The Aliasing of Images:
A Neurophysiological Basis for Some Reading Problems

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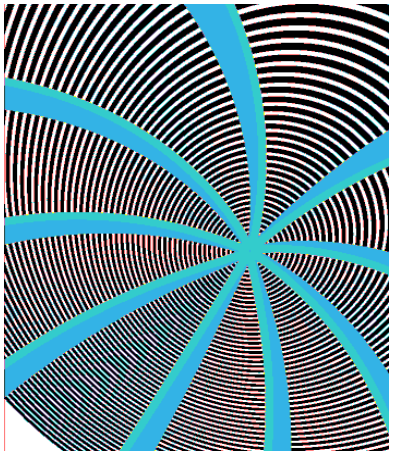
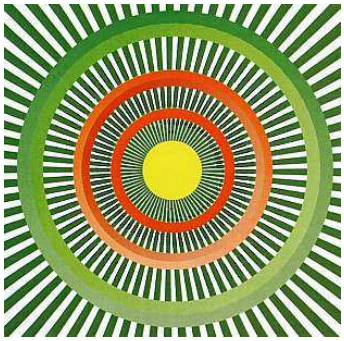
APPARENT, ILLUSORY MOVEMENT

The figure at the right is called the Enigma Painting because of the apparent movement in the rays/arms. Where is the movement in this illusion occurring? The answer is, in your brain, of course. Now, close one eye. The illusions will reduce for most observers. Switch eyes. Did the quality of the movement change? Remember this - keep this in mind.

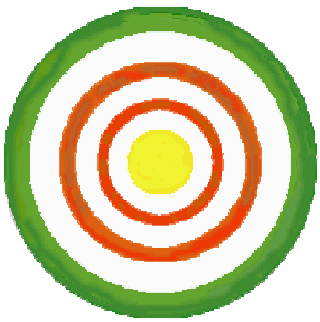




On the left is another variation of the illusion.

Do you see the counter-directional race going on in the tracks? It seems to me that when I look at a track and move my eyes clockwise in a short bit, the movement goes clockwise. And when I do the opposite, the movement goes counter-clockwise. Anyone else note this now? At the right is the same pattern, but the scientist wanted to determine if it was the rings or the rays that contributed the "active ingredient" to the illusion. So, he isolated the rings. Note that there is no movement. It is the striping of the rays - the grating that the rings are set in - that makes the movement occur.

Have you ever heard a patient complain that the print moves on a page? Similar to the illustration in FIG. 4 below. This is an illustration of a child's description of the "River" motion – taken from Rhonda Stone's book "*The Light Barrier*" – with words rippling as though water was running down the page. Or, perhaps there will be shimmering, a swirling movement like in FIG. 5. This is the swirling pattern. Please note that this illustration is take from Helen Irlen's book, "*Reading by the Colors*". The fixation point is clear, but the peripheral text is swirling and smeared in appearance.



