INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

SMR.853 - 18

ANTONIO BORSELLINO COLLEGE ON NEUROPHYSICS

(15 May - 9 June 1995)

"Manifesto on Dyslexia"

Gad Geiger
The Media Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02139
U.S.A.

These are preliminary lecture notes, intended only for distribution to participants.

MAIN BUILDING STRADA COSTIERA, 11 TEL. 2240111 TELEFAX 224163 TELEX 460392 ADRIATICO GUEST HOUSE VIA GRIGNANO, 9 TEL. 224241 TELEFAX 224531 TELEX 460449
MICROPROCESSOR LAB. VIA BEIRUT, 31 TEL. 224471 TELEFAX 224600 TELEX 460392 GALILEO GUEST HOUSE VIA BEIRUT, 7 TEL. 22401 TELEFAX 2240310 TELEX 460392

Facets of Dyslexia and its Remediation
S.F. Wright and R. Groner (Editors)

MANIFESTO ON DYSLEXIA

G. Geiger and J. Lettvin
Department of Biomedical Engineering
Rutgers University, Piscataway, N.J. USA

APPROACH

Whatever we speculate to be the cause of dyslexia we still must try to explain the process. Our study concerns only the testing of a specific performance and the inferences to be drawn about process; it does not address structural cause.

Dyslexics can foveally identify isolated letters presented tachistoscopically against a blank background, performing as well as ordinary readers. But when short letter-strings or words are presented foveally dyslexics do considerably worse than readers (see also Bouma and Legein, 1977). They complain that letters are "crowded" so that neither letter-identity nor letter-order can be had in the interior of the string, whether the string is a word or a random series of letters. Thus because they speak language and understand the language they hear, it cannot be language that is compromised but something more primitive since it is not judgment, but perception itself, that seems confused. Since each letter can be identified in isolation the acuity is sufficient. By standard optometric tests, the optics of dyslexics (corrected for any refraction error) and the sensory apparatus do not differ from the normal.

The problem in dyslexia is then somewhere between early visual process (i.e., perceptual) and late process (i.e., interpretive). However, it is difficult to decide what is the case by a priori or conventional argument, and there is no reason for assuming one or the other without evidence. Disorder of eye movement as causal is ruled out by the problem surviving under tachistoscopic presentation. Disorder of visual word comprehension as primary and causal is ruled out by the difficulty with letter strings that are not words; for. how can one visually interpret what is not comprehended? Disorders of form recognition of symbols or letters is ruled out because in isolated presentation they are as easily identified by dyslexics as by ordinary readers. Thus there must be some visual degrading property in the seen aggregate which is not inferable from the aggregate as a collection of individuals.

There is an ancient principle that all the information in perception is provided by the senses and no contribution is had from expectation, will or belief of the perceiver. Sharpened over two millenia, that principle in one or another phrasing keeps us from the philosophic vacuity of pure solipsism. Under this rule no information can be added by the perceiver, but there is nothing that says that all sensory information must be preserved in process. Indeed, the concept of information processing involves the sacrifice of information to gain intelligibility; it is always degenerative of information. (e.g., the data which are fitted by a function cannot be recovered from the function). Accordingly there is no prohibition to keep the perceiver from actively reducing the information supplied by perception so long as none is added. And so perception itself can be systematically degraded by the perceiver without violating the principle stated above.

This is all the fiat needed to investigate perception directly for signs of a shaping influence from higher functions, not contributory to the content of perception but degradingly modulatory of it, diminishing the content to facilitate visually guided action. We suspected that such shaping influences were different between ordinary readers and dyslexics. We proposed that there are task-directed strategies of vision that shape, but do not augment the content of visual perception, that these strategies are learned in the course of achieving expert task-performance, and that dyslexia represents such a strategy misused.

EMPIRICS

The empirics sketched here are given in detail by our recent paper (Geiger, Lettvin & Zegarra-Moran, 1992) which is too long to be rewritten for inclusion in this chapter. We direct the reader to it as a reference paper.

The method is a simple perceptual test, easily replicated. Pairs of letters are projected tachistoscopically on a screen (we do not use a CRT display in working with the peripheral visual field). One letter of the pair is always presented at the centre of gaze and the other letter in the peripheral field along the horizontal axis. In successive presentations the peripheral letters are presented at different eccentricities (angular distances to either side from the centre of gaze). Each test consists of 200 such presentations. The response to each pair is recorded and the plot of the average of correct peripheral letter identification against eccentricity is called the "form-resolving field" (FRF).

