Early and Recent Views of Factors Affecting Stereopsis

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Stereopsis is one of the human visual system's most remarkable achievements : people can make accurate binocular depth judgements based on horizontal positional disparities as small as a few seconds of visual angle. Clearly, stereopsis qualifies as one of the most impressive of the so called hyperacuities (Westheimer 1979). But just how and to what degree do several different subjective or internal as well as objective or external variables influence an individual's experience of stereopsis?

Stereopsis is a binocular phenomenon involving the visual "blending" of two similar but not identical images (one falling on each retina) into one, with resulting visual perception of solidity and depth (Cassin and Solomon 1984). If the disparity between the two retinal points is not too great, the images will be fusible even though they do not fall on exactly corresponding retinal points. This is attributable to the disparity allowance within Panum's area (the zone to the front and back of the fixation object). This small fused disparity is responsible for stereopsis (Griffin 1988, 51). The level of stereopsis usually determines the level of binocular status - if there is high functioning stereopsis, binocularity will be also. However, the opposite cannot similarily be stated. Why is this so? Why may an individual possess normal sensory and motor fusion, yet be unable to see stereoscopically? One proposal lies within the first 'internal factor' of stereopsis. This is the fact that stereopsis is a neuropsychological cortical phenomenon. Somewhere in the brain, the information from the two monocular images is combined. The individual may lack cortical <u>binocular</u> disparity cells which are responsible for this processing of information. It is thought that this deficiency is genetic. "If lack of <u>both</u> types of disparity detectors (crossed and uncrossed) are inherited, an individual may lack normal binocular vision <u>and</u> be at risk for strabismus" (Griffin 1988, 415).

Another interesting relation of cortical processes linked to stereopsis was researched by Kosslyn et al (1989). They found that the left cerebral hemisphere was responsible for categorical spatial judgements of objects such as on/off, left/right, and above/below. This process was to be differentiated from the channel of stimulation of the right cerebral hemisphere which enabled a subject to make quicker judgments regarding <u>distance</u> evaluations about an object. Thus evidence was provided that there is a psychological and neurological distinction between the processes of recognizing objects and recognizing subtle differences in location, the latter process an element of stereopsis. Also, although still regarded as speculative, there is also some evidence that the right cerebral hemisphere is primarily responsible for global (as opposed to local) stereopsis. Global stereopsis refers to the perception of whole objects in stereoscopic depth as opposed to the depth perception of localized features of objects in local stereopsis (Dale 1982, 46).

Another internal factor may answer the question of how a normally functioning system capable of sensory and motor fusion cannot see stereoscopically. This factor is the learned component associated with stereopsis. This may also be explained by Lotze's theory of local signs. Kaufman (1974, 293-294) explains the theory as follows, "....each point on the retina produces a unique though undefined sensation when it is stimulated. The unique qualities of each such point-stimulation allow the organism to relate them to different spatial directions. This comes about, according to Lotze, because the eye must move through a given angle and in a given direction to get any single image point into the fovea. Thus if an image of a point were to be located above and to the right of the fovea, the eye would have to move downward and to the left to get the image into the fovea. Since the originally excited point on the retina produced a unique sensation to begin with, in time the organism comes to associate that sensation with the need to move the eye a given amount in a particular direction. Hence, the perceived spatial layout of points distributed on the retina is derived ultimately from the sensations associated with the muscular effort necessary to view objects with central vision. Through experience each point on the retina comes to have a local sign to identify the visual direction of an image impinging upon that point."

Kaufman explains that this theory could be extended to include depth perception by reasoning that in order to get a peripheral stimulus onto the fovea, muscle effort is required. Thus this same muscle effort is involved in the vergence change needed to see a disparate image as single. Experience is then obtained with the need to see objects as single until the vergence changes ultimately lead to stereopsis. The disparity resulting from the formation of half-images in places with different local signs would produce vergence changes. Different magnitudes of vergence changes would come to be associated with different disparities. This would allow the perception of disparate images to be seen in depth. This theory completely depends on past experience in changing vergence to convert disparate images into a clear stereoscopic image.

