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Eidolons & Capricious Local Sign

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Abstract

Experimental phenomenology probes the meanings and qualities that compose immediate visual experience. In contradistinction, objective methods of classical psychophysics intentionally ignore meanings and qualities, or even awareness as such. Both have their proper uses. Methods of experimental phenomenology that address "equivalence" in a more intricate sense than "visible–not visible" or "discriminable–not discriminable", require stimuli that go beyond the mere level of magnitude-like parameters and perhaps intrude into the realm of semantics. One investigates the cloud of eidolons*, or lookalikes, that mentally surround any image. "Eidolon factories" are based on models of the psychogenesis of visual awareness. The intentional fuzziness of eidolons may derive from a variety of processes. We explore the effects of capricious "local sign". Elsewhere, we formally proposed explicit eidolon factories based on such notions. Here we illustrate some of the effects of capricious local sign.*

Introduction

Experimental phenomenology [1] requires methods that address the meanings and qualities of visual awareness, exactly the elements of visual experience that classical psychophysics attempts to ignore. Indeed, by its very nature phenomenology deals with the concrete actuality of vision, which is subjective and idiosyncratic. The tools—that are experimental paradigms and stimuli—are thus quite distinct from what is conventional in psychophysics. Here we focus specifically on *stimuli*.

On Looking

"Looking" is an action that tends to be dominated by involuntary acts of various types. The visual agent seeks to synchronise with its immediate environment through body movements, eye fixations, the use of a variety of "seek images" [2, 3] and so forth. Looking is primarily a mind building activity, that involves the whole body, including the brain [4, 3].

Techniques of Looking

Psychogenesis—here specifically "visual mind building"—wields a variety of tools. Among these is the (involuntary) selection of fixations. This is very important, because the human visual system is very focally (as opposed to "ambiently") oriented. Indeed there is a broad fringe of awareness that should perhaps be called pre- or proto-awareness. In Leibniz's[5] terms awareness is *apperception*, which is relatively clear and distinct, but is rooted in infinitudes of *petites perceptions*, either unaware or infinitesimal perceptions. This makes good phenomenological sense.

If a friend says "did you notice the threatening sky?" you may think "yes, indeed, that's what I was aware of all the time, only didn't notice that I did", that is an example of the importance of proto-awareness, or unawareness. If you hear a single voice in your mind's ear after listening to a Bach fugue as a complex sound–texture, that is an example of becoming aware of a *petite perception*. (Leibniz's example is the contribution of a single droplet to the sound of a mighty wave.)

Here are the most important *techniques of looking* from a phenomenological perspective:

A ***glimpse*** only lasts for a single moment and does not result from a fixation. Glimpses are usually ignored. The awareness of a glimpse is mostly confabulation of memory after the fact. Glimpses are singular occurrences of a protopathic nature, in that sense they are not even truly *visual*.

A ***glance*** also lasts for a single moment, but does result from a, usually involuntary, fixation. You get a lot from a glance. Some (rare) glances are due to a voluntary fixation and you get even more. The difference with glimpses is the fixation.

A ***good look*** involves a voluntary fixation as well as a few involuntary ones. Good looks are very informative. They result from something *you do* and you bring expectations (questions!) with that. A good look involves a few consecutive moments. Both glances and good looks are generic parts of the natural flow of vision.

Scrutiny involves the deployment of any number of good looks. It obstructs the natural flow of vision. Even in scrutiny you may fail to address even major parts of the optical structure, so called inattentional blindness, but what you scrutinised, you saw well in terms of what you were looking for.

Notice that these familiar techniques of looking fit our schematic model of psychogenesis rather more naturally than the mainstream notion of vision as the result of some computation [6]. The mainstream attempts to model the results of the techniques of looking in terms of "attention", which I consider to be a concept science would do better without.

Apart from the techniques of looking, we need to consider the contributions of peripheral versus focal views, as well as their interactions with fixations. Peripheral vision shares many attributes with glimpses or glances. Moreover, ambient vision contributes an overall spatial scaffold. Perhaps unfortunately, we don't have the space to develop such an important topic here in any detail.

Psychogenesis

How does visual awareness come about? Evidently no scientific account is possible, because awareness is neither physical nor physiological. We sketch a heuristic "cartoon account" of psychogenesis that at least allows us to frame research questions in experimental phenomenology.

The front-end visual system continually overwrites a volatile buffer that we call the *blackboard*[3]. The blackboard contains the structure of the radiance at the corneas in brain-readable format. The visual system performs sophisticated filtering, formatting and sorting. The blackboard thus contains conveniently addressable, but meaningless structure. Perhaps "meaning–free" would be the better term, for any structure may acquire almost *any meaning* in psychogenesis. We prefer to think of it as analogous to the file of a forensic investigation, which contains well–structured data, most of which will never be used to actually solve the case. (Indeed, the presence of a fingerprint may just as well incriminate a person as prove him guiltless!) It is there when needed, indeed any item may turn out to be of crucial importance, although in retrospect most items will turn out to have been ignored.

Awareness results from a process that starts at the inner core of the self[4]. It creates imagery that derives from basic drives and generic situational awareness. The imagery starts with emotionally charged gists, evolves over dreamlike states and progressively articulates, ending in *manifest actuality* (not to be confused with *reality*, see below). At that stage the creative imagination has been checked against what is in the blackboard. This is how the agent synchronises with the physical environment, it renders the concrete actuality a "controlled hallucination". It is exactly the "scientific method", at least, the only method known to Richard Feynman [7], if anyone in a position to know!

When the control is weak, or absent, the hallucinations freewheel and the agent goes through psychotic states. This happens after taking hallucinogenic drugs, or in certain cases of mental illness. In generic circumstances manifest actuallity serves the agent very well in efficacious acting in its physical environment, or "reality" if you want. The latter is willy–nilly outside the agent's mind frame. Thus two agents may well enjoy different manifest actualities in the same physical environment, think of cats and dogs. Reality is something for physicists to worry about. Agents act on the basis of their manifest actuality, there is no other option.

Psychogenesis is a legato-style systolic process that runs at a rate of about a dozen beats a second. Each beat starts at the core and ends when no further articulation is possible. We think of it as a *process of probing*, or *questioning*, again like the work of a forensic investigator following up a *plot*.

A plot allows framing questions and starting to look for answers in the blackboard. Like in the Game of Twenty Questions[8] you sharpen or change your questions until you guess the answer—right or wrong as the case may be—or when your 20 questions are used up.

This process of questioning and probing the blackboard is what generates meaning. For meaning is not in the answers, it is in the questions[9]. Strictly speaking, the blackboard does not contain any answers at all. Answers are created in the process of looking for them in the context of some question. Likewise, the presence of some fingerprint in a forensic file is meaningless, except in the context of some plot. *Meaning is imposed* [10], it cannot be computed. But it is not arbitrary either.