We have redrawn one of the figures from Geiger et al. (1992) to show how the FRF of 10 ordinary readers differs from that of 10 severe dyslexics (Fig. 1). The FRF of ordinary readers is monotonic, narrow and symmetric to the left and right of the centre of gaze. That is, eccentric letter identification for ordinary readers is best in and near the centre of gaze and it falls off rapidly with eccentricity. The FRF of the English-native severe dyslexics (Fig. 1a) is similar to that of ordinary readers on the left side but is markedly different on the right side, i.e. it is distinctly asymmetric. Their FRF on the right side is not monotonic and it is wider. For these dyslexics, best recognition of the letter pairs occurs when the peripheral letter on the right side is at 5°-7.5° eccentricity. Recognition extends farther in the peripheral field than it does for ordinary readers. And with 2.5° eccentricity on the right, the recognition of the letter pairs is significantly lower than with 5° eccentricity (Geiger & Lettvin, 1989).

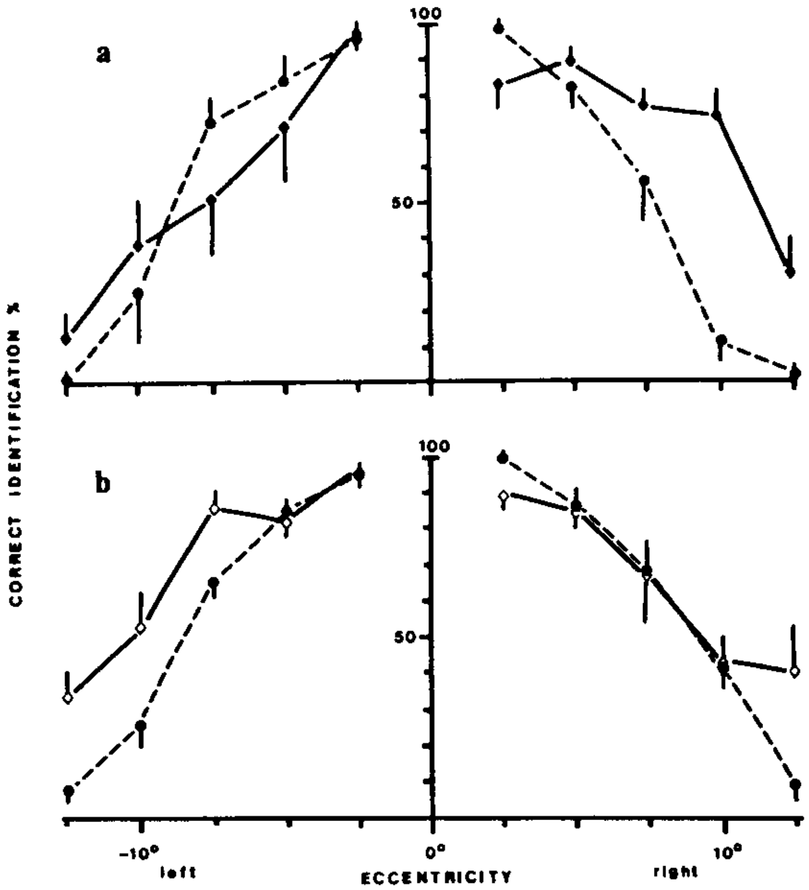

FIG. 1. Depicts the % correct identification of the peripheral letter as a function of eccentricity. The solid lines are for adult severe dyslexics, the dashed lines for adult ordinary readers. a. English-natives. On the right, at all eccentricities except for 5°, the differences between ordinary readers and dyslexics are statistically significant. On the left side the plots are not significantly different. b. Hebrew-natives. The plots are similar on the right side except at 2.5° where they are significantly different. On the left side, the plots are significantly different except at 2.5° and 5° eccentricities. The recognition of the central letter of the pairs in all cases has been above 90%. The vertical bars denote the standard deviation.

On the other hand, the FRF of 5 adult Hebrew-native severe dyslexics (Fig. 1 b) is also asymmetric but inversely directed with respect to that of English-native dyslexics. It is wide to the left, but narrow and similar to that of ordinary readers on the right. There is a dip of recognition near the centre on the right as with English-native severe dyslexics. The FRF of 5 adult Hebrew-native ordinary readers is symmetric and narrow and is similar to that of English-native ordinary readers.