So the perceiving of depth may be the result of learning - moving about and touching objects. Many psychologists believe this is why the world appears three-dimensional even though the retinal image is flat. The evidence for this lies in experiments which show that adult sensorimotor coordinations are in fact modifiable (Kaufman 1974, 409). A very early experiment which demonstrated this fact was written by Stratton (1896, 1897). Stratton investigated the effects of exposure to a rearranged visual stimulus. He wore a Galilean telescope (which reversed the image right/left as well as up/down) over one eye and blindfolded the other eye. One of the questions at hand was, if all verticality is preserved (the feet were still seen in contact with the ground and birds flying in the sky) why would the world appear inverted? In other words, are not the terms "up and down" purely relativistic? One answer is that the world would appear inverted because the visual information would be in conflict with the other senses. According to Stratton, this conflict is the result of the course of development in which retinal local signs become associated with other sensory information. However, his experiment showed that over time, different retinal local signs of the now inverted visual information could be "relearned" so that it was no longer in conflict, but now associated with the other sensory information. Upon removing the telescope after eight days of wear, Stratton made incorrect reaching movements, and the world appeared disoriented (Kaufman 1974, 416-418). Also of notable importance, when Stratton first put on the telescope, and he moved his head and eyes, the world appeared to move about. Position constancy was disturbed by the telescope (position constancy refers to the awareness that objects have maintained a constant spatial position even when moving the head and eyes and causing a retinal image position change.) The disturbance was due to the image of an object shifting to the right on the retina when Stratton rolled his eyes to the left. "This is opposite to what normally occurs, so that the reafference was inconsistent with the efferent signal to the eyes. As time went by, Stratton noticed less of this movement of the world. Position constancy was restored." "Something new was learned while wearing the telescope and this something supplanted the old customary relation between the reafference and the efferent signal." Although Stratton's experiment was purely monocular, it did show that adult sensorimotor systems are modifiable (Kaufman 1984, 459). More recent studies have proven the same principle while employing binocular concepts.

From 1947 to 1950 Ivo Kohler of Innsbruck University performed three experiments involving the wear of inverting spectacles (Holt, Rinehart, and Winston 1968, 476-478). He reported that simultaneous touch sensations were a determining factor of the transition period of inverted vision becomming seemingly upright. When the subject was permitted to reach for and touch an object in his immediate vicinity, the object first seen as inverted suddenly appeared upright. Kohler also commented on the gravitational component of the reorientation process. When the subject was given a pendulum, he was able to sense the relative position of the weight and correctly perceive more distant objects. Kohler discussed a third influence upon the reversal process - that of familiarity with objects. For example, the subject was able to view a burning cigarette. The direction of the smoke enabled the subject to orient himself in relation to external directions.

Kohler concluded that the subject's adaptation was virtually free of perceptual errors after five days, and the subject's overt behavior appeared normal after two days.

A very recent experiment was conducted in 1987 by Alice O'Toole entitled "Structure From Stereo by Associative Learning of the Constraints". In this study, the author addresses the previous problems associated with using random dot stereograms as a stereo model. "The ill-posed nature of stereopsis is that there are an infinite number of three-dimensional worlds that can give rise to any given set of two-dimensional images on the retinae." Computational models of structure from stereo utilize different constraints in an attempt to alleviate this problem. One of the most important constraints is smoothness, since disparity varies smoothly almost everywhere. Thus, the author created a large number of surfaces according to a statistical surface model, sampled these surfaces from slightly different eye positions, and coded this information in the form of vectors. The vectors contain the activity of disparity-tuned units which respond to matches of intensity change information at different convergent, divergent, or zero offsets in the left and right retinae. Then, the vectors of disparity cell activity are correlated to the depth change map of the surface they represent. The important point is that in this model, constraints develop naturally on the basis of examples of image-to-depth transformations learned by the subject. The model also allows for the creation of a variety of surfaces which have not been learned, yet created according to the same set of rules. Thus the assumption is given that the constraints the subject has learned on the basis of the example surfaces should be appropriate for solving these new surfaces even if the system has not learned the test surfaces. The experimental data did in fact support this assumption. An important feature of this model is that rather than computing depth at different points on an image, it computes depth change from point to point across an image. Thus the output is a representation based on the activity of many cells rather than a relationship to single cells.

Griffen (1988, 413) reports that Simons concluded, after observation of various stereoacuity tests, that binocular visual development is not complete by the age of five years. Also, Cooper et al. relay that normal adult findings of stereoacuity among young children were reached by age seven, and that scores improved with age beginning at age two (stereopsis is difficult to test in those younger than this). Also of interest is the fact that when the children in the age bracket of two to five years were given operant conditioning, the result was superior stereoacuities when compared to earlier studies in which operant conditioning was not employed.