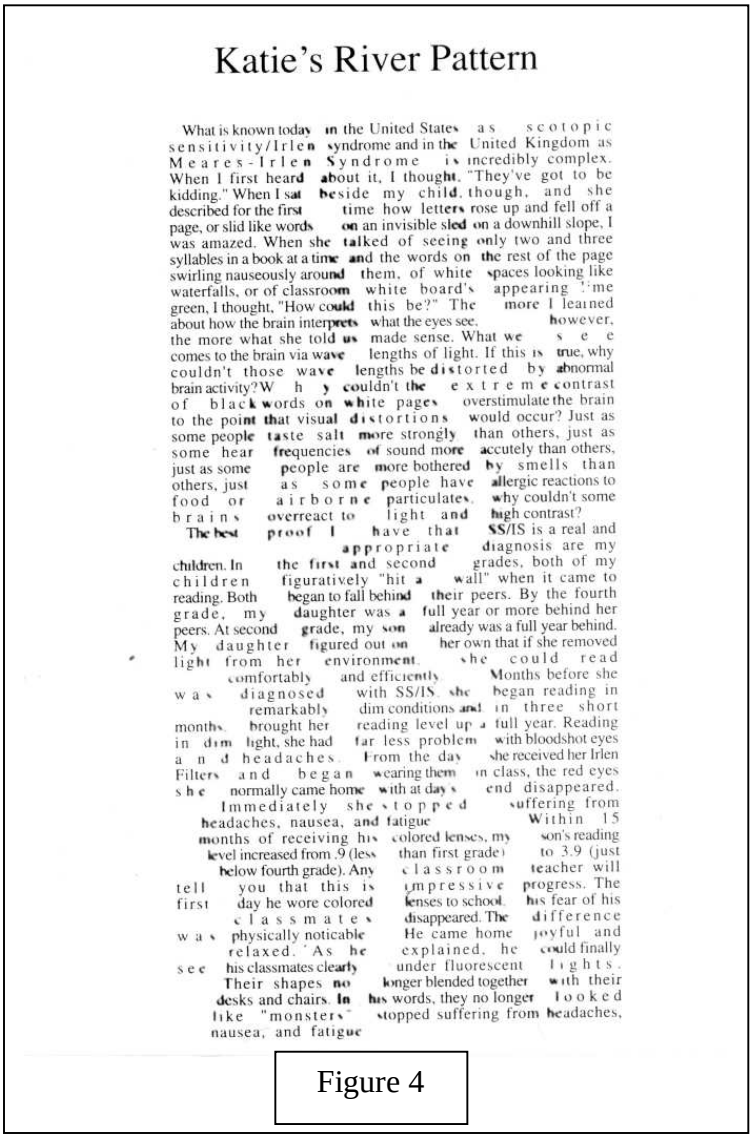


Figure 4

Irlen has had mixed success using colored filters to stabilize the image for certain sensitive individuals for short to long-term periods. Solan did experiments while studying Parvo- and Magnocellular functioning of the Lateral Geniculate Bodies and has recorded a reading change effect with blue filters only – blue stimulates S-cones and the Koniocellular layers 4 and 5, which may be significant, as will be seen later.

Let's go back to grating illusions.

If the grid of FIG. 6 is too problematic for some of you, cover or close one eye or cover the image. Some of you may react strongly, some moderately, some lightly (which can intensify as you look) and some of you won't react at all. (Please don't feel cheated if that is so…) Some of you are seeing ripples, some pastel colors in the white intervals, some a loss of line caliber overall…and many of you are seeing a large, ghostly diamond in the mid periphery.

The significance of this is that these grating lines correspond grossly to the lines of text in a book. If you close an eye, the illusion will disappear, for most, one eye or the other. A few will see them worse.

What's going on here?

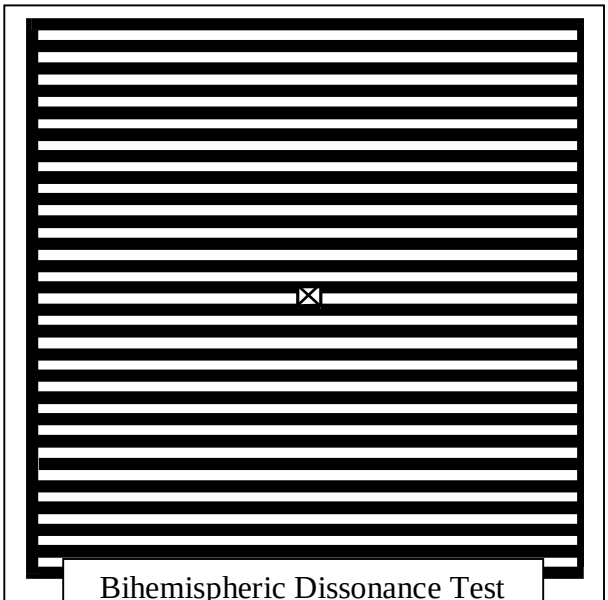
ALIASING

It's called aliasing. Aliasing is a distortion that occurs when two signals that don't match are processed together to form an intermediate signal—a resultant signal—one in-between the real signals. This happens frequently in audio signals, digital representation of graphics, and video displays of complex patterns that are regular— repetitive—in structure.
In the visual system, image aliasing occurs when the retinal photoreceptor mosaic is coarser than the image on the retina, so the very fine spatial details will be improperly registered in the neural image – and, when blended with the parallel image from the other eye – creates the problem being called ***visual aliasing***. The smallest receptor field areas are foveal; the largest field areas are peripheral. This would result in a fall-off in sampling the further away from the fovea that the image falls. In aliasing, undersampling, especially peripherally, causes distorted perception of spatial structure. The eye can detect the form, but its resolution is compromised.

Figure 5

From "Reading By the Colors," Helen Irlen, Penguin Putnam/Perigee Div. Publishing, New York, USA.

Filtering of the image will tend to limit the disturbances of undersampling. Refractive error can also introduce a blur that helps resolve the distortion of aliasing. Let's think about that for a moment. (Pause). Fine, let's go on.



Bihemispheric Dissonance Test
Figure 6

Cortically hypersensitive patients appear to have some sort of problems either neurally or optically and thus experience the dissonance created by aliased signals. Note the pattern of the coat in the picture at the far left in FIG. 7. Notice what undersampling does to that pattern in the picture at the right side. You've all seen this happen on your TV screens when clothing patterns or Venetian blinds clash with the raster of your set.