During the last few years we have measured 47 adult ordinary readers and 11 ordinary reading children, altogether 58 ordinary readers. These subjects were reading according to their developmental levels and did not show any other learning problems. The FRFs of some of these subjects were tested a few times during the years and showed no changes. All the ordinary readers had FRFs similar to that of the ordinary readers in Fig. 1. Over the same time we have measured 10 adult residual dyslexics (Geiger & Lettvin, 1987), 10 adult severe dyslexics, and 34 other dyslexics of whom 20 were children, i.e. 54 dyslexics in all. The FRFs of the dyslexics were similar to what is depicted in Fig. 1 for severe dyslexics and were distinct from the FRF of ordinary readers individually and as a group.

The dyslexic subjects had all been diagnosed by independent psychologists and neurologists prior to their arrival in our laboratory. Except for the 10 residual dyslexics who were assigned to us by their teachers, all the dyslexics arrived in our laboratories (in the USA, Italy, Israel and Germany) upon hearing about us. We did not select or choose them and, as far as we know, we were not recommended to them according to any specific sub-type of dyslexia. All these dyslexics had normal or above normal intelligence, they comprehended language and spoke without any difficulties. None of them had any evident neurological symptoms but all had marked handicap in reading. The adult severe dyslexics had grave reading difficulties and had not been in any remedial training for at least three years prior to our testing. In order to read at their low level of competence they had adopted many kinds of reading methods (letter-by-letter, skimming, mirror image reading etc.). The adult residual dyslexics who had been in long term remedial training for reading were in college and had serious reading problems although not as extreme as those of the severe dyslexics.

The dyslexic children had reading levels at least 2 grades below their age and the level of their other academic achievements. Each dyslexic had a personal way of reading and these ways or styles were most diverse. However, the FRFs of all the dyslexic individuals were similar, asymmetric with wide eccentric-letter recognition in the direction of reading (to the right for English and Italian natives, and to the left for Hebrew natives). There was lessened letter pair recognition in and near the centre of gaze where the other letter always appeared.

The differences in the FRFs between adult ordinary readers and dyslexics were independently verified by Perry, Dember, Warm & Sacks (1989) who have tested the subjects by using an optical projection display. On the other hand, when we performed the same tests using a CRT display the differences between dyslexics and ordinary readers were smaller and not significant (see also Klein, Berry, Briand, D' Entremont & Farmer, 1990). The reasons for the differences between results with the CRT and the image projection methods are interesting technically (Zegarra-Moran & Geiger, in press) but outside the realm of this chapter.

We attribute the differences in shape of the FRF between ordinary readers and dyslexics to different distributions of a feed-back influence on perception. Later discussion will enlarge on this point. This influence is best known by one of its manifestations, lateral masking (as described, e.g., by Bouma, 1970), sometimes called "crowding". It is the loss of identifiability of a form due to the presence of neighbouring forms in the visual field, and was first studied in peripheral vision. The effect is demonstrated by Figure 2. If instead of single eccentric letters in the FRF test we use strings of three letters, ordinary readers show a steep increase of lateral masking with eccentricity, strongest for the middle letter. Dyslexics, however, show a more shallow increase of lateral masking with eccentricity and beyond 5° eccentricity, the middle letter is markedly less masked than for readers (Geiger & Lettvin, 1987, 1989, Geiger et al., 1992).

As a diagnostic measure the FRF is an easier test to perform than analysis of lateral masking within short strings of letters at different eccentricities. It distinguishes the same populations although it does not give the same detail of interaction between neighbouring symbols. In the peripheral field isolated letters against a blank background have a "self-masking" property that is less in foveal presentation. The parts of a complex letter seem to interact to ambiguate the letter shape (Fig. 2). But in the fovea self-masking is not obvious. Bouma & Legein (1977) have shown that dyslexics recognize isolated letters in or near the centre as well as ordinary readers do, but dyslexics recognize strings of letters or words in and near the centre worse than do ordinary readers.

The different shapes of the FRFs between ordinary readers and dyslexics and their associated distribution of lateral masking indicate how these two groups differ in visual perception. When ordinary readers gaze at a word, the letters comprising the word mask each other very little but the surrounding text away from the direction of gaze is strongly masked. On the other hand when dyslexics gaze at a word the letters in and near the centre of gaze mask each other. However, dyslexics perceive the letters best in the near periphery in the direction of reading but at the same time they perceive a large portion of the surrounding text, since it is poorly masked. Hence they do not perceive words in isolation as ordinary readers do. Consequently dyslexics do not recognize well the form of words, cannot isolate words adequately; the text seems to be "seen all at once" as they say.