In spite of the previous examples provided to support a learned component in stereopsis, many arguments are given against the theories and many experiments have been done to emphasize the contrasting genetic component to stereopsis. Although Stratton and Kohler highlighted the acquired capability of stereopsis, others argue that the modifications of perception are dictated by the innate structure of the organism. They propose that there are fixed inborn relations between visual directions and retinal positions. They also argue that in experiments such as Stratton's it was the proprioceptive rather than the orientation sense of the world which changed. In 1965 Charles Harris made this arguement when he said and showed that modification of the normal feel of the body's position was the basis for the occurrence of adaptation (Kaufman 1974, 432-433). In other words, the visual perception remains unchanged, that it does not predominate over touch, rather proprioception is readjusted. Also, Hemholtz demonstrated a built in limitation of the visual system which contradicts the assumptions of Stratton. He showed that the eyes cannot diverge more than a very small amount. While wearing a Galilean telescope and fixating a distant object, the half images of a near object will be in the nasal hemiretinas. The eyes would have to diverge a very large amount to include the half images of the near object in the foveas. Thus double vision of near objects would result, and evidence shows that this is not able to be adapted to. Rather suppression (amblyopia) would occur. Also, Hubel and Wiesel (1965) have demonstrated destrucution of cortical units in the visual areas of the brain upon artificially produced misalignment of the eyes of kittens (Kaufman 1974, 421).

Other interesting findings associated with this view involve the experiments performed to explain the "mere exposure effect." In these experiments the component of familiarity with an object was shown not to be a critical factor in distinguishing between an objectively familiar and objectively unfamiliar object when compared with the component of <u>preference</u> for the object. These findings of perceptual organization may be extended to undermine the view of "learning" stereopsis through experience. The mere exposure effect is used to examine the relationships between conscious and unconscious processes. Stimuli are presented in a supraliminal exposure phase and then the subject is asked to judge these stimuli also in a supraliminal form. The result in early experiments has been an enhancement of both liking and familiarity for objectively familiar stimuli - Harrison (Todman 1989). Then in 1980, Kunst-Wilson and Zajonc altered the experimentation by presenting the stimuli of the exposure phase in a <u>subliminal</u> form, and the results were that only liking and not familiarity were enhanced. Thus the question evolved as to just what does a subject need to encode for the mere exposure effect to occur. Zajonc and his coworkers proposed that "the preference enhancement is contingent upon products of early perceptual processing that are different from those required for the enhancement of recognition memory. They also contend that the former products are formed prior to the latter." Another view was postulated by Seamon and his colleagues who hold that "preference and recognition memory share products of early perceptual processing." In a recent experiment (Todman, 1989) these competing views were analyzed. The findings were that "subjects were able to discriminate between objectively familiar stimuli and objectively unfamiliar stimuli on the basis of preference judgements but were unable to do so on the basis of familiarity judgements." They concluded that Zajonc's interpretation appears incorrect. The stimuli used in this experiment consisted of two-dimensional numbers on pages, and the author commented that it would be interesting to determine whether the same results would be present when more complex stimuli were involved. This could include three dimensional objects or stereograms.

It is unclear whether inherent or learned factors are responsible for the "manner" in which stereopsis usually occurs. Stereopsis appears to 'grow' over time - it does not occur all at once when a stereogram is first viewed. Also worth noting is the fact that a gradual loss of depth appreciation occurs after staring at an isolated point in a stereogram. Kaufman suggests that at "any one time there may not be an isomorphic representation of three-dimensional space in the brain. This representation appears to be constructed over time.....". Support of Kaufman's theory may be found in a recent experiment by Braunstein et al., 1989. They attempted to test Hoffman and Richard's (1984) minima rule which stated that the human visual system divides three-dimensional shapes into parts at negative minima of curvature.