Such a process actively constructs a "counter-world" or "mirror-world" using barrages of "seek-images" in the terminology of von Uexküll[2], the father of ethology. This type of process theory indeed has a very biological flavor, being similar to the evolution of species on a vastly compressed timescale. Indeed, the questioning involves the genesis of extensive, evolving generations of subquestions and the remorseless extinction of generations that fail to lead anywhere.

The imagery at the conclusion of a beat becomes the next moment of awareness, that is your manifest actuality. It is your best bet in dealing with your physical environment, in that sense it is as "real" as can be. But—of course—it is not the God's Eye view[11], not "reality" in *that* sense.

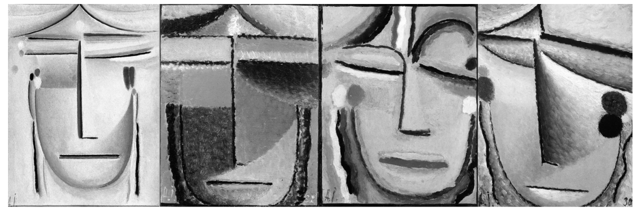

Figure 1. *These faces by Alexej Georgewitsch von Jawlensky (1864–1941) are obviously members of a well defined eidolon, although they are mutually different at first blush. "Equivalence" is very different from "indiscriminability".*

Biological agents have to make do with their manifest actuality, which will be different for each of them. That is one reason why one also speaks of an "interface theory of perception"[12, 13] whose elements are not "veridical", but are rather idiosyncratic "templates" or "Gestalts".

Eidolons

The optical structure momentarily present at the eyes probably never repeats in one's lifetime, except for trivial cases such as pitch darkness, or (approximately) in laboratory settings. Thus vision cannot be based on precise template matching, and any effective template—or seek image—is necessarily visually equivalent to an infinite set of lookalikes, or doppelgänger. These range from cases of imperceptible differences, the JND's of psychophysics, to cases where the difference will be immediately seen, yet the instances appear obviously similar (figure 1), or even cases where the difference might be huge, such as a Picasso portrait painting and a photographic snapshot of the sitter.

We refer to the fuzzy cloud surrounding any image as an "eidolon", sometimes we also use "eidolon" for a single (any) member of the cloud. Any such member is also surrounded by a cloud of lookalikes, which at least partly overlaps with the former eidolon. The eidolon is more important than the fiducial element that generated it. In fact, it makes no difference when you lose the fiducial element. There will be eidolons arbitrarily close to it anyway, the fiducial member is in no way singled out. In the case of Jawlensky's faces (figure 1) there *never was* a fiducial to start with, except (perhaps, vaguely) in the artist's mind. No problem! The eidolon—that is the cloud—autogenerates its "fiducial", which is perhaps much like one of Eleanor Rosch's "prototypes" [14]. Such a prototype is only virtual, but in the case of Jawlensky's faces we have hundreds of eidolons in museums and private collections.

The term eidolon is from the Greek *eidos*, form. For instance, Euripides (c. 480–c. 406 BCE) famously claimed that Helen of Troy never physically was at Troy, but that the legendary battles on the Troy beaches were about an eidolon [15]. Thus the Greeks fought a bitter war over an eidolon for ten years, with mainly grievous losses at both sides to show for it, perhaps suggesting that we should take our eidolons very seriously.

Such apparitions were apparently common enough at the time. To use the term in the present context seems apt, especially because often used synonymously with *phantasma* or *simulacra* in the early theories of vision and optics [16].

Eidolons and the Creative Observer

The creative subject was introduced by Brouwer[17] in mathematics in his attempt to formalise the continuum. Brouwer understood a real number as in an eternal state of becoming, thus never being manifest actuality. Examples are numbers like 1.0000… and 0.9999… (invented by Simon Stevin [18] in the 16^{th}c.), which for a creative subject might be equivalent to a virtual item "1".

Numbers like $1 + \varepsilon a$, where $a \neq 0$ is some real number and $\varepsilon \neq 0$ a solution of $\varepsilon^2 = 0$, are neither larger nor smaller than 1, thus "just as good as 1" and come in arbirary multitudes[19]. Notice that $|n\varepsilon| < 1$ for any natural number n, no matter how large (for $(n\varepsilon)^2 = 0$ for any n because $\varepsilon^2 = 0$). Thus even a trillion steps ε won't take you away from your origin.

Each real number is surrounded by such an infinite cloud of "eidolons" (the nil-square infinitesimals defined above), rendering the very "existence" of *the* real number irrelevant. Does π (you know, the "3.14…–thing") *exist*? Who knows? Does it matter? NO! Indeed, *no*, if one may construct eidolons sharing as many decimal places with "π" (whether it exists or not!) as needed for the occasion. On October 8, 2014, a (temporary) record of 13,300,000,000,000 decimal places were verified (see [19] for an up to date list). It should serve us for some time.

This is a complete, formal instance of an eidolon in the theory of continua. We submit that perception is much like that—although messier and impossible to formalise. *Manifest actuality* is an eidolon that renders the existence of "reality" something for philosophers to help earn their keep.

In the visual arts (as in poetry and so forth) one asks of anything *"what else is it?"*[20], that is to say, there are only eidolons. The *locus classicus* in Western art is Picasso's bull's head made from discarded bicycle parts (*Tête de taureau*, 1942). But remember that Bernini's *Neptune and Triton* of 1622–3 (London, *Victoria & Albert*) sports a fluttering drapery that is often seen as a dolphin's head, which was greatly praised in its original setting at the Villa Montalto in Rome. Indeed, the use of equivalence is endemic in the arts.

Such equivalences may even be due to random cause, consider [21]:

The wdoos are lveoly, drak and deep.	The wodos are llevoy, drak and deep.
But I have pomeirss to keep,	But I have poemirss to keep,
And miels to go befroe I seelp,	And mlies to go brefoe I selep,
And mlies to go bferoe I selep.	And melis to go boefre I seelp.

are evidently equivalent texts. It is even hard to find the differences. This is *typoglycemia* (here I kept the initial and final version of each word and randomly shuffled the letters in between). Most fluent readers easily read such texts, sometimes even hardly notice [22]. It is not different in vision or hearing.

Districts of the Eidolon Cloud and their Uses

There are numerous eidolon "styles". In fact, it is impossible to put any fundamental limit on what goes. The cloud of eidolons is the construct of a creative observer, it is never a closed book, but ever in a state of becoming.

To set the picture we succinctly discuss a few examples of fully different realms of the eidolon cloud that have gained some degree of recognition in vision research. For a start, consider "pepper–and–salt noise" [23] eidolons of some image (figure 2).