As appears from these measurements, the FRF has one shape for ordinary readers and another for dyslexics. Another shape of the FRF can be shown in a group of 5 Italian-native "speed readers" whose FRF is wider to the right than that of ordinary readers; but it does not resemble that of dyslexics (Geiger & Lettvin, 1991). Other measurements have shown differences in the FRFs related to different stimulus types (letters vs. line drawings of objects) and for different age groups as related to different tasks (Zegarra-Moran & Geiger, in press).

We have determined that the differences between ordinary readers and dyslexics correlate with the differences in their FRFs and it occurred to us that the FRF measures a visual strategy that is learned. To show causal relations between a learned visual strategy and the skill of reading we had to show that it is possible for a dyslexic to learn a new visual strategy, that this learning also improves the reading skills as a consequence, and that the change is reflected in the FRF.

Four severe dyslexics volunteered to participate in a practise regimen which is described in detail in the reference paper. The regimen was not devised as a remedy but as a test for our hypothesis of visual strategy. This regimen had two complementary activities. One was to devote two hours a day to novel small scale hand-eye coordination activities like painting, drawing, clay modeling, etc. The other was to practise recognizing words at that eccentricity where letter strings were best recognized. We asked the subjects to use a specially designed mask which they laid on the text to be read. The mask was a blank sheet with a rectangular window, cut to be somewhat larger than a long word in the text. Left of the window and at the optimal eccentricity determined by the individual FRF of the participant we drew a fixation mark. The subjects laid this mask on the text to be read, fixed gaze on the mark, and read the word which appeared in the window on the right They shifted the mask along the text and read it word by word.

After 2 1/2 to 4 months (different for each participant) of this combined practise which we purposely did not monitor or supervise, we measured their FRFs and observed how well they read and with what effort. The shape of the FRF for each individual and for the group had shifted to resemble that of ordinary readers (Figs. 6, 7, 8 in the reference paper). At the same time their reading had improved dramatically and took much less effort.

This combined practise achieved two complementary objectives: exercise in construction of new task-related visual spaces and, in proximate time, exercise in form recognition for words in the part of the visual field where letter strings were most distinct. The practise of the novel small scale hand-eye coordination tasks provided new maps of operational space through active coordination of sensory-motor with visual control (Held & Gottlieb, 1958; Held & Hein, 1958; Kohler, 1962). At the same time the peripheral reading through the window provided blanking of the text surrounding the words and so enabled the perception of the isolated words as distinct forms in that region of the visual field where lateral masking for them was least. This also ensured that the new practise did not clash with an entrenched existing strategy of masking in the centre.

The subjects used the text mask in the beginning of the practise. But soon they claimed that at last they saw "the forms of the words" and not long after they did not use the mask any more except when they were very tired. According to their report they gazed at the fixation mark as long as they used the mask while reading. We had no way of verifying that. What is clear however, is that when they began the regimen they gazed at the fixation mark while they read, and a few months later they seemed to gaze directly at the words they read.

All but one of the group stopped the practise after we saw and tested them at the end of the few months of training. They felt that in learning this new visual strategy they had gained reading at the expense of other skills involving multi-attentional performances and artistic competences which they valued more. A few months later we measured again the ones who stopped practice and found that the FRFs had reverted to the shapes they had when the subjects came to us first. Their reading ability deteriorated markedly at the same time that the FRFs reverted. Perhaps by psychotherapy and other reinforcements we might have kept them reading. But it was not clear to us that it was our province to make decisions for them. The one case that chose not to revert was a college student who had every incentive to continue.

The last point to cover is a small set of subjects (3) that we call "conditional dyslexics". They fluctuate between being ordinary readers some of the time and being obviously dyslexic some of the time. One case serves to illustrate the character of the change, but the details of timing differ considerably from one case to another. This subject is an adult man whose profession is in the graphic arts. When he wakes in the morning he reads easily and well but his artistic skill is not at its best. By afternoon he cannot read easily at all and feels "tired". At the same time his graphic skill improves and he has no trouble at all in pursuing his work. By the FRF test he is an ordinary reader in the morning but a definite dyslexic in the afternoon. Under a simple regimen he found it easy to switch into the dyslexic mode in the morning so that he could work all day. But he could not switch back to the reading mode in the afternoon. The FRF changes appropriately with his voluntary switching (Geiger & Lettvin, 1989, Geiger et al., 1992).