Now, let's add filtering to the undersampled mix in the next figure and see what happens. Note that the detail is gone, but so is the aliasing of the undersampled pattern. Visually, filtering can occur naturally by corneal, lenticular and retinal cell imperfections. It can also be created by amblyopia (both the usual monocular amblyopia and the more rare bilateral amblyopia, a functional vision loss sometimes called Streff Syndrome), astigmatism and larger amounts of farsightedness.

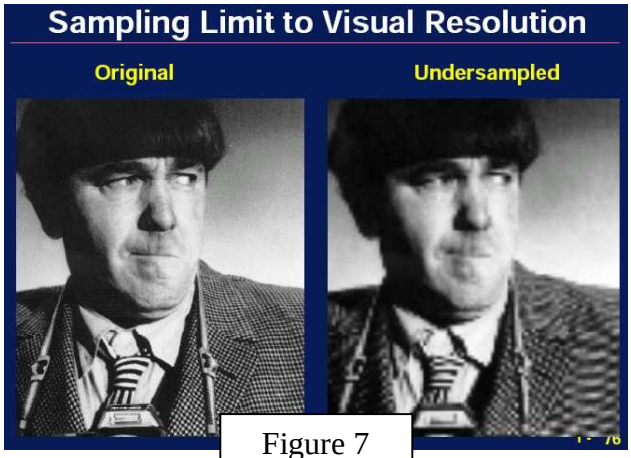


Figure 7

Filtering has its great value in helping us to resolve an image even when details are confusing. Consider the picture in FIG. 9 of a woman at a window. This Dali-esque picture is a curious illustration of the value of filtering. Does anybody see anything else in the picture? Try squinting your eyes to add a filtering effect. What do you see now?

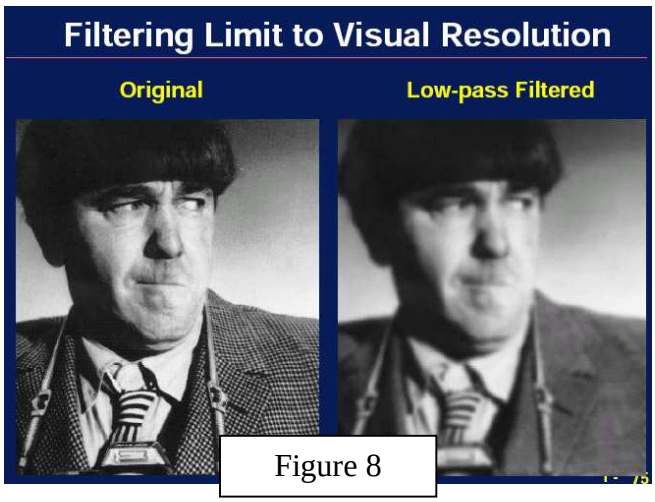
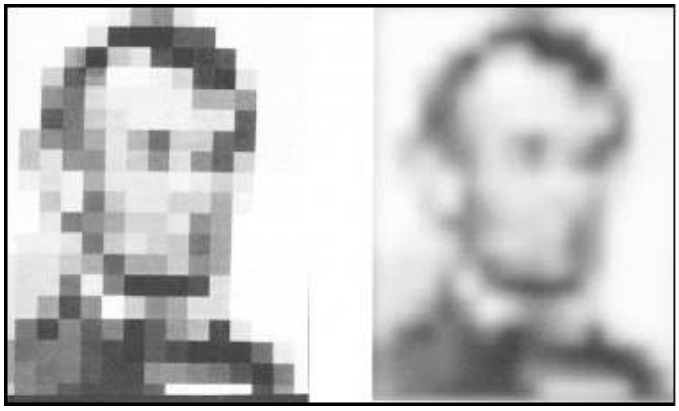


Figure 8

Humor me on this next and you'll learn the value of filtering -- keep your eyes squinted and tell me if you see any difference between the following two pictures. With your eyes squinted yet, which image of Lincoln looks to be the better image? The one on your left, correct? Now open your eyes wide. The right image has been filtered down and the great accuracy of your 20/20 vision no longer serves you as well for the undersampled left image. May I say that blur has its place.

The issue at hand is the matter of critical sampling. The critical level is called the Nyquist interval. That is the point at which one has at least one relatively unstimulated neuron between two relatively stimulated neurons. With a sine-wave grate of the frequency shown in FIG. 10, the critical sampling rate meets the minimum requirements as seen in the middle illustration. Oversampling, seen at the top, gives a more refined resolution of the image, but undersampling – seen at the bottom – gives rise to an erroneously perceived image.

Figure 9



Undersampling can also result in misperception of the orientation of the pattern. (Swirling is thought to arise from this aspect of aliasing.)