Visual shapes are divided into parts for the purpose of easier visual recognition. Through three experiments, sufficient evidence resulted to support the minima rule. The minima rule "divides surfaces into parts at high curvature points within 'dents' or 'valleys' on the surface. Since we interact with objects in many ways it is likely that many different representations of objects are used according to the task at hand. It is Braunstein's idea that if we wish to recognize an object rather than to grasp it, we would represent its shape in a manner independent from its spatial relationship to the body. One of the ways this is represented by the human visual system is through the minima rule. There are four major reasons why the rule is employed. First, when two objects are interfused, the rule allows for the dividing of the composite object onto two parts, each part corresponding to one of the two interfused objects. Secondly, the parts the rule defines do not depend on the relative positions of viewer and object due to the intrinsic geometry of the rule. Thus, the same parts are obtained from different viewing angles. Third, it is not required for an object to be familiar to be broken into its parts, and lastly, the rule with its partitioning character seems necessary as the visual system recognizes objects even from only partial views, and even when components of the object change their spatial relationship. Also of interest in this experiment is the fact that when a task could not be performed on the basis of parts divided at negative minima, there was a general degradation in performance. That is, an object was shown to subjects who could then choose from four alternatives the part that was a portion of the object. When not given a minima as one of the four choices, correct responses were much less frequent than when minima were provided as choices, subjects would attempt to reverse figure and ground in order to change maxima into minima. The choice of figure and ground is depended upon in the defining of the parts of a surface in the minima rule. Thus the correct figure ground choice (assignment) must be made by the subject if the parts predicted by the minima rule are to be perceived. Since the experiment proved that the minima rule is most often employed in the representation of a three-dimensional object, then the correct figure ground relationship is usually chosen. Perhaps the time taken to choose the correct figure/ground assignment accounts for some of the delay prior to the appreciation of depth to a three-dimensional object.

Other components influencing stereopsis are the amount of concentrated attention as well as attitude of the individual. As with most perceptual processing the role of selective attention is that of increasing the quality of visual output. The preconceived attitude of the subject can greatly effect the final perception. An interesting experiment performed by Gilinksky (Kaufman) demonstrated that effect of attitude on size and distance judgements. In his experiment, a standard triangle was placed at several different distances from 100 to 4000 feet from the observer. Another triangle was always at 100 feet from the observer and this one was varied in size by the observer to match the standard triangle. Two very different sets of instructions were given to match sizes. One set required the observer to match sizes as if both triangles were going to be measured by a ruler. The second type of instructions required the observer to adjust as if photographs were going to be taken of the two triangles. Those involved with the first set of instructions matched the linear, or distal sizes. Those of the second group would vary according to the fact that if a more distant triangle were photographed, it would produce a smaller picture. The different instructions presented prior to the task produced much different results. Those of the first group tended toward over-constancy, with some even making the variable triangle larger than the standard as distance to the standard increased. Those of the second group perceived the standard as much smaller as their decision was based on the law of visual angle rather than size constancy due to their differing instructions.

H.W. Dove demonstrated in 1841 that stereopsis was possible under very brief 1 millisecond exposures. Since this is too short of a time to account for muscle activity, the secondary binocular vision cues of convergence and accommodation can be bypassed and disparity can be the cue given credit as contributing to the event. Holt et al. note that this does not mean that the influences of proprioception and convergence do not affect stereopsis upon longer exposures. Dove's finding show that stereopsis can occur as a result of CNS processing alone. Holt et al. also noted that the effects of smaller target area sizes, more complex surfaces and larger parallax shifts all increase the time required for stereopsis to occur. Another experiment demonstrated an "internal attention mechanism" in stereopsis. It involved the presentation of two pairs of stereo images. The two pairs had disparity in different directions, requiring the successive perception of each pair to result from the maintainence of attention for the same perceptual organization (depth plane). The picture elements of the second pair were different from the first, thus the second pair erased the afterimages of the first pair. Thus the presentation time for the first pair was found. When presentation time was adequate, researchers found that the second pair was perceived at the same depth as the first. The perception of the second pair was found to be greatly influenced by the perception of the first pair, even when the first pair was not consciously perceived. However, when the first pair was presented for a time shorter than the adequate time for stereopsis, or when the second pair was delayed for a period longer than the 'attention time' then the second pair could be perceived as having depth opposite the first. This shows that the first stimulus acts as a depth marker, or as an internal attention mechanism. It 'marks' possible depth organizations which should be given attention.