Three main empirical results emerge from our study:

1. Dyslexics and ordinary readers are systematically different under a specific visual perception test (the FRF) and the difference is in the hemifield corresponding to the direction of reading. Dyslexics who were first taught to read from left to right (English, Italian) are symmetrically different by this test from dyslexics who were first taught to read from right to left (Hebrew).

2. Dyslexics can learn a new visual (perceptual) strategy and as a result their test records come to resemble that of ordinary readers at the same time that their reading skills markedly improve.

3. There exist "conditional dyslexics". They are ordinary readers part of the time and dyslexics at other times. The switch of phases takes time, an hour to a few hours, and the FRF test shows the correlated change.

Now we turn to the concept of task-determined visual strategy and the tactics of lateral masking.

ARGUMENT

From the results we infer that there are two grossly described visual strategies one for ordinary readers and one for dyslexics. Both strategies demonstrably exist for the conditional dyslexics and for the English-native severe dyslexics who learned to read under the regimen we devised. In the dyslexic strategy lateral masking is strong in the fovea and immediate parafoveal region, and it is least at 5^{o}-7.5^{o} to the right of the centre of gaze. Further away from the centre, 7.5^{o} and beyond, the eccentric letter recognition stays significantly better and decays slower with eccentricity than for ordinary readers. In the acquired reading strategy the FRF comes to match that of the ordinary reader; lateral masking in the near foveal region is much lessened. and instead appears mainly in the peripheral field, steepening the decay of the FRF with eccentricity.

That lateral masking can be relieved in peripheral vision was shown by us earlier before the work on dyslexia (Geiger & Lettvin, 1986). That establishes the variable nature of lateral masking action. The present work establishes that the distribution of lateral masking can be controlled.

It would be useful here to give a clear concise verbal description of lateral masking, but in the language of visual psychology, indeed even in common language, the effect is not easily described and is better given by illustration. Fig. 2 will serve to demonstrate what is meant by lateral masking. It is evident that under lateral masking the spatial order of parts in an individual thing and the spatial order between things have become innominate in the interior of an arrangement. There is no blurring of boundary nor decay of contrast, but simply a degradation from a collection of forms, individually describable, to an aggregate that has a texture, i.e. some sort of collection of things that cannot be well told apart or well related spatially. Much less information is provided by the collection as a spatial distribution than as a set of distinct forms related by distinct distances between them.

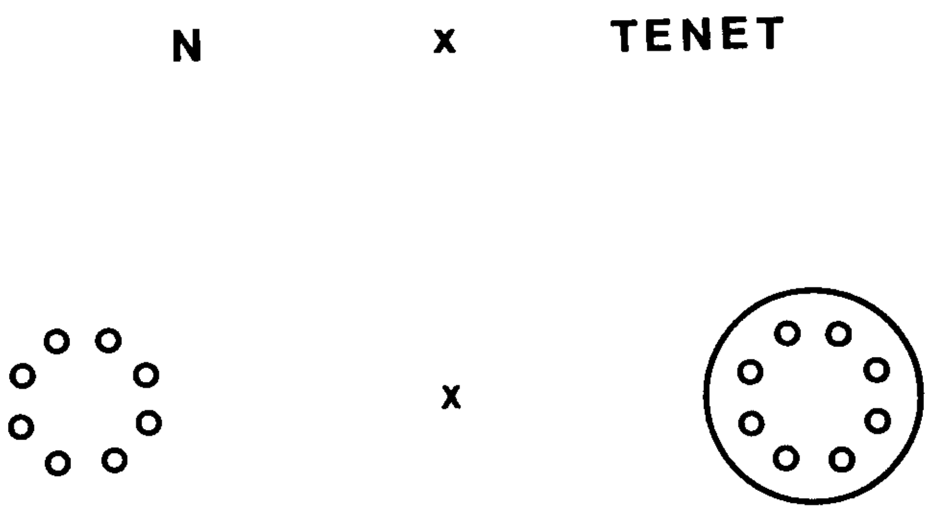

FIG. 2. Two different demonstrations of lateral masking. Fix your gaze on the X in the top line. Without moving your gaze you will recognize the N on the left, however, the N on the right will not be recognizable. The letters surrounding the N on the right "laterally mask" each other. If you fix your gaze on the lower X you will see the small circles on both sides. However the one on the left will suggest the spatial arrangement of a large ring or diamond. The circles on the right surrounded by the large circle will appear as a distinct heap of small circles without a particular spatial order.