Note that the undersampling in FIG. 11 can result in a total change of the perceived direction of the pattern.

Of course retinal cells and receptor sites are not laid out in neat linear patterns, they are irregular. So, here we have a grate at the top that, when sampled by the irregular array in the middle, winds up with a veridical (accurate) representation of the target. But, with the sampling array remaining the same, but with a more complex grate, the sampling fails to accurately reproduce the grating and aliasing will occur.

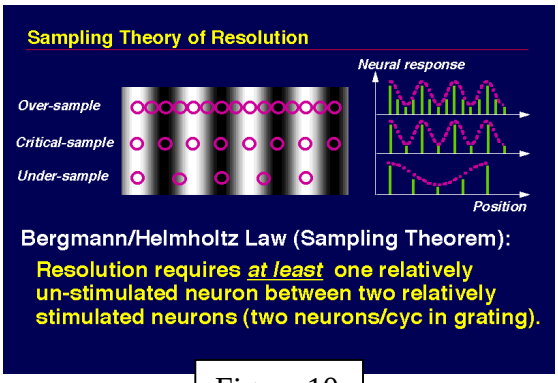


Figure 10

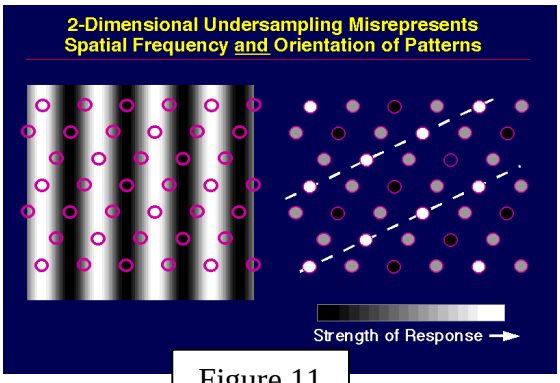


Figure 11

FIG. 12 illustrates some subjective responses to undersampling caused by the target being presented 30 degrees off-axis. The Nyquist factor at 30 degrees off-axis was determined to be 5.5 cycles per degree. So, at 2 and 4 cycles, there is no distortion. There is veridical – accurate – perception.

However, at 6, 8, and 17 cycles per degree, the targets were misperceived, as seen in the illustrations. The center one is the most interesting, since the perceived orientation appears to be 90 degrees off-axis.

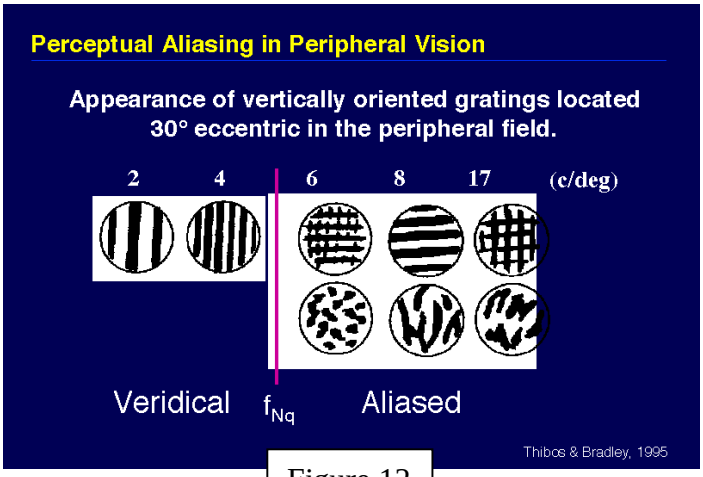


Figure 12

WHERE DO THE ILLUSIONS OCCUR?

The illusions that are most often seen with the grid, in decreasing frequency, are:

- shimmering of the periphery of the grid, or the whole grid;

- color fringes between the lines;
- rivers of motion, in streaks running down the grid;
- loss of caliber between the lines; and,
- ghostly geometric shapes in mid-periphery –frequently a large diamond.

The mechanism for all this appears to be in the pathway between the retinal mosaic and the Lateral Geniculate Bodies, probably in combination with a unique neural hyperirritability (which needs to be explored to clarify it further, since this doesn't happen equally in all individuals).

We won't go into it closely for purposes of this overview, but quickly, let's look at the possible mechanism: The layers of the LGB, as seen in schematic fashion in FIG. 13 are:

The four Parvocellular layers;

And the two Magnocellular layers.

Layers 1,4 and 6 are from the ganglion cell axons of the contralateral eye; Layers 2,3 and 5 are from the ipsilateral eye.