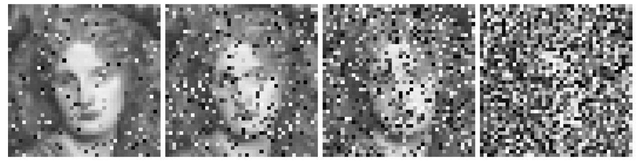

Figure 2. *The application of "pepper–and–salt noise" is a simple style of eidolon factory. The probability of swapping a pixel for a random one is (from left to right 10%, 20%, 40% and 80%, whereas the probability of the random pixel being some gray value is taken as uniformly distributed between black and white. At 10% you simply ignore the noise, at 80% that is really no longer possible. At 40% you're still squarely with the eidolon cloud. You're losing some detail though. It is easy to measure the eidolon boundary in the direction of this style.*

Figure 3. *Fourier phase scrambling became popular when many people actually believed(!) that the brain entertains a fourier transform of the optical input. Phase is scrambled via a wrap–around normal distribution of standard deviation (from left to right) of $\pi/8$, $\pi/4$, $\pi/2$ and π. Again, it is easy to measure the eidolon boundary in the direction of this particular style.*

This type of eidolon style derives from the importance of noisy images as they arose in applications in the early days of image capture and communication. A pepper–and–salt grain represents a lost pixel, the pixel being replaced with a lighter ("salt") or darker ("pepper") random one. The main parameter is the probability of inserting such random pixels. This "method" is based on the study of noise pollution, yet it evidently produces an eidolon cloud of some interest.

Next consider the method of fourier phase scrambling [24], shown in figure 3. This method of moving away from the fiducial image derives from the (in our view seriously mistaken) notion that the brain represents the optical structure in terms of a global fourier transform. This strange notion seems to derive from a limited, or mis-understanding, of formal functional analysis. This style moves in a completely different direction in the eidolon cloud than the pepper–and–salt noise style. It has been used for a number of interesting studies in vision research.

Notice that the phase scrambling is a global process. Changing the phase of a simple fourier component leads to changes all over the image. Formally phase scrambling is similar to pepper–and–noise in the fourier domain. In contradistinction, pepper–and–noise is local in space but a single speck has effects all over the fourier spectrum. This is important from a conceptual point of view, for it is much more likely that the visual system is organised on a local basis than via something akin to fourier analysis.

Thus the eidolon style may well either fit or contrast with one's ideas on the nature of visual processing. Different eidolon styles will affect different aspects of such processing. This renders eidolon factories of considerable potential use in forging

Figure 4. *Block-images became popular with Harmon and Julesz[25] work.*

Figure 5. *At left a block-image and at right a blurred version of it. Perhaps perversely, the blurred image looks "sharper" to us than the sharp one! Of course, "sharp" is more of a state of mind than a physical fact. It depends on what your awareness makes the image content out to be.*

tools for vision research.

The blocks-style was introduced by Leon Harmon and Bela Julesz[25]. (See figure 4.) Their portrait of Lincoln was an eidolon near enough the edge of the cloud that many had trouble recognising the familiar portrait. The blocks–style was evidently inspired by the image processing at that period, much like the pepper–and–salt style was inspired by communication technology. Notice how different this style is from either pepper–and–salt noise or fourier scrambling!

What is common to these pepper–and–salt and the blocks styles is that the eidolon can be brought nearer to the prototypical center through blurring, the blur attenuates artefacts that have no relation to the image content and serve to mask the latter. Such blurring will not work in the case of phase scrambling. The block's style mainly addresses the fact that scales interact in visual processing: the sharp edges of the blocks (fine scale) mask the blurry image content (course scale). We show an example in figure 5. Remove the edges and the image content is amply sufficient to recognise the image for the portrait of the person it depicts

Notice that blurring creates an eidolon style by itself. In fact, it creates many such styles, because you can blur in various ways. This has led to a whole field of endeavor in the *bokeh*, or "drawing" of defocussed lenses in photography [26]. Some styles are sought for in background rendering (gaussian blurring is good), whereas others (e.g. the drawing of catadioptric lenses) are avoided like the plague.

When the blocks are changed into random polygons the result looks far less artificial (figure 6). It is a different "style". Numerous styles are possible. For instance, consider figures 7 and 8. Here the interiors of the polygons have been mutually randomly displaced. This style uses "local sign" dither (see section below).

So the eidolon cloud has many distinct — though fuzzily bounded — districts, a district being characterised by a recognisable "style". It is evidently impossible to classify such districts

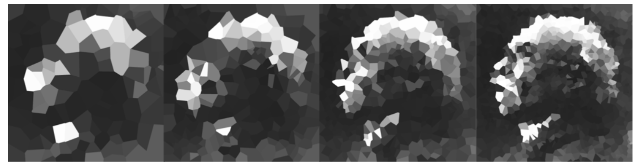

Figure 6. *In this case the interiors of the fragments have been uniformly filled with the median gray level of the corresponding fragment in the original image. Such renderings are like the Harmon and Julesz block eidolons[25], except for the random shapes of the tesseræ (we used a Poisson–Voronoi tessellation). When the fragments are smaller and thus more numerous, the image becomes quite easy to read, in fact, easier than the block-style images of equivalent coarseness.*

Figure 7. *A fragmented image. The interior of the tiles is filled with randomly displaced parts of the corresponding location in the original, though shifted by a vector with normally distributed coordinates.*

once and for all, just as it is impossible to classify all styles in painting. Visual awareness is a creative imagery and may accept, perhaps "recognise", styles seen for the first time, a bit like single paintings are often reputed to be at the root of some style in the visual arts.

The various districts have different uses in vision research, because they tend to address different subprocesses of psychogenesis. Thus eidolons are well suited to a type of experimental phenomenology that is akin to a *psycho–anatomy* (conventionally called "microgenesis" [27]).

The specific eidolon factory that we will discuss below allows for a formal, parametric description of a fairly large number of mutually diverse districts. Many of these are interesting from a phenomenological perspective because they appear similar to the texture–like appearance of scenes seen at a glimpse, in the background of some focal subject matter, or in peripheral vision. The use of such eidolons in psycho–anatomical research is still in an early phase, but one is likely to see more in the not to distant future.

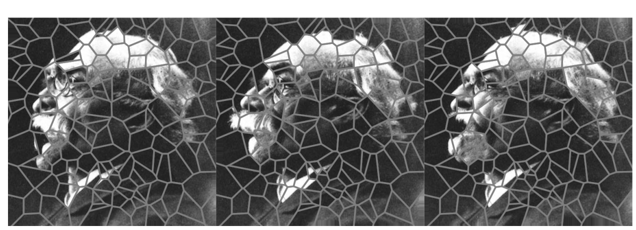

Figure 8. *Like figure 7, except that some gray grout has been superimposed to mask spatial discontinuities. Such fragmented images read a little easier.*

Lotze's Local Sign

This section of Hermann Lotze's *Medical psychology or physiology of the soul*[28] introduces his concept of *Localzeichen*:

> In case we encounter a spatially ordered, somatotopically organised sensory system, it makes sense to infer that Nature strives to impress the spatial order of stimulation on the mind. But such a conclusion is premature, for the physiological structure does in no way *explain* awareness. Instead, one needs to search for other ways by which the local activities may be impressed as *qualia* on the mind. The localisation of an element of awareness is independent of its qualities, for the same loci in awareness may carry very different qualities at different times. Thus every stimulation of a specific neural element must contribute its specific "coloration". We refer to this as its *local sign*. — my translation

The eye is a good example of a system where an aspect of the environment, the pencil of visual directions at the cornea, is roughly mapped point by point to the retina and further on, all the way to the primary visual areas and so on. There is no need to enter into details, clearly the primary visual system is a good example of a spatially ordered sensorium in Lotze's sense. In Euclid's *Optics*[29] it is taken for granted that this spatial order is somehow imprinted upon the mind, we are immediately aware of it—at least most people are.

