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Developmental Neuro-Optometry

The Scientific Basis For the Functional Approach to Vision Care Behavioral Optometry

Steven J. Cool -- Pacific College of Optometry

Topical Outline

1. Hebb's Hypothesis: The Organization of Behavior 1949. The functional stimulus interactions that the individual had with the environment, especially early in life, shape the synaptic organization of the visual nervous system.

2. Selye's hypothesis: The Stress of Life, 1956. Stress acts as a major variable in determining the efficiency of behavioral interactions with the environment. The GAS: 1. The alarm reaction. 2. The stage of resistance. 3. The stage of exhaustion.

3. Skeffington's hypothesis: Basic Premise of the OEP Approach to Vision Care. The individual's visual perceptual information processing abilities can be functionally modified by specified environmental stimulus interactions. That is, the functional interactions of individual with environment share, modify, and otherwise control the visual nervous system structure, and the degree to which the organism is placed under stress will determine the direction and efficiency of these structural modifications.

4. Physiological data of the 50's and 60's substantiates Selye. (Ref.: Psychology Today, August 1985, pp. 44-49)

5. Behavioral data of the 50's and 60's substantiates Hebb. A. McGill Studies by Hebb, Fergus, Thompson, Heron B. Cornell Studies by Gibson, Walk, et. al. C. MIT Studies by Held, Hein, et. al.

6. Physiological data of the 50's, 60's and 70's substantiates Hebb. A. Hubel & Wiesel B. Hirsch & Spinelli C. Blakemore D. Pettigrew E. vonNoorden

7. Nobel Prize of 1981 to David Hubel & Torsten Wiesel for their studies of the "functional architecture" of the visual system.

8. Why, if Hebb and Selye have been substantiated, does Skeffington continue to be scoffed at? A. "Placebo", "Black Magic", "Witchcraft" B. The concept of the "critical period"

9. "Critical period" phenomena: A. Prior to 1975 A definite, final, and irreversible end. Hubel & Wiesel, vonNoorden & Associates B. Since 1976 An end, but not definite, not final and certainly not irreversible!! Duffy and associates Spear and associates

10. Physiological data of late 70's suggest a "repression/derepression" model. A. Hubel & Wiesel B. Blakemore & Pettigrew C. Hirsch & Spinelli

11. Attention appears to be a regulator of the "critical period" phenomena. A. Cynader and associates B. Pettigrew and associates

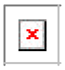
12. Question: If attentional mechanisms are important in regulating the "critical period"/"functional neuroanatomy" phenomena, might these same mechanisms also be important for reversing early experience deprivation effects? A. Early, successful "reversal" studies. 1. vonNoorden early 70's 2. vanSluuters late 70's B. Recent, successful "reversal" studies. 1. Pettigrew and associates later 70's -- importance of the locus coeruleus in controlling selective attention. 2. Singer, Tretter, & Yinon, 1982 -- successful reversal of early deprivation effects. 3. Kasamatatsu and associates 1983-1986 -- stimulation of the locus coeruleus, post critical period.

13. Moral of the story? Two separate neural mechanisms are integrally involved in the plasticity/modifiability of cortical visual information procession!! A. Midbrain reticular activating system mechanisms associated with selective attention/arousal levels. This mechanism "sets a gate" on the primary sensory information input system, and helps to determine what and how much sensory information with "get through". B. The primary visual information input system mechanism -- the "traditional" retino-geniculo-cortical visual system. This mechanism is responsible for visual information processing; but it is "gated" or "modulated" by the first mechanism, the selective attention/arousal level mechanism.