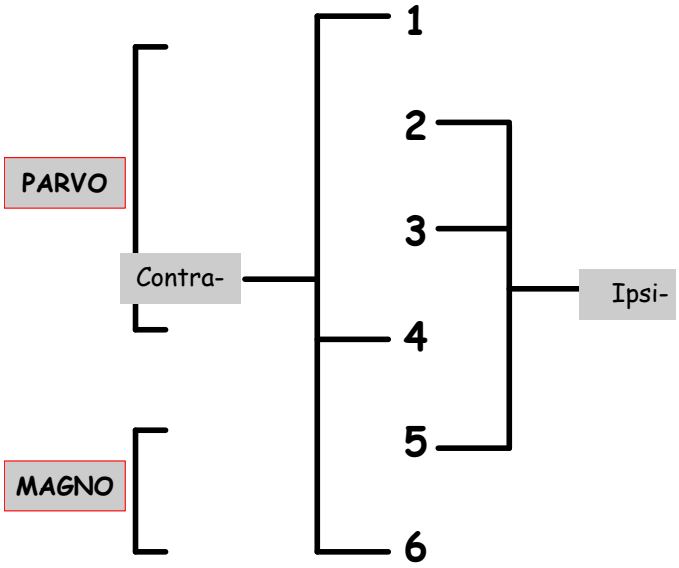


Figure 13

Neuroanatomists tell us that Parvo layer 4b also contains Magno cells from layer 5 (note that these layers are from opposite eyes – dissonance begins to be a distinct possibility at this point, with the P cells reporting color and luminance and the M cells sensitive to and reporting shape and movement).

We also need to consider the interlaminar layers, those that lie between each of the P and M layers. Those are called the Konio-cellular layers. Konio means "dust." They are numbered from bottom to top, K1, 2, 3, 4, 5, and 6. They have a number of various functions, but Konio layers 3 and 4 have function of more interest to us. They are between M and P layers 5 and 4, and P layers 4 and 3. They process S-cone output -- the yellow-blue cone output – plus, they straddle the color-responsive P-cells and the motion-responsive M-cell layers. It may be noteworthy that they are 10 times more sensitive to motion than to color. This is another plausible point of color/motion conflict between the visual inputs.

We need to consider two very important observations:

- Closing one eye eliminates or reduces the mirages for most people (but it can increase the disturbances in a relatively rare few); and,

- Monocular patients have illusion experiences, as well.

PRISMS

Therefore, it is difficult to avoid the conclusion that the primary clinical issue is probably BIHEMISPHERICITY, since the LGB's take input from both eyes, consisting of both central and peripheral field data, whether that information is high or low quality. The more peripheral the target, the poorer the quality, since receptor sites are larger. In highly sensitive brains, the more likely there will be aliasing of these more peripheral images, creating illusions of undersampling.

There are only 5 ways that clinicians can utilize to change the brain. Let's look at the 5, using David Letterman's approach, from the least desirable to the most desirable:

> The #5 way to change a brain is by surgery;
> The #4 way to change a brain is chemically, either via nutrition or pharmacologically;
> The #3 way to change a brain is by biofeedback, training the person to redirect the brain's electrical activity;
> The #2 way to change a brain is by teaching and rehabilitation. This is what we use in visual therapy and Perceptual Therapy; and,
> The #1 easiest way to change brain activity is with lenses, prisms and filters.

There is a third observation to be made right about here:

- Small amounts of base-in prism greatly reduce the image disturbances described earlier. (Sometimes the beneficial effect is amplified with small amounts of plus in combination with the prism, sometimes plus alone accomplishes the benefits.)

However, the liberal use of prism is a clinical no-no in all schools of optometry and ophthalmology residencies. We are told to make the patient earn their prism and to beware of the patient "eating up" prism. I have been recently suggesting, that, based upon these current neurophysiological findings that prism may actually be a GIFT to our patients who are cortically hypersensitive to textual stripes, who experience an undersampled, aliased cortical image. (The "eating up" of prisms is only seen clinically when they are used compensatorally. We are referring throughout this discussion to therapeutic levels of application, not compensatory.)

The dissonance in cortical visual representation is bihemispherically-dependent. Usually, that means binocular vision is involved, but as we are finding, that isn't necessarily so. We have recordings of monocular patients (who only have one functioning eye) whose reading skills improve dramatically with base-in prism placed in front of their good eye. This is not easily understood from a purely optical standpoint, but

it there for all to see and hear (as these individuals read). The same changes do not generally—if at all—occur with prism in any other direction.

