (1989) found a higher frequency of attentional problems in this group of young children than expected.

Attention deficit disorder has implications relating to attention. Overactivity, restlessness, distractability, and short attention span are characteristics of the disorder (American Psychiatric Association, 1982). Matlin (1983) states that "a child with attention deficit disorder finds selective attention difficult because the disorder does not allow him or her to screen out the irrelevant messages". In 1987, the American Psychiatric Association changed the name of this disorder to attention deficit hyperactivity disorder, emphasizing that hyperactivity is an important aspect. Attention deficit hyperactivity disorder occurs in approximately three percent of children, and the onset is at a young age. Stimulant medications will help eighty percent of the children (Shaywitz & Shaywitz, 1988). These medications decrease distractability and impulsivity, and increase attention span. Meents (1989) reports that a common approach "emphasizes the use of psychostimulant medications, supplemented with behavior therapy and special education programming".

There may be a relationship between aging and attention. It was thought that there was a generalized reduction in attentional resources with age to explain cognitive declines in the elderly (Craik, 1977). Others suggest that there is a decline in the storage mechanisms with age (Parkinson, et.al., 1980), or a general slowing of mental operations (Cerella, 1985). In many of the experiments testing the attentional abilities of older adults, speed is often a critical factor (Somberg & Salthouse, 1982), and it has been shown that older subjects have a poorer performance with tachistoscopically presented stimuli (Walsh, et.al, 1979; Somberg & Salthouse, 1982). In attempting to measure divided attention abilities of older adults, Somberg and Salthouse (1982) compensated for the decreased performance of tachistoscopic stimuli by varying the time of presentation to achieve an eighty to ninety percent correct response level. Presentation time was an average of 216.3 milliseconds longer for the older subjects, but the accuracy was nearly the same. This removed the differences of performing one task at a time. Under these conditions, older adults performed as well as younger subjects on divided attention tasks. Burke, White, and Diaz (1987) also found no age-related deficit in attention, and suggest that the deficit is most likely in episodic memory rather than an attentional problem. Further research will be required to understand the aging process, and the implications to attention.

As an optometrist, the role of aiding in a clear retinal image and visual information processing is obvious. However, just a clear retinal image may not insure improved visual information processing. Other areas such as accommodation, convergence, eye movements and strabismus play important roles.

Ludlum (1976) studied the effects of an inefficient visual system and how it related to information aquisition, sustained reception, and the attention process. All three of the above were improved when the inefficiencies were eliminated through such activities as vision training. With the correct control over these visual systems, improvements in attention, reading, and other academic skills were achieved (Ludlum 1976, 1979, 1981).

The act of reading is a complex process. The functional components involve an integration of eye movements along with higher cognitive processes such as attention, memory, and the utilization of the perceived visual attention (Garzia, et.al., 1990). Research with learning disabled children revealed that mechanical vision problems and visual perceptual-motor difficulties contribute at a much higher rate than problems such as refraction, pathology, and strabismus (Sherman, 1973; Hoffman, 1980). Therefore, a problem with any part of the components could result in reading difficulties. A reading disabled child is defined as someone with normal of better intelligence with no known behavioral or organic disorder, and who, despite normal schooling and average progress in other subjects has a reading disability of at least 2.5 years (Williams & Lecluyse, 1990). These children also have no visual or hearing impairments (Lovegrove, et.al., 1990).

A study done by Ludlum and Ludlum (1988) explored what happens to reading comprehension after inducing a visual problem. They introduced 9 D of base-in plano prism to normal individuals who were asked to read passages while keeping the words clear and single. The results showed that reading comprehension was affected especially if the passage was long and many questions were asked. The difference in comprehension between prism versus no prism was due to such things as motivation, fatigue, and attentional factors. Ludlum and Ludlum (1988) speculate that the prisms created enough fixation disparity to account for the reduction in reading comprehension scores. Many factors may contribute to why the person has reading difficulties, attention may be one of them.

Numerous questions now arise about this complex cognitive process known as attention. As understanding improves, the number of questions increases. Thus, it is necessary to universally define the concept of attention in order to maintain an accepted and approved knowledge base on this topic. Also, in order for valid research to be conducted, investigators need to operate from the same terminology. Optometry can play a vital role in future attention research. Some specific areas relevant to Optometry include the relationship between visual attention and Attention Deficit Disorder, the affect of attention in vision training, and the relationship between the visual system and the learning disabled. Research and eventual answers to these questions and others will define and expand the role and significance of Optometry in the process of attention.

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