14. Personal Speculation! (of Dr. Steven J. Cool) A. Primary sensory input to the visual cortex and organization of information processing in the cortex is a function of cholinergic synaptic connectivity. B. The functional validation/functional neuroanatomy that is set up by the individual's early environmental interactions (via the primary visual, cholinergic inputs) is modulated by attentional mechanisms. C. These attentional mechanisms (via locus coeruleus) constitute a large adrenergic input to the visual cortex. D. Physiological/psychological stress leads to a general state of 'sympathetic arousal" -- a systemic "pumping" of the adrenergic systems, both neural and endocrine. E. Moderate amounts of stress may modulate the attentional system such that we are in a heightened state of awareness and readiness -- moderate stress/arousal sets us on a "hair-trigger" of alertness. F. But, too much stress may produce a high level of 'spontaneous activity" in these cortical adrenergic system, causing an increased 'noise' level in the primary cholinergic sensory system and interfering with information processing. G. You can't get a meaningful signal pumped through and excessively noisy system. H. On the other hand, a lowered state of stress/arousal/selective attention may reduce the sensitivity of the primary sensory system, making it equally difficult to get a meaningful signal pumped through the system. I. To get selective attention mechanisms to work, in order to effect "functional cures", you first have to reduce the "noise" level, or raise the arousal level such that the system can sense "meaningful information" -- i.e., you may have to reduce stress/raise arousal in the system first before the 'reversal therapies' can work. J. That's the "2X4" of functional optometry: Reduce stress/raise the arousal in the system --- lower/raise the general adrenergic arousal level, such that attentional mechanisms can operate at a reasonably efficient level, and then treat the patient's primary sensory

mechanisms can operate at a reasonably efficient level, and then treat the patient's primary sensory cholinergic information processing deficit.

15. The model: A possilbe mechanical analog model: Light comes in from the left and impinges on the eye. The signal is modulated by the levels of arousal and attention. The end result, moving to the right, is information processing.



To the left is the lowest level of arousal and attention where the "prism" is blocking most of the signal which means that little or no information get through. In the middle, the optimum level of arousal and attention has been obtained allowing the cleanest signal, properly related to it's ground to get through. All the way to the right, the last place alignment of the "prism", allows too much signal to get through and there is far too much overflow into noise in the system which interferes with efficient information processing. Only when the level is at the optimum setting does the correct amount of signal get through.

16. Suggestions for clinical practice? The key to successful applications of functional optometric techniques in the remediation of visual system problems is the use of a two-step process: A. First, The patient's selective attention/arousal level system must be "set" such that the primary visual system pathways are maximally sensitive to visual information input (low plus lenses to reduce stress? Yoked prisms to induce interest/arousal?). B. Then, When the first mechanism is "set", specific visual system therapeutic techniques may be used to modify the information processing capabilities of the primary visual system mechanism.

Selected Annotated References

1. Baker, F.H., Grigg, P., & Von Noorden, G.K., "Effects of Visual Deprivation and Strabismus on the Response of Neurons in the Visual Cortex of the Monkey", Including Studies on the Striate and Prestriate Cortex in the Normal Animal. Brain Research, 66, 1974, 185-208. Studies demonstrating the shift in ocular dominance resulting from deprivation of one eye or sugically induced squint. Deprivation results in the non-deprived eye dominating cortical inputs; and squint results in the non-squinting eye dominating -- stronger shift in dominance for eso than for exo.

2. Crawford, M.L.J., Blake, R., Coo, S.J., & Von Noorden, G., "Physiological Consequences of Unilateral and Bilateral Eye Closure in Macaque Monkeys: Some Further Observations.", Brain Research, 84, 1975, 150-154. Expansion of the findings reported by Baker, Et Al. Also includes some data on the nature of the "critical period" phonomenon in stimulus deprivation amblyopia.

3. Cynader, M., Berman, N., & Hein, A., "Recovery of Function in Cat Visual Cortex Following Prolonged Visual Deprivation.", Experimental Brain Research, 25, 1976, 139-156. One of the earlier attempts to reverse the critical period" deficits introduced by early visual deprivation.

4. Cynader, M., & Mitchell, D.E., "Prolonged Sensitivity to Monocular Deprivation in Dark-Reared Cats.", J. Neurophysiology, 43, 1980, 1026-1054. Demonstration of the importance of paying visual attention to the stimulus array in order for the "critical period" effects to take place. No attention to the visual stimulus

the stimulus array in order for the "critical period" effects to take place. No attention to the visual stimulus leads to no modification of cortical cell processing. There is also a lengthening of the "critical period" following an early period of no attention.

5. Duffy, F.H., Snodgrass, S.R., Burchfiel, J.L., & Conway, J.L., "Bicuculline Reversal of Deprivation Amblyopia in the Cat", Nature (Lond.), 260, 1976, 256.267. By blocking neuroal inhibition in the nervous system, they were able to show that information from an amblyopic eye was able to get through to the visual cortex. Their suggestion was that the amblyopia may be a result of active inhibition of information from the "bad" eye.