How do these low-power lenses work to alter the visual processing? In reverse order from least likely to most likely, the suggestions are that it may be:

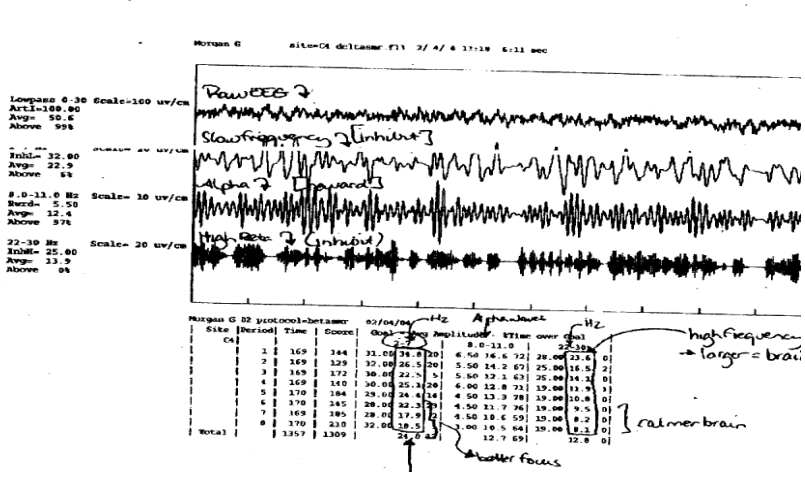
1) Novelty. But this is by far the least likely to directly result in the changes that we can hear occurring.
2) Parvo/Magno-cellular effects in the Lateral Geniculate Body. Certainly, this is where some of the aliasing is created, but it isn't clear just how this might happen directly.
3) Increase of Panum's area (the area in which the brain can fuse two similar targets)? This is more interesting. Because of the smaller vertical dimension of Panum's area, any optical change in retinal image size might make fusion more stable vertically.
4) Changing the SILO response, since both BI prism and plus lenses push the image farther away in space, altering the learned neural responses to the habitual space lattice within which the person has operated.
5) Enlargement of the retinal image – even slightly – will increase the number of cells stimulated in the retinal mosaic, increase the number of receptor fields, thus reduce undersampling and will increase the signal-to-noise ratio in the entire pathway.
6) Though highly speculative, there may be some merit to the possibility that a new pathway is being stimulated.

Lastly, all of the effects noted will have a neural effect and this total combination may change the cortical processing rate. But! What about the novelty issue? Let's look at the learning process.

When presented with a novel task, the Mind's curiosity starts an "intent to search" – for meaning – in the brain. Most often, that becomes a visual search, which releases Dopamine (DA) from the Dopaminergic Amacrine cells in the retina, thought to amount to 1 in 30 of them. It is plausible that the release could trigger a cascade from the more plentiful Dopaminergic cells in the mid-brain and cerebellum. Thus, curiosity – novelty – may be the driving force in any benefit that low plus and prism have in resolving the distress and illusions of aliased text.

Here's what the literature tells us about retinal DA release:

1. Visual acuity increases;
2. Contrast sensitivity increases;
3. Retinal color vision effects (Y-B);



4. Saccadic eye movements improve (via basal ganglia relationships);
5. There is a pleasure response.

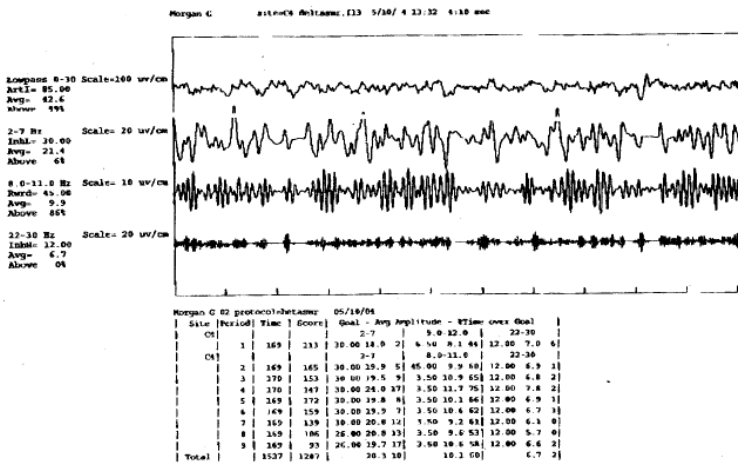
Let's look at a case where DA release had a significant effect.

Below is the EEG of an 11 year-old girl.

As you might suspect from the illustration, this very noisy tracing is showing a brain that is epileptic – photosensitively epileptic. She suffers 30-40 absence seizures per DAY at this point in February 2004.

In response to a listserve request for suggestions, her optometrist and I began a dialogue that resulted in low plus lenses and 1^BIOU prism being applied. This resulted in an immediate change in the girl's ability to initiate the seizures and in her sense of comfort (a common comment with low prism). The neurofeedback therapist managing this child's case for the past two years commented on the dramatic change in the girl's EEG's with the prisms in place.