Brain scientists side with Euclid in that there is no need for local sign. Instead of an ordered array of visual rays they consider a somatotopically ordered array of the pyramidal neurons of the mammalian prefrontal cortex, a difference in detail if not in kind. Lotze would have considered it a notion wanting in explanatory power. People like Helmholtz[30] were keenly aware of Lotze's point and worried about it, something we moderns are only too glad to forget.

Helmholtz[30] famously held that

> ... these qualities of sensations belong only to our nervous system and do not extend at all into the space around us. Even when we know this, however, the illusion does not cease, for it is the primary and fundamental truth. The illusion is quite simply the sensations which are given to us in spatial order to begin with ...

I would like to suggest that scientists like Lotze and Helmholtz (and numerous others, of course) were not entirely stupid. I'm worried that pyramidal cells not only don't broadcast their location in the visual field, but also are silent about the nature of their receptive fields, state of adaptation and so forth (see below). It is fully unclear to me how visual awareness might be "computed" from such a mess. Indeed, it seems most likely to me that it isn't. This probably also occurred to Helmholtz, who used the sign–theory as his much needed glue (or "psychophysical linking hypothesis") between mind and brain.

Today one does not need such a glue anymore, because the distinction between mind and brain is conventionally ignored. Of course, this implies that visual awareness (consisting of meanings and qualities) does not exist, there are only electrochemical processes in brain tissue. This is indeed good science. However, that phenomenology is not a science does not imply that it is irrelevant. It will never go away. In fact, the correct position of the hard-core physicist should be that awareness is the basic, irreducible fact and that all scientific insights and facts ultimately derive from that [31, 7]. Perhaps we would do wise to adopt some kind of glue after all.

There is another complication that needs to be mentioned upfront, namely that there exist two categorically distinct types of local sign, which we will designate "internal" and "external" local sign. External local sign refers to locations outside the body (see [32]), whereas internal local sign refers to the relative mutual position of body parts [33], or even the mutual position of mental objects [34]. Helmholtz famously mentions that in cases of toothache the patient is often unable to locate the pain in either the upper or lower jaw, to the patient's awareness the teeth are spatially coincident, they have the same internal local sign [30].

In this paper we refer to internal local sign throughout. Notice that the bulk of the literature on local sign is on the external variety, usually without specifically mentioning this.

Generalised Local Sign Consider a neuron contributing to the blackboard, say V1. It is in a certain state due to the optical stimulation of the immediate past. To complicate matters, the optical input itself is partly due to psychogenesis, for part of its probing involves pointing the eyes in involuntary fixations. However, we'll ignore that for the moment. How can psychogenesis ask for the state of the neuron and why would it care? This involves various aspects of what we will call "generalised" or "extended local sign". Just consider that:

- the output of the neuron being action potentials, all neurons look the same to the casual observer;
- neurons do not broadcast their type (e.g., simple or complex cell);
- neurons do not broadcast their defining parameter (e.g., orientation of a line detector);
- although neurons constantly adapt, they do not broadcast their current amplification factor (say);
- as Lotze noticed, they don't broadcast their locations;
- and so forth ...

Thus the "meaning" of the action potential trains pumped into its axon must derive from other things than the neuron itself. We must assume that psychogenesis holds some kind of "key" to the neuron, this is its generalised local sign.

No one has the slightest idea how this works, but that is not the issue here. What is of relevance in this context is that sloppiness and noise will induce a variety of ambiguities and (at least locally) systematic errors. The result is a major enrichment of the cloud of eidolons enabled by the blackboard activity as it is sampled by psychogenesis. Psychogenesis is essentially a creative construction, or hallucination, which is constrained by the blackboard representation. Thus its presentations will grow more idiosyncratic and less strictly bound by the optical structure due to sloppy generalised local sign.

In order to model this one considers various formal *representation theorems*. One arrives at these by way of formal scale–space theory. The basic scale–space structure [35] is due to the fact that the derivative with respect to scale at some given scale equals the Laplacian of the optical structure at that (single!) scale. The kernel that generates the scale–space structure is the isotropic, unit weight gaussian

$$g(x,y,s) = \frac{\mathrm{e}^{-\frac{x^2+y^2}{2s^2}}}{2\pi s^2}, \tag{1}$$

where $\{x,y\}$ are Cartesian coordinates of the image plane and $s > 0$ the scale parameter. This kernel is well known to have the unique properties that yield a well behaved scale–space. The key property that defines the "deep structure", that is the behavior over scales as opposed to the image structure at any fixed scale, is

$$L_s = s\,\Delta L, \quad \text{where} \quad L(x,y,s) = L(x,y) \circ g(x,y,s), \tag{2}$$

where $L(x,y)$ is an image at "infinite resolution" ($s = 0$) and the operator $\circ$ denotes convolution. (We use L_s for $\partial L/\partial s$, L_{xx} for $\partial^2 L/\partial x^2$ and so forth.)

Thus $L(x,y,s)$ denotes a family of blurred images, that is the scale–space representation of $L(x,y)$. The point here is the partial differential equation 2 that links the deep structure L_s to the shallow image structure $L(x,y,s)$ at the fixed scale s.

This implies that the Laplacean ΔL, pooled over scales reproduces the optical structure except for its average value, for

$$\int_0^\infty \Delta L(x,y,s)\; s\,\mathrm{d}s = L(x,y,\infty) - L(x,y,0). \tag{3}$$

Of course, the limits 0 and ∞ are merely symbolic here, in actual applications they are always finite. The limit $s = 0$ denotes the resolution of the fiducial image, which is a physical entity, whereas the limit $s = \infty$ denotes the size of the fiducial image, which is necessarily limited to some finite value. This implies

$$L(x,y) = \overline{L(x,y)} - \int_0^\infty \Delta L(x,y,s)\, s\,\mathrm{d}s. \tag{4}$$

This is one (important) representation theorem. Here $\overline{L(x,y)} = L_\infty$ is the spatial average of the image intensity and $L(x,y) = L(x,y,0)$.