How the image of a local arrangement of distinct separate things in perception can be reduced to the impression of a texture in the same part of the visual field is a technical process that would be idle to pursue here. More to the point is that the regional process of form-to-texture degradation is demonstrable and can be shown by experiment to be regionally reversible under training. Lateral masking can be controlled in its distribution; it is the tactical arm of visual strategy; different distributions define different strategies. Dyslexia now becomes crudely understandable in terms of the how dyslexics describe what they see. Consider first a vague argument. If indeed there is lateral masking between letters in central vision and little masking peripherally, how can a dyslexic ever see individual words in textual context ? And if they can't see them how can they reinforce learning to read in central vision? Rather, the failure reinforces itself as is known to happen elsewhere, and the condition seems intractable since the problem is in perception not in action. If they but knew what to perceive, the words as forms had from specific serial arrangements of letters, the task would be defined and they could improve. It is a strange concept. But the four severe dyslexics whom we brought to read called us independently after a few weeks to report one way or another that finally they saw "the shape of a word" in the eccentric window of the text masker. Only then, when they knew what to look for, did the task of reading become experientially defined.

There is no way of dealing with task-driven form-texture transitions (as were described in the previous paragraph) by conventional theories of visual perception and certainly no way of excluding intention in its various forms. But an elementary approach through task performance is useful. We each have an internal model of the world by which we decide what actions to take on the information received from perception. Those actions are taken to change what we currently perceive to what we want to perceive. To be able to operate at all in a complex world we have to relegate to background what is not relevant to attaining that new perceptual state as a goal, otherwise the amount of informational processing needed is enormous. It is not that we attend what is relevant by enhancing it in perception --that is regenerative, unstable, and violates the canon of perception by adding something to it. Rather we choose cognitively what is relevant and degrade everything else, reducing information about everything else and relegating it to background. This is degenerative, stable and consistent with the canon.

Lateral masking is the way of degrading form to background. For this to work as a system there must be a representation of what we intend by which to degrade everything else. We practise acting not only to refine what we do but to limit the content given by perception so as to speed our action. It is that practise that shapes the particular distribution of lateral masking. To act towards a goal there must be some representation of it, some model of what we want to perceive, and if there is none we flounder with inappropriate action. This can lock us into a mode of degrading precisely what is needed for conceiving the goal. To break this block it is necessary to by-pass it so as to evolve a new strategy. Battering against the block only reinforces it. That guided what we did with the four severe dyslexics.

Emerging from this loose formulation is a specific point. The strategy of degrading a region to background by the distribution of lateral masking is not shaped by cognition unaidedly acting back on perception. As in any action it is necessary to predict what is expected in the immediate future where in the visual field it will occur and how it is to be processed. Degrading to background is not specific but merely applies to everywhere in the field except where intended or expected change is to happen. This involves two factors in our internal model of the world, a notion of where the predicted perception is to occur and what the nature of the content will be. In turn these two factors are developed only by practise in the real world for which the model is to be developed in cognition. Suppose in over-simplification we consider the visual field divided into two regions, the central or foveal field, and the surround or peripheral field. And imagine that form-to-texture degradation can be switched between the two fields depending on whether we are interested in predicting detail of the stationary scene (foveal vision) or detecting what moves in the scene (peripheral vision). It is easy to see how, without prior knowledge of what to look for, a wrong strategy can be acquired, an inappropriate state of the switch. And with the practise of wrong strategy, the "what to look for" cannot be conceived and a vicious cycle freezes the practise against certain specific tasks. The important point is that the switch of distribution of degrading-to-background is a switch of visual perceptual strategy that is task-determined to be sharpened and shaped by active practice, not by gedanken-experiment. It is acquired by training, not by an arbitrary effort of the mind to conceive what has never been experienced so as to experience it.