Here's what the therapist saw:



The entire picture is calmer.

The girl is now experiencing only 4-5 seizures per day and is able to repress them at times when she senses the prodromal signs.

It was during a visual therapy exercise being done while she was practicing neurofeedback therapy that the technician noted a DA release. (A sudden drop in Alpha would manifest this; a drop in frequency to the lowest levels, 6-7 cycles per second, down from the normal 10 or so.)

In a call from her optometrist while this was being prepared, she confirmed that the girl is still 90-95% seizure-free and has been discharged from office-based visual therapy.

SUMMARY:

Brain function appears to be changing in some presently indeterminate regions under the influence of lenses, prisms and filters. These changes are manifested in reading changes. The Bihemispheric Dissonance Test is one way of predicting those patients who will benefit from the prisms and plus, and DA may very well be the chemical mediator of the performance changes.

This all brings up a series of observations and questions:

First, the observations:

- There is a neuro-visual effect that occurs with printed text in certain individuals and that effect can be modulated with lenses, prisms and filters.
- Image aliasing is occurring in some or all individuals, apparently due to retinal→V1 pathway undersampling or other indefinite sort of dissonance.
- This aliasing does not appear to be dependent on binocularity.
- There is some global sort of neural change that is occurring:
    - Image changes occur;
    - Photophobia decreases;
    - Color saturation increases;
    - Patients often report a sense of comfort or calmness that occurs.
- The image distortions respond positively to small amounts of plus and prism.
- Reading rate and comprehension both change, evidenced—for now—by fluency and storytelling changes, indicators of cognitive increase.
- Tracking and scanning skills may increase.

Second, the questions:

- Who are the individuals whom are affected by the aliased images?
    - What are the dependent variables that determine the degree of sensitivity?
    - Is there a genetic link in their families?
- Where in the visual pathway does the aliasing occur?
    - Retina;
    - Lateral Geniculate Body;
    - Primary Visual Cortex;
    - Dorsal or Ventral Pathways; or,
    - Other locations (i.e., Basal Ganglia, Cerebral areas)?
- What are the variables in interventions? Are there limitations to the effects of any of the interventions?
    - What are the dependent variables that determine the degree of sensitivity?
    - Is there a genetic link in the families of these individuals?
- Why do small powered lenses change the response (see text above for further explanation)?
    - Novelty.
    - Parvo/Magno-cellular effects in the Lateral Geniculate Body.
    - Increase of Panum's area.
    - Changing the SILO response.
    - Enlargement of the retinal image.
    - Filtering effect.
    - Extraocular muscle effect.
        - Superior oblique stimulation
        - Medial rectus stimulation

The Bihemispheric Dissonance Test
Preface

Certain individuals—thought to amount to up to 40-50% of the general population and 50-60% of a clinical population—have neurophysiological differences in the makeup and functioning of their visual cortex that results in a heightened sensitivity to striped patterns. Printed text with a 50% duty cycle (that is, the printed lines and spaces between have a 50/50 relation-ship) has the same effect as striped patterns of that proportion, which appear to be the most mirage-provoking relationship. These individuals often suffer from headaches and other aversive symptoms when reading.

This test helps to identify those individuals who respond either strongly, moderately, mildly, or not at all to the patterns. Those who screen out positively on the test grid should have a precision-based visual analysis to determine what, if any, performance prescription lenses might be desirable for reading, study, computing, and any and all other near work (video games, hobbycrafts, etc.).

Over almost 15 years of related clinical application, these prescriptions have proven remarkably resilient to change in the majority of cases, though individual differences occur.