Another observation is that the Laplacian equals the pooled activity of line detectors over all orientations. For the Laplacean in Cartesian coordinates is defined as

$$\Delta L = L_{xx} + L_{yy}, \tag{5}$$

where the choice of the XY–directions is arbitrary. This again implies that $\Delta L = \langle L_{uu} \rangle$, where the U-axis ranges over all orientations. The kernel corresponding to L_{uu} is ($r^2 = x^2 + y^2$)

$$g_{uu}(x,y,s) = \frac{(u^2 - s^2)\,\mathrm{e}^{-\frac{r^2}{2s^2}}}{2\pi s^6} \tag{6}$$

It is a good model for the receptive field structure of a Hubel and Wiesel simple cell, or "line detector" (figure 9). The consequence is that

$$L(x,y) - L_\infty \propto \overline{g_{uu} \circ L}, \tag{7}$$

where the pooling is over scale and orientation. Thus the pooled activity of all "line detectors" reproduces the optical input except for its average value. Equation 7 may be the most relevant representation theorem for cortical area V1.

Of course, such terms as "line detector" or "edge detector" are nonsensical in the context of the psychogenesis as sketched in this paper. Such terms apply to the vision model that goes

Figure 9. *These three images are sufficient to define the activity of a full orientation column of line finders. The cortical area V1-representation is very over-complete, which offers a diversity of advantages.*

RETINAL EXCITATION → *processing* → ...→ *more processing* → AWARENESS,

which—in our understanding—is obvious nonsense.

The important representation theorem 7 can be interpreted in many, conceptually diverse ways. Two of these are of considerable heuristic value.

One interpretation is to see that

$$\int_{s_1}^{s_2} \Delta L\, s\mathrm{d}s = L(x,y,s_2) - L(x,y,s_1), \tag{8}$$

that is

$$(g(x,y,s_2) - g(x,y,s_1)) \circ L(x,y). \tag{9}$$

This involves the conventional receptive field profile

$$\mathrm{DOG}(x,y,s_1,s_2) = g(x,y,s_1) - g(x,y,s_2), \tag{10}$$

that is a "Difference–Of–Gaussians" receptive field.

Another—heuristically more useful—interpretation is to notice that

$$g_u(x,y,s) \circ (g_u(x,y,s) \circ L(x,y)) = g_{uu}(x,y,s\sqrt{2}) \circ L(x,y). \tag{11}$$

Here

$$g_u(x,y,s) \circ L(x,y), \tag{12}$$

is the output of an "edge detector" in the U–direction. Indeed,

$$(g_x(x,y,s) \circ L(x,y))^2 + \left(g_y(x,y,s) \circ L(x,y)\right)^2, \tag{13}$$

is the conventional result of an "edge finding" algorithm, although the result is usually thresholded in order to avoid "finding edges" at every pixel [36] (figure 10).

An interpretation of this result in terms of our model of psychogenesis is that g_u is an operator that results in a measure of "edginess", that is a structure in the blackboard. Psychogenesis may "paint edginess" with a "local edge presentation", the icon used for a "local edge presentation" being g_u. The resulting presentation is formally equivalent to an application of g_{uu}. In this interpretation [36] the "line finders" are actually instrumental in presenting *edges* (not lines), at least, if psychogenesis chooses to use their activity.

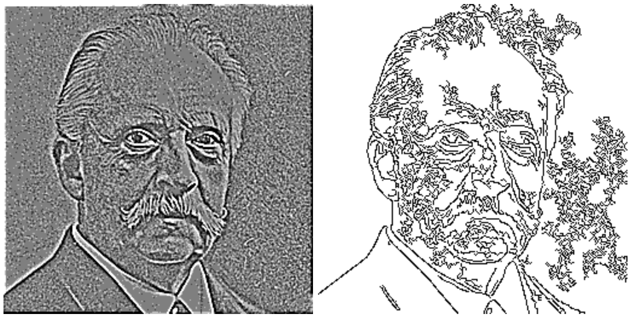

Figure 10. *A comparison between a "local edge representation" (left) and "edginess" as defined by some conventional "edge-detector. In the latter case "finding" implies the (essentially arbitrary) application of a threshold.*

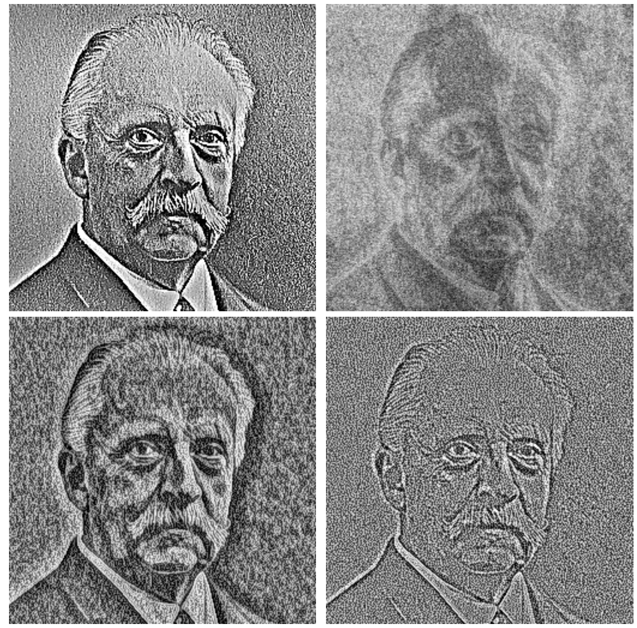

Figure 11. *These are reconstructions from boundary representations (the "line detectors"), where we kept various sparse parts of the data. The image at top left uses the full data, that at top right ignores 50% of the data at random. The Image at bottom left uses only the sign of the (full) representation. The image at bottom right uses only the signs of the 10% strongest responses.The full representation is highly overdetermined. That only the signs of the loudest voices do a creditable job might be understood as a sign that independent adaptation of line finders need not pose a major problem.*

Thus the front–end visual system V1 mainly contributes a multi–scale edge representation to the blackboard. This is immediately reminiscent to the use of various types of edges in the technique of painting in oils.

In practice, one finds that the V1–representation grossly over–represents the optical structure (figure 11). Reconstruction using a small fraction of the available representation tends to result in well recognisable images. When one selects the most active units a few percent suffices. It seems likely to us that psychogenesis routine ignores the bulk of the structure that is on the blackboard. It merely addresses what is of momentary importance to keep its hallucinations in check.

This is akin to the time proven methods of forensic investigation in which arbitrarily large data files are collected at the site of the crime, most of which will never even be consulted. The investigator uses the file to check hunches of possible plots, ignoring everything else. All that is needed to successfully "solve" a case is to find a coincidence of a number of mutually independent, individually rare events, thus rendering the overall probability of the coincidence very small [37]. This solves the case "beyond reasonable doubt". Certainty cannot be had, either in detective work, or in psychogenesis.