Another factor which obviously contributes to the extent to which stereopsis occurs is contrast. The first of two recent studies conducted by Halpern and Blake in 1988 showed that stereoacuity was affected by variations in contrast with the better 'performance' observed at higher contrasts and was "optimum when contrast was 1 log unit above threshold." (Four spatial frequencies were used and observers adjusted retinal disparity of a stimulus by method of adjustment.) In their summary of these experiments the authors included explanations for just how contrast affects stereoacuity. They first considered the possible effect of contrast on the disparity selectibity of the binocular neurons. They reasoned that if the disparity tuning curve of a neuron became steeper with increasing contrast, the same criterion response could be obtained from that neuron by smaller disparities at higher contrasts. However, the neuron's signal to noise ratio could be affected as the neuron may respond variably with contrast. Thus the reliability with which the signal changes in disparity would be affected. Another hypothesis is that increasing contrast causes the ingathering of additional neurons into the disparity calculating process. Increasing the contrast to a high level potentially allows viewers to use disparity information carried by spatial frequencies which were below detection threshold at lower contrasts. This hypothesis however does not hold for higher frequencies since Schor and Wood (1983) showed that stereo performance remains unchanged for those frequencies greater than 2.5 cycles deg -1. A second version of this 'ingathering' model suggests that different contrast thresholds are possessed by different disparity selective neurons. Increasing the contrast would increase the number of cells responding, which would increase the chances that some subset of those neurons would reliably register a near-threshold disparity. Halpern and Blake note that their results are consistent with "models positing that disparity is computed at different spatial scales, if we assume that this computation is based on signals filtered through spatial frequency tuned channels whose outputs pass through a compressive contrast nonlinearity that varies with spatial frequency. If stereoacuity is limited by feature localization at the outputs of such channels, then perhaps the effect of stimulus contrast on stereoacuity is one of lowering the precision with which features are localized. How the disparity mechanism uses the outputs of those filters is unclear."

The second study conducted by Halpern and Blake in 1988 investigated the effects of intraocular differences in contrast on stereoacuity. Stereoacuity was found to steadily degenerate as the interocular difference in contrast increased as long as the fixation targer contrast on one eye was high and the contrast was progressively decreased for the other eye. When the one eye's fixation target was of low contrast and the other's was successively raised, small contrast increases caused no effect on the performance. Then once a certain amount of difference between the two eyes was reached, the stereoacuity began to deteriorate. In an attempt to use these results to determine at which <u>stage</u> in visual processing contrast exerts its influence on stereopsis, the authors tied in the results of the first study. They assummed that the effect of contrast, that is the degrading of stereoacuity with lower contrast, results from "influencing the precision with which spatial location of a feature is registered, and that this takes place at the <u>monocular</u> processing stage. Therefore the stereoacuity would be limited by the precision of the monocular feature localization in the eye with the <u>lower</u> contrast image, and feature localization of the high contrast image would be as accurate as when both eyes view the same high contrast. The resulting stereoacuity in bilateral conditions should be the same as in unilateral conditions if contrast is decreased. However, it is found to be worse in the unilateral situation than in the bilateral. Thus, this effect of contrast on feature localization is not solely monocular. Holt et al. (1968, 469) also observed that two images can be perceived monocularly as very dissimiliar yet be still fusable and stereoscopically viewed. They reasoned that this is evidence that the processing of the configuration must occur after the binocular combination of the stereoscopic images has occurred. Halpern et al. (1988) also showed that contrast does not operate at a "<u>single</u> exclusively binocular site".

Finally, the authors made an interesting ovservation on the relationship of stereopsis and amblyopia based on their findings. It is commonly held that stereo deficiency in amblyopia could result from a lack of adequate numbers of binocular neurons. Amblyopia may be sumulated by the differences in interocular contrast of the experiments. However, since the two imbalanced monocular inputs caused difficient stereopsis even with plenty binocular neurons, the 'amblyopia' was not due to a lack of these cells.

It has also been shown that stereopsis can occur in spite of several other different typed of distortion of each of the retinal images with respect to each other (Kaufman 1974, 468-469). This is to be expected since distortions such as shape and brightness differences are usually present in everyday stereoscopic visualizations. One of the distortions that has been clinically simulated and shown to be unable to prevent normal stereopsis is that of uniform expansion (of up to approximately 10%) of the field of one eye's image compared to the other. Another example is rotation of one field compared to the other of up to seven degrees, even in time exposures less than that to afford cyclotorsional eye movements.