Conducting The Binocular Dissonance Test

1) For use in screening, try to have the patient wear their habitual lenses; for diagnostic use, the patient's subjective prescription to best visual acuity should be assembled into a trial frame. If the patient has contact lenses for the test, the best spherical overrefraction should be in place.
2) Lighting should be as nearly daylight color temperature as possible, but can be effective (and revealing) in bright incandescent light, as well. Pink fluorescent lighting is to be avoided.
3) The patient should be comfortably seated or standing, holding the cards so that there is no surface glare.
4) The tester asks: "What can you see?" (The response may be any of the following or may be "Nothing," or "Stripes with a square in the middle." This is fairly common.) If the answer has been less than the mirage values that occur, the tester then asks simply, "Do you see any colors?" and waits for comments. "Any movement?" – and, if needed – "Any shimmering or dancing in the pattern like snow on a TV screen?" and waits for comments. "Do you see any shadowy shapes? Any geometric forms?" and "Do you see the ink running together between the lines, like the ink ran on poor paper?" If there is strong aversive reaction as the target is presented, allow the patient to gradually expose themselves to the grid, assuring them that they can quit if they are bothered too much, or if they get nauseous or headachy. The examiner is attempting to determine (at least) the degree of disturbance and/or reduction that can be attained with closure of one eye, and even that measure of control may be enough to coax a reluctant observer to view the uncomfortable target (knowing that they can stop any distress by closing one eye).
5) The response is judged by the tester for its quality. "Strong responders show physical reactions, pulling back or pushing the target away, facial distortions, and other bodily reactions. "Moderate" responders show no overt aversive movements but easily report mirages: the movements described in the questioning, color fringes (frequently pastels of yellow, pink, blue, or green), geometric shapes (most frequently a large diamond, triangles, more rarely arcs to either side of fixation) and caliber losses in varying amounts. "Light" responders may have to have their positive signs drawn out by the questioning (being careful not to lead the patient into satisfying you with positive answers). In clinical experience, these Light responders have often started out with no mirage awareness, but may gradually attune to the types of observations being called for and can eventually observe almost all the mirage effects as the test progresses. "No response" responders show no overt awareness of the illusions, but yet some have shown dramatic response on the sample paragraphs and with long-term application of base-in prism. Thus, empirical trials may reveal great benefits to be had for even these apparently non-responsive individuals.
6) The subject is then asked to rate any amount of decrease in the mirage effects on a 10-1 scale. (This may not be possible on some adults and many children under 10 years of age or so. In these cases, the graded paragraphs are used in lieu of the grid.) With the initial response being given a quality value of 10, each lens and lens/prism combination is tried and rated for any improvement (or, rarely, a worsening – seen thus far mostly in individuals who were color deficient) of the effect. If the patient has had a S, M, or L response, ask the patient to close one eye and to note to what degree the effect changes. This is the benchmark reduction of effect that we are seeking to reproduce with the lens and prism combinations. It is often helpful to start the evaluation process by asking, "Has the disturbance gotten any better? If so, by how much? Is it down to a 5? Are we above or below a 5?" If there has been no improvement, try a different lens or lens/prism combination and repeat as necessary through all the lens/prism combinations, attempting to achieve as close an approximation with the lenses as the person sees with one eye closed. It may be helpful to ask, "Have we changed it to below a 5, is it a four? How much change has occurred? Is it above a five? Has it decreased to an eight?" (This helps the person to initiate a self-determined assessment, in terms of the quality of their comfort.) It is entirely appropriate for this to be a subjective process, for it is the person's subjective comfort that we are assessing as far as the patient is immediately concerned, with the objective changes playing an very important, but more secondary role.
7) The best lens/prism combination is then confirmed via an oral reading task with the graded paragraphs. First, empirically select a card of what seems to be an appropriate grade level, have them read and then adjust up or down a level or two, finally choosing the card where reading fluency seems at its peak. (It may be wise to assure a reluctant reader that this is *not* a reading test, but a vision test that *uses* reading.) Then, after the person has read two or three sentences of the last selected card, introduce the lens flipper that achieved the best result on the mirage reduction, and note any changes in fluency, word attack, inflection, speed and vocal quality changes as a positive indication of the need for a pair of performance lenses. As noted above, even "No-response" patients may demonstrate notable changes in reading with as little as 1Δ (Delta) BI, which can be ground into their lenses, but needs to be verified closely at dispensing.

Non-Responders

Children under 10 years of age—or even some adults—may not be sensitive enough observers or have language skills to describe what they are seeing on the pattern grid. The graded paragraphs included with this test are reproduced in the 50% duty cycle ratio for use in these cases. Assure the individual that though he or she will be reading aloud, that this is not a reading test but is a vision test to see if their reading can be helped with minor changes in their eye coordination. Select an appropriate paragraph (parents can be asked for the approximate grade level for a second or third grader). Allow the individual to read two or three sentences, then introduce the flippers with the lenses, prisms, lens/prism combination while they continue to read. Note any changes in reading speed, inflection, fluency, appropriate following of punctuation, word attack, inflection, accuracy of tracking and voice quality.

Prescribing:

The individuals who respond most dramatically are usually sensitive to all aspects of their lens needs, including small cylinders, axes, and anisometropia. Therefore, the most precise subjective lens evaluation that can be determined is used as a base for the flipper lens trials and ultimate prescription. This prescription should be quickly assembled in a trial lens frame and the demonstration conducted over those lenses.

The total time for this evaluation is usually less than five minutes, but is an extremely valuable contribution to the individual's reading, work, and learning experience. The final prescription may take on the form of a reading-only pair of glasses, or a bifocal (the +0.50's responders),or a Subjective to first 20/20 (in OEP parlance, the #7 value, usually a +0.25 D. or +0.50 D. difference).

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