An eidolon generator is easily constructed from any representation theorem by simply perturbing the elements that enter into the pooling. The degrees of freedom here are the type of representation theorem and the nature of the perturbation. Perturbations could be in magnitude, orientation, location, . . . and could have stochastic structure extending over space–time and scale.

This perspective on potential "eidolon factories" is so broad that it can hardly adequately be reviewed in this short paper. What we do is identify a few key degrees of freedom.

Eidolons and Local Sign So what is the relation between eidolons and local sign? Well, as it turns out—and is a well kept open secret of the visual arts—psychogenesis picks and chooses from the blackboard, but is not too picky as to where things are. The spatial framework is largely based upon what Gibson[38] called "nested solid angles", a kind of set-theoretical mereology [39], but—perhaps surprisingly—it deals gracefully with major dislocations and even transpositions in the optical structure. The typical finding is that the awareness always *makes sense* even when the stimulus is *messed up*. In such cases psychogenesis—the "creative subject" in Brouwer's sense—apparently assigns local sign as it sees fit. Local sign derives (at least in part) from a "creative observer" that unabashedly bends "the data" so as to fit its imagery [3]. Psychogenesis has much in common with the *modus operandi* of a—perhaps occasionally slightly dishonest, but usually very effective—criminal investigator.

That this might be the case is clear from a disability known as *tarachopia* (scrambled vision), a specific form of *amblyopia* (blunt vision). In tarachopia one may show psychophysically that the blackboard structure is fully intact, thus the disability is an *agnosia*, rather than an anatomical or physiological defect of the sensory system[40]. These patients suffer from a defective local sign.

Such insensitivity to dislocation and transposition was perhaps first noticed in the time domain, perhaps first by astronomers at the close of the eighteenth century [41]. Apparently time in awareness is not clock time. This was explicitly noted by the physicist Ernst Mach in an influential book [42]. The *Zeitverschiebung* was extensively investigated by Wilhelm Wundt [43], but real progress starts with Vittorio Benussi [34] who worked from a Gestalt (experimental phenomenology) perspective. Benussi's methods were inventive, but cumbersome because technology was not sufficiently advanced at his times.

Nowadays such insensitivity to dislocation and transposition is easily demonstrated in space, time and spacetime (scrambled video), but only successful if the singularities due to the dislocations are suitably masked. A short flash of uniform color effectively masks a temporal dislocation singularity and a thick,

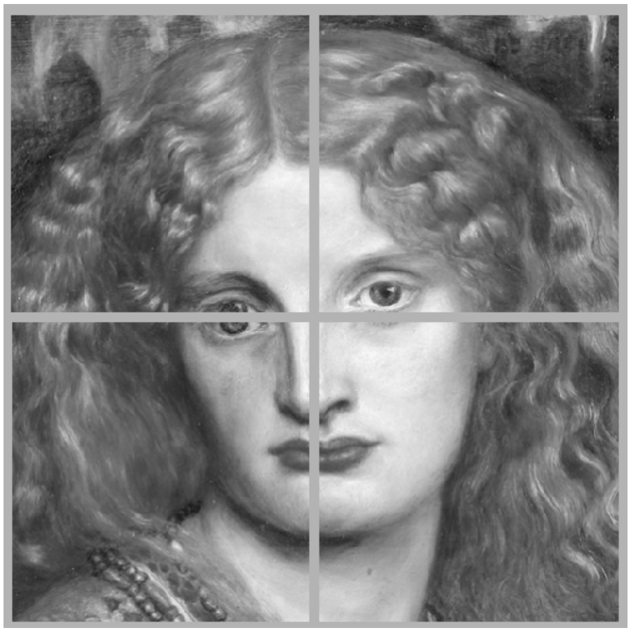

Figure 12. *This is a regular portrait, except for the "masking", which really doesn't mask anything here because there is nothing to mask: the four quadrants have been "pulled apart", so the masking strips do not delete any of the original pixels. This makes the image a bit larger. The trick can be used to magnify images by up to 50% [44], without any loss of resolution! Of course, no structural information is actually added in the process.*

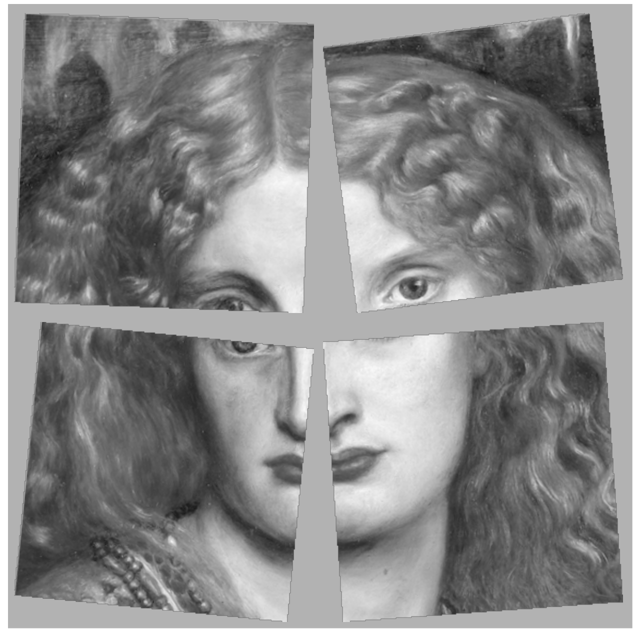

Figure 13. *This is the result of quite severe dislocations, both translations and rotations of the quadrants. Again, all original pixels have been retained. Notice that you easily "read" the image. In eccentric vision (fixate the margin of the page) you are not aware of any dislocations at all. The same happens in short presentations, but that is hard to demonstrate here.*

overlaid uniform strip effectively masks a spatial dislocation singularity. What happens is that one is aware of an integral image "behind" (indeed, amodally completed) grid of maskers (figure 12 and 13).

This no doubt happens because the singularities are primary visual features; they are how psychogenesis detects the dislocations in the unmasked stimuli. It does not so much detect dislocations as such, as primarily the singularities that derive from these. A little masking goes a long way and any type of masking will be effective as it gets rid of the singularities.

Only when the masks become too marked (as individual objects in space or time) themselves the awareness becomes that of a fragmented pattern because the parts are no longer spontaneously associated (or "grouped"). However, the associations are very robust over surprisingly wide gaps. Something similar happens in time.

In spacetime the singularities give rise to apparent motions that disrupt the fluency of the evolving scene. Masking in time and in space easily solves this. One is aware of a smoothly running video "behind" a grid of mask-lines and a sequence of masking flashes. The masks are not experienced as part of the video and are easily ignored.[1]

The figures 12 and 13 show a simple example. Notice that rotations are handled just as easily as translations, so do more general affine deformations like size changes or shears (not illustrated). Such deformations are fun to play with.