6. Gibson, E.J., & Walk, R.D., "The 'Visual Cliff'", Scientific American, April, 1960. Showed that certain aspects of visual system function seem to be innately present in the infant organism, but that other aspects of visual information processing are definitely "learned" early in life, according to the types of sensory experiences that the infant has.

7. Hebb, D.O., The Organization of Behavior, New York: John Wiley & Co., 1949. A major work, which first formally introduced the concept that the way in which the brain is physically "wired-up (The way in which synaptic connections between nerve cells are formed in the brain) is very much a function of the kinds of sensory and motor experiences which the very young infant has. Begins people thinking about "perceptual learning" early in life.

8. Held, R., Plasticity in Sensory-Motor Systems, Scientific American, November, 1965. Discusses the importance of having sensory-motor (e.g., Eye-Hand) co-ordination/integration experiences early in the life of the organism. Without such experience, the organism seems incapable of performing skilled sensory-motor integration tasks as an adult.

9. Hirsch, H.V.B., & Spinelli, D.N., "Visual Experience Modifies Distribution of Horizontally and Vertically Oriented Receptive Fields in Cats", Science, 168, 1970, 869-871. A study in which kittens were raised such that the only visual experiences which they were allowed was looking at vertical or horizontal lines. As adults, these animals seemed functinally blind to lines oriented 90 degrees away from the directions of lines they had seen as kittens; and the cells in their visual cortex were all specialized to respond only to stimuli oriented in the same way as the lines they had previously experienced.

10. Hirsch, H.V.B., & Spinelli, D.N., "Modification of the Distribution of Receptive Field Orientation in Cats by Selective Visual Exposure During Development", experimental brain research, 12, 1971, 509-527. A more in-depth report of the same results as noted in their previous article (reference #9).

11. Hubel, D.H., & Wiesel, T.N., "Receptive Fields, Binocular Interaction and Functional Architecture in the Cat's Visual Cortex", J. Physioilogy, 160, 1962, 106-154. One of the major landmark papers of their career, which describe, in great detail, the organization of cellular information processing in the visual cortex. It is for this work, together with that described in references #13 and #15, that they received the Nobel prize in 1981,.

12. Hubel, D.H., & Wiesel, T.N., "Receptive Fields of Cells in the Striate Cortex of Very Young Visually Inexperienced Kittens", J. Neurophysiology, 26, 1963, 994-1002. One of several articles by Hubel and

Wiesel dealing with the ways in which altered binocular visual experience early in life (by monocular deprivation, artificially induced strabismus, etc.) drastically alters what they called the "functional architecture" of the visual cortex. That is, the early alteration of binocular visual experience drastically changes the ways in which the visual cortical cells process information.

13. Hubel, D.H., & Wiesel, T.N., "Receptive Fields and Functional Architecture in Two Nonstriate Visual Areas (18019) of the Cat.", J. Neurophysiology, 28, 1965a, 229-289. One of the major landmark papers of their career, which describe, in great detail, the organization of cellular information processinng in the visual cortex. It is for this work, together with that described in references #11 and #15, that they received the Nobel prize in 1981.

14. Hubel, D.H., & Wiesel, T.N., "Binocular Interaction in Striate Cortex of Kittens Reared with Artificial Squint", J. Neurophysiology, 28, 1965b, 1041, 1059. One of several articles by Hubel and Wiesel dealing with the ways in which altered binocular visual experience early in life (by monocular deprivation, artifically induced strabismus, etc.) drastically alters what they called the "functional architecture" of the visual cortex. That is, the exarly alteration of binocular visual experience drastically changes the ways in which the visual cortical cells process information.

15. Hubel, D.H., & Wiesel, T.N., "Receptive Fields and Functional Architecture of Monkey Striate Cortex.", J. Physiology, 195, 1968, 215-243. One of the major landmark papers of their career, which describes, in great detail, the organization of cellular information processing in the visual cortex. It is for this work, together with that described in references #11 and #13, that they received the Nobel prize in 1981.