The role of contours in stereopsis was given by Hemholtz long ago, and his views on this topic are still accepted (Holt et al. 1968, 470). Through his experiments he drew the assumption that contours are crucial for stereopsis. Holt et al. defined a contour as a "boundary between white and black clusters". In Hemholtz's experiment, one of the stereo images was a drawing of a simple white object on a black background and the other stereo image was the negative (complement) of this. The stereo pair was able to be fused. He concluded taht the contours were crucial for stereopsis since the two fields were totally different except for the location of the contours. However, it has later been shown that when the object is very spatially complex, stereopsis is much more difficult to achieve.

Holt et al. attempted to explain the aspects of stereopsis in this as well as other experiments. The general principles and assumptions are able to be made as stereopsis in these studies was studied in its purest form with the pre-arranged conditions and techniques. One explanation of the occurrence of stereopsis involves minimum visual criteria in order to perceive stereopsis. They observed that in order for a given disparity to be perceived as depth, the corresponding point domains in the two fields must be of a certain size and have a minimum number of picture elements. As disparity increases, the critical point domain size also increases. With an increase of brightness level in the stiumuli, this critical factor decreases. They reasoned that this makes sense because any two images of uncorrelated, random black and white picture elements have, by chance, 50% identical elements. This chance identity is reduced to 33% or less when the stimulus picture contains three or more brightness levels. So under these conditions, more <u>correlated</u> points would be needed in the left and right fields. With a smaller number of brightness levels, the critical size of corresponding point clusters has to be increased since the probability increases that <u>adjacent</u> <u>non</u>-corresponding dots will form false correlations. To achieve stereopsis, the corresponding areas need only be similar, not identical if they are above the critical size. However, the similarity has to be greater than the chance correlation. As the fields that contain them become larger, the probability of finding large false clusters increases. Likewise, with greater disparity (a greater image area to be searched for corresponding forms), in order to achieve stereopsis the size of the critical area has to be increased. Many of the visual phenomena in the experiments involving stereopsis were seemingly "searches for connected clusters in the combined binocular field". They confirmed that patterns could be "matched based on finding connected clusters formed by adjacent points of similar brightness". This corresponding of patterns could be accomplished without recognition of the patterns. It is a crucial factor in stereopsis. The configurations which interfere with this coalescence the most produce the most degradation of perception (Holt et al. 1968, 469).

It has been shown that stereopsis can be perceived in the absence of monocular cues - that is, monocularly recognizable patterns as well as all binocular depth cues with the exception of disparity. In a familiar environment, many monocular cues such as the superimposing of near objects on far objects, apparent size, and linear perspective strongly influence the visual outcome. However, stereopsis has been shown to occur without any of these. Also of interest is the fact that in spite of the absence of these other depth cues, the quality of stereopsis was not degraded in the least. Quality refers to time required for stereopsis, fused image stability, amount of binocular rivalry, etc. Kaufman (1974, 352) noted an interesting contrast betweem monocular and binocular views of the Necker cube. He phrased it as "some monocular cues and binocular disparity may not work in parallel." When this figure, an empty cube is viewed monocularly, it's hard to tell which face of the cube is the nearer one and it changes perspective as one looks at it. However, when viewed stereoscopically, the spontanious reversals in perspective of depth do not occur and the amount of apparent depth is greater between the nearer and distant faces of the cube. He thus concluded that "while the available monocular cues provide qualitative information about the existence of depth, its magnitude and direction are given binocularly". He also reasoned that the information gathered through monocular cues may assist the binocular system in a more precise assessment of a view by giving crude indications of the object's features.

A recent study performed by Chipalkatti and Michael A. Arbib (1988) addressed the contribution of monocular cues in stereopsis. Their purpose was to present support for "the cue interaction model" which uses monocular and binocular cues to estimate depth. This model uses monocular cues to overcome the mismatch of the projection of the retinal images of the two eyes that occurs using binocular cues. This model specifically uses monocular accommodation cues to disambiguate between the correct and incorrect matches of the two retinal images. They proved that the model "successfully achieves its goals by suppressing the cues which represent the 'incorrect matches' ".

Although some environmental as well as inherent influences of stereopsis have been discussed, it is not possible within the scope of this presentation to cover all of the extensive research that has been done over the years on this intriguing subject of stereopsis. An attempt was made to join and compare the earliest theories with the latest on several factors affecting stereopsis. There is, however, much more to be done regarding the unanswered questions of this subject. For example, further investigation is needed to identify the specific neurophysiological pathways in the brain that are utilized to enable stereopsis to occur. Hopefully in time the "depth" of our understanding of this and many other related aspects will be expanded.

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