[1]We ran a formal demonstration at the *Illusoria mente* session at the ECVP2012 at Alghero (Sardinia). It was clear that the (perhaps amazing) "mental unscrambling" works flawless for essentially everyone of a large audience.

Eidolon Factories

Of course, we can also apply a spatial dither on all references to the blackboard. The result will depend on a small number of essential parameters. Here we have an interesting case, for these are models of various kinds of tarachopia. We propose them as useful, because intuitively parameterisable, "eidolon factories" [45]. Each set of parameters yields as many mutually independent instances as desired.

You may find the necessary tools at `http://www.allpsych.uni-giessen.de/EidolonFactories/index.htm` (MatLab, Processing) and at `http://www.gestaltrevision.be/en/resources/our-software` (Python). The Processing version is meant for playing, which makes a good start, whereas the MatLab and Python versions are designed for serious work.

Of course, hard-core frontier-men will always roll their own!

Degrees of Freedom

Consider the simplest case, the mere fuzziness of local sign of point samples. The "points" may be of arbitrary sizes though.

The formal description of such a spatial representation is "scale–space" [35], a well understood theory with numerous daily applications in image processing, for instance for medical images. A slight excursion to the very notion of "point" is required here. Just consider: *What is the size of a point in the blue sky?'* [46]. There evidently is no answer to such a silly question.

For psychogenesis there are no points in the blue sky. In order for a point to exist in awareness there must be a mark, that

Figure 14. *This is the result of putting spatial dither on local sign. It is like figure 7, but applying a continuous instead of a piece-wise constant random deformation field. The effect is that of a stochastic diffusion.*

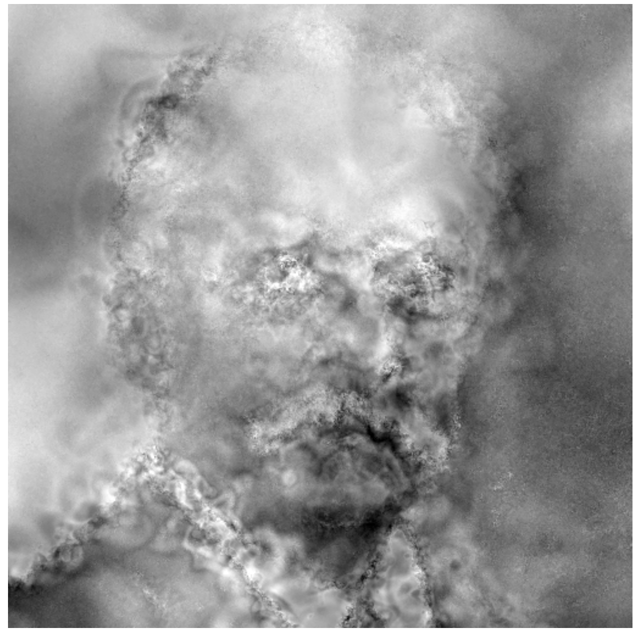

Figure 15. *Here all perceptive field sizes have been dithered in proportion to their sizes. This destroys inclusion relations, thus it also leads to diffusion of shape, although the effect is quite different from that of some uniform granularity. It is a kind of fibrous dissolution.*

is to say, a point needs a background [46]. Thus a star appears as a point, because it contrasts against the black fond of empty outer space.

A real "point" should always be accompanied by a background [46]. The neural system implements this principle through the use of center–surround receptive field. The center is the point proper, the surround is its background. The combination is a point that takes its background along with it, just like a tracked vehicle like a military tank takes its road along with it. In the formal scale space account one identifies the Laplacean as a point. Its kernel formalises the receptive field center surround structure. Remember the representation theorem: The sum of all Laplaceans (all locations, all size) reproduces the image except for its (irrelevant) average level. Thus the pool of all "points" is — perhaps unsurprisingly so — a *complete representation* of the optical structure [36].

To turn this representation into an eidolon factory is immediate: simply disturb the locations of all points! If such perturbations are fully random over all locations and all sizes the result is similar to blurring. This is one style of eidolons, but perhaps not the most interesting one. In order to arrive at more interesting styles the perturbation needs to be a *field*, with specific structure both spatially and in the scale domain (figures 14, 15 and 16).

The simplest spatial fields are smooth Gaussian random fields at a fixed scale. In order to perturb locations one needs such — mutually uncorrelated — fields, to be used as the Cartesian components of the displacement vectors. This uses the key fact that the Gaussian is separable in Cartesian coordinates. Such fields are simple to generate. They have two parameters of interest:

- the *reach* (see figure 17), that is the amplitude, and,
- the *grain* (see figure 18), that is the correlation length.

These parameters are quite intuitive. As you increase the reach from zero the eidolons become increasingly distorted, in a fixed, easily recognisable style. The effect is seen in figure 17.

As you decrease the grain from quite large to small, the eidolon becomes increasingly ruffled. With large grain you find areas that are visibly displaced, but internally coherent, whereas for very small grain the effect is more like locally shuffling the pieces of a jigsaw puzzle. The effect is seen in figure 18.

Thus the parameters that apply to a single scale are readily understood. The effects of combining such deformations at different scales are more intricate. We illustrate the major effects that play a role in the schematic figure 19. Here the scales are indicated with circular disks. For the ease of understanding, we illustrate the case of only two, mutually very different sizes.

In figure 19 top–right all points, regardless of scale, have been randomly displaced by a spatially incoherent (very fine grain) with a reach independent of scale. Notice that this essentially destroys the spatial relations. It is impossible to figure out mutual overlaps and inclusion relations from the result.

In figure 19 bottom–left the reach has been taken proportional to the point size. In this case one sees that the small points come in groups that evidently belong together. It is even possible to guess to which large points they "belong". However, such groups of small points do "break loose" from the large points in which they were contained. Thus one obtains a dissociation between scale layers.

In figure 19 bottom–right the small points are made to piggy–back on the large points. Now there is shuffling in all scale layers, but the mutual relations over scale are pretty much conserved.

We describe this with a parameter we call "coherence". Low coherence describes the cases of figure 19 top–right and bottom–

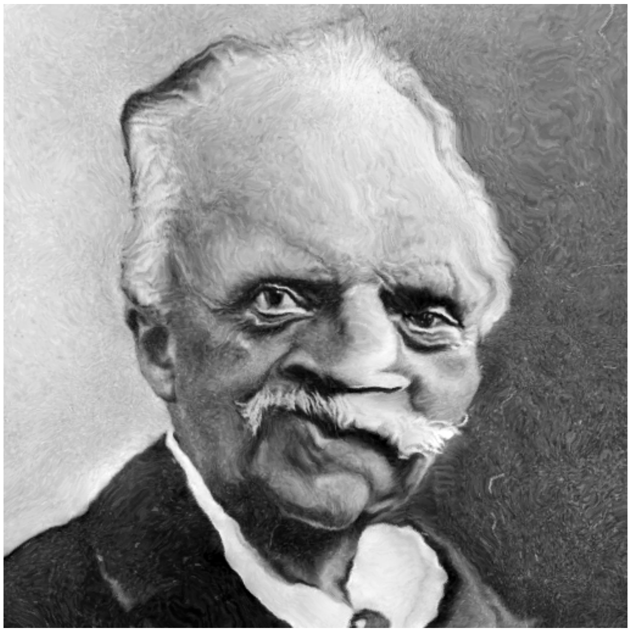

Figure 16. This is similar to the previous case, except that the large perceptive fields tend to drag the small ones along with them. As a result, local structure is largely retained and the result is more like a deformation than a diffusion. Such deformations are not unlike the ones one sees in Picasso's portraits painted in the nineteen-forties.