By this crudely put argument we justify the concept of task-determined visual strategy. By itself, the strategy does not determine competence which is gained only by practise under the strategy. Expertise is another matter. For example, young ordinary reading children who have first learned to read have the same FRF as adult ordinary readers (Zegarra-Moran & Geiger, in press). Thus, there is a wide distribution of reading competence among ordinary readers (Shaywitz, Escobar, Shaywitz, Fletcher & Makurch, 1992).

Visual strategies can be delicately designed but our evidence for this will take much too long to develop here. The idea of learnable visual strategies shaped by task-performance and practise is the central point of our analysis of dyslexia as a learned perceptual dysfunction rather than a fault in cognition. By "learning" we do not mean the acquisition of some abstract explanation but the competence to perform a task --the ability to use what is had in concept. Without use there is no knowledge.

We believe, in line with what has been discussed above, that all of us possess many discrete task-determined visual strategies between which we switch easily and rapidly as task changes. Checking for specific strategy is hard to reduce to experiment unless there is a detectable absence of a required strategy as occur in dyslexics, or a "sticky switch" as in the conditional dyslexics or simply an inappropriate working strategy.

We do not deny that there can be traits, organic predispositions, hereditary, neurological etc., that can be involved with dyslexia, but the expression of the trait is not a necessary consequence of having it, and having the expression does not attest the existence of the trait in the individual. Our study was designed to show that developmental dyslexia is a learned visual strategy, that it can be acquired without any organic cause, and that it need not prevent acquiring a reading strategy.

POSITION

Developmental dyslexia is generally a learned visual strategy, rather than the product of neurological or genetic predestination. There are ways of establishing a separate reading strategy for dyslexics. Both strategies can coexist in the armamentarium of vision but only one can be used at a time. For the task of ordinary reading there seems to be a basic strategy and for dyslexia several aberrant strategies: but the crude classification into two general types of strategy serves our purpose in this paper.

REFERENCES

Bouma, H. (1970). Interaction effects in parafoveal letter recognition. *Nature* 226, 177-178.

Bouma, H., & Legein, Ch. P. (1977). Foveal and parafoveal recognition of letters and words by dyslexics and by average readers. *Neuropsychologia*, 15, 69-80.

Geiger, G., & Lettvin, J Y. (1986). Enhancing the perception of form in peripheral vision. *Perception* , 15, 119-130.

Geiger, G., & Lettvin, J.Y. (1987). Peripheral vision in persons with dyslexia. *New England Journal of Medicine* , 316, 1238-1243.

Geiger, G., & Lettvin, J. Y. (1989). Dyslexia and reading as examples of alternative visual strategies. In C. von Euler, I. Lundberg, & G. Lennerstrand (Eds.), *Brain and Reading*, London: Macmillan Press Ltd. pp 331-343.

Geiger, G., & Lettvin, J. Y. (1991). The form-resolving field (FRF) as a measure of specific visual strategies. *Invest. Ophthal. Vis. Sci*, 32(4), 1238.

Geiger, G., Lettvin, J. Y. & Zegarra-Moran, O. (1992). Task-determined strategies of visual processing in readers and dyslexics". *Cognitive Brain Research* , 1(1), 39-52.

Held, R. & Gottlieb, N. (1958). Technique for studying adaptation to disarranged hand-Eye Coordination. *Perceptual and Motor Skills*, 8, 83-86.

Held, R. & Hein, A.V. (1958). Adaptation of disarranged hand-eye coordination contingent upon re-afferent stimulation.. *Perceptual and Motor Skills*, 8, 87-90.

Klein, R., Berry, G., Briand, K., D'Entremont, B. & Farmer, M. (1990). Letter identification declines with increasing retinal eccentricity at the same rate for normal and dyslexic readers. *Perception and Psychophysics*, 47(6), 601-606.

Kohler, I. (1962). Experiments with goggles. *Scientific American*, 206, 62-72.

Perry, A. R., Dember, W. N., Warm, J. S. & Sacks, J. G. (1989). Letter identification in normal and dyslexic readers: a verification. *Bulletin of the Psychonomic Society.*, 27, 445-448.

Shaywitz, S. E., Escobar, M. D., Shaywitz, B. A., Fletcher, J. M. & Makuch, R. (1992). Evidence that dyslexia may represent the lower tail of a normal distribution of reading ability. *New England Journal of Medicine*, 326, 145-150.

Zegarra-Moran, O. & Geiger, G. Visual recognition in the peripheral field: letters vs. symbols and adults vs. children. *Perception* , (in press).