16. Jonsson, G., & Kasamatsu, T., "Maturation of Monoamine Neurotransmitters and Receptors in Cat Occipital Cortex During Postnatal Critical Period", Experimental Brain Research, 1983, 50, 449-458. A further investigation of the material discussed in reference #19.

17. Kasamatsu, T., "Enhancement of Neuronal Plasticity by Activating the Norepinephrine System in the Brain: A Remedy for Amblyopia", Human Neurobiology, 19821, 1, 49-54. A further investigation of the material discussed in reference #19.

18. Kasamatsu, T., "The Role of the Central Noradrenaline System in Regulating Neuronal Plasticity in the Developing Neocortex", Progress in Clinical Biology Research, 1985, 163C, 369-373. A further investigation of the material discussed in reference #19.

19. Kasamatsu, T., & Pettigrew, J.D., "Preservation of Binocularity After Monocular Deprivation in the Striate Cortex of Kittens Treated with 6-Hydroxydopamine", J. Comparative Neurology, 185, 1979, 139-162. A study demonstrating the importance of the locus coeruleus inputs to visual cortex in establishingg "critical period" effects in visual information processing. By eliminating the influence of the locus coeruleus on the visual cortex, they were unable to modify the information processing abilities of visual cortical cells; however, as soon as the locus coeruleus inputs to visual cortex were re-established, the "critical period" modifications were, once again, able to be induced by specialized types of visual experience provided to the subjects.

20. Kasamatsu, T., Watabe, K., Scholler, E., & Heggelund, P., "Restoration of Neuronal Plasticity in Cat

Visual Cortex by Electrical Stimulation of the Locus Coeruleus", Society for Neuroscience Abstracts, 9, Part 2, 1983, 911. A further investigation of the material discussed in the previous paper (reference #19).

21. Kratz, K.E., & Spear, P.D., "Effects of Visual Deprivation and Alterations in Binocular Competition on REsponses of Striate Cortex Neurons in the Cat", J. Comparative Neurology, 170, 1976, 141-151. A study further amplifying the work of Duffy, et al. (See reference #5). In this investigation, they show that, not only is the information from the amblyopic eye being actively inhibited and prevented from influencing visual cortex cells, but that a large amount of that active inhibition was actually coming from the on-going input from the "good" eye.

22. Kratz, K.E., Spear, P.D., & Smith, D.C., "Post-Critical-Period Reversal of Effects of Monocular Deprivation on Striate Cortex Cells in the Cat", J. Neurophysiology, 39, 1976, 501-511. A companion paper to the previous one (reference #21).

23. Kupperman, B.D., & Kasamatsu, T., "Changes in Geniculate Cell Size Following Brief Monocular Blockage on Retinal Activity in Kittens", Nature, 1983, 306, 465-468. A further investigation of the material discussed in reference #19.

24. Kupperman, B.D., & Kasamatsu, T., "Enhanced Binocular Interaction in the Visual Cortex of Normal Kittens Subjected to Intracortical Norepinephrine Perfusion", Brain Research, 1984, 302, 91-99. A further investigation of the material discussed in reference #19.

25. Nakai, K., & Kasamatsu, T., "Accelerated Regeneration of Central Catecholamine Fibers in Cat Occipital Cortex: Effects of Substance P.", Brain Research, 1984, 323, 374-379. A further investigation of the material discussed in reference #19.

26. Pettigrew, J.D., "The Locus Coeruleus and Cortical Plasticity", Trends in Neuroscience, 1, 1978, 73-74. A companion paper to the one by Kasamatsu & Pettigrew (reference #19). In this paper, Pettigrew suggest that the locus coeruleus is involved in the mechanism of selective attention, by "gating" what is allowed to be represented in visual cortex cells.

27. Selye, H., The Stress of Life, New York: McGraw-Hill, 1956. The major work by Selye, which pulls together all of his thoughts and ideas on how stress ifluences the ways in which the physiological systems of the body function. His major thesis is that excessive amounts of stress for prolonged periods of time leads to failure of the physiological mechanisms and, potentially, to the death of the organism.

28. Sherman, S.M., & Spear, P.D., "Organization of Visual Pathways in Normal and Visually Deprived Cats", Physiological Reviews, 62, No.2, 1982, 738-855. A major literature review paper of virtually all of the work done int he field between 1960 and 1980.

29. Singer, W., Tretter, F., & Yinon, U., "Central Gating of Developmental Plasticity in Kitten Visual Cortex", J. Physiology, 324, 1982a, 221-237. One of a pair of papers dealing with the reversal of early experience "critical period" effects in cats. They show, among other things, that, if a major modification of cortical cell information processing is made during the critical period, this modification may be reverese in the

adult animal --- POST-Critical Period --- if the adult is forced to attend to the stimulus array used for the reversal procedures. In these studies, that meant forcing the animals to perform visually-guided behaviors, using only their previously deprived eye, in order to find food and water and to survive.

30. Singer, W., Tretter, F., & Yinon, U., "Evidence for Long-Term Functional Plasticity in the Visual Cortex of Adult Cats", J. Physiology, 324, 1982b, 239-248. One of a pair of papers dealing with the reversal of early experience "critical period" effects in cats. They show, among other things, that, if a major modification of cortical cell information processing is made during the critical period, this modification may be reversed in the adult animal --- POST-Critical Period --- if the adult is forced to attend to the stimulus array used for the reversal procedures. In these studies, that meant forcing the animals to perform visually-guided behaviors, using only their previously deprived eye, in order to find food and water and to survive.

31. Spinelli, D.N., Hirsch, H.V.B., Phelps, R.W., & Metzler, J., "Visual Experience as a Determinant of the Response Characteristics of Cortical Receptive Fields in Cats", Experimental Brain Research, 15, 1972, 289-304. A continuation of the material presented in references #9 and #10.

32. Thompson, W.R., & Melzack, R., "Early Environment", Scientific American, January, 1956. A very early behavioral study showing that the sort of sensory experiences an organism has during the early infancy and childhood period of life play a major role indetermmining how that organism will perceive the world as an adult.

33. Timney, B., Mitchell, D.E., & Cyander, M., "Behavioral Evidence for Prolonged Sensitivity to Effects of Monocular Deprivation in Dark-Reared Cats", J. Neurophysiology, 43, 1980, 1041-1054. A continuation of the material presented by Cynader and Mitchell (reference #4).

34. Van Sluyters, R.C., "Reversal of the Physiological Effects of Brief Periods of Monocular Deprivation in the Kitten", J. Physiology, 284, 1978, 1-17. One of the first studies to show really effective reversals of early experience "critical period" effects in an animal model system.

35. Van Sluyters, R.C., & Freeman, R.D., "The Physiological Effects of Monocular Deprivation in Very Young Kittens", Society For Neuroscience Abstracts, 3, 1977, 433. A brief presentation of the same material covered in the previous paper (reference #34).

36. Watabe, K., Nakai, K., & Kasamatsu, T., "Visual Afferents to Norepinephrine-Containing Neurons in Cat Locus Coeruleus", Experimental Brain Research, 1982, 48, 55-80(?). A further investigation of the material discussed in reference #19.

37. Wiesel, T.N., & Hubel, D.H., "Effects of Visual Deprivation on Morphology and Physiology of Cells in the Cat's Lateral Geniculate Body", J. Neurophysiology, 26, 1963a, 978-993. One of several articles by Hubel and Wiesel dealing with the ways in which altered binocular visual experience earl in life (by monocular deprivation, artificailly induced strabismus, etc.) drastically alters what they called the "functional architecture" of the visual cortex. That is, the early alteration of binocular visual experience drastically changes the ways in which the visual cortical cells process information.

38. Wiesel, T.N., & Hubel, D.H., "Single-Cell Responses in Striate Cortex of Kittens Deprived of Vision in

One Eye", J. Neurophysiology, 26, 1963b, 1003-1017. Same comments as above.

39. Wiesel, T.N., & Hubel, D.H., "Comparison of the Effects of Unilateral and Bilateral Eye Closure on Cortical Unit Responses in Kittens", J. Neurophysiology, 28, 1965a, 1029-1040. Same comments as above.

40. Wiesel, T.N., & Hubel, D.H., "Extent of Recovery From the Effects of Visual Deprivation in Kittens", J. Neurophysiology, 28, 1965b, 1060-1071. Same comments as above.

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