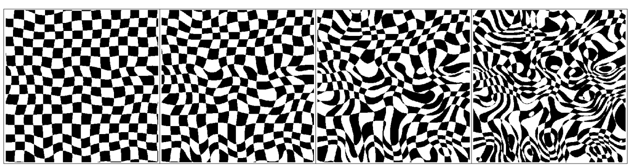

Figure 17. Here the reach varies (in steps of two) from small to quite large. This style of deformation is seen in figure 14. Notice that reach and grain are very different parameters.

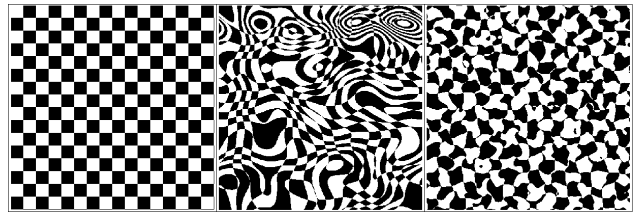

Figure 18. From left to right, an image (the rectangular grid enables one to immediately notice any deformations), a perturbed image with a large grain and a perturbed image with a small grain.

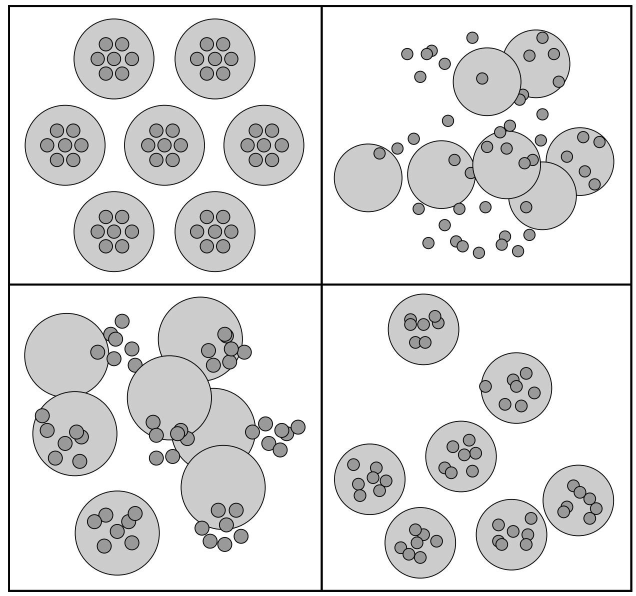

Figure 19. At top left a configuration of large and small receptive fields. at top right these have been perturbed with the same reach. Notice that inclusion and overlap relations are largely lost. At bottom left the reaches are proportional to the receptive field diameters. Notice that the inclusion relations are lost. Finally, at bottom right the small receptive fields piggyback on the large ones. Here the inclusion relations are retained, though there is disarray at all scales. These methods of perturbation give rise to very diverse styles of eidolons.

left, whereas high coherence describes the case at bottom–right. Coherence is a continuous parameter, one may easily construct cases that interpolate between the cases illustrated in the bottom row.

Notice that the cases illustrated in figure 19 top–right and bottom–left are both incoherent, but still very different. We refer to the case of the top–right figure as "Lotze–type disarray", that of the bottom–left figure as "Helmholtz–type disarray", descriptive terms that refer to expectations from certain theoretical mechanisms for the genesis of local sign by Lotze and Helmholtz. In principle one may again interpolate between these cases and introduce another parameter. We will not do that here, because the Lotze–type disarray tends to lead to a kind of image diffusion that is unlikely to find much application.

The basic eidolon parameters identified here then are GRAIN, REACH and COHERENCE. They have fairly immediate intuitive meanings (figures 20, 21 and 22) and — at least after some experience — can usually be detected as specific of an eidolon "style".

Of course, there is no reason to stick to single scale gaussian noise fields. For instance, in figure 23 the local sign has been dithered by a fractal dislocation field. It is also easy enough to apply spatially variant dither, for instance to create a "focus of attention".

Coda

Lotze's local sign has since long sunk below the horizon of science, only a few philosophers bother about it anymore. The reason is that people like Lotze and Helmholtz thought about awareness (and the mind in general) as categorically different from the brain. Both Lotze and Helmholtz had primarily a medical education, although Lotze became a philosopher/psychologist and Helmholtz a mathematician/physicist.

Since modern science has decided that mind does not exist (except, perhaps, as an epiphenomenon of the brain) no serious university would consider hiring such nit-wits today. A remark like Lotze's "we are not in space but space is in us" could hardly be tolerated coming from a present–day scientist.

Psychogenesis has been replaced by the notion of *inverse op-*

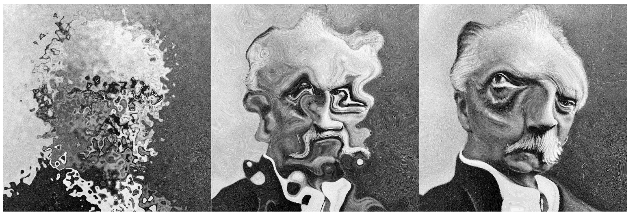

Figure 20. *In these figures the reach is fixed and the disarray is fully coherent. The grain varies (from left to right) from one quarter, equal to and four times the reach.*

Figure 21. *The interaction between grain and reach is elementary, but essential. A little understanding goes a long way. Here the grain is fixed, whereas (from left to right) the reach is two, four, and eight–times the grain. Notice that the effect varies from deformation to diffusion. In more realistic settings this would play at all scales.*

tics computations, leaving no room for a creative observer. The future will show which view is the more fruitful for academic progress.

On a more positive note, local sign can be used to design "eidolon factories" that—we expect—will become very important in a number of psychophysical research directions. If you want, you can forget that these algorithms were designed to model psychogenesis, in fact they can be easily dressed up in the latest brain-science newspeak so as to render them respectable.

What is important in practice is that they yield a cloud of eidolons for any image that is intuitively parameterisable. Such images can vary from being close to the original to appearing almost completely different. They tend to be "natural" in the sense that they come to look more like the original in short presentations or in eccentric viewing. Of course, the latter phenomenological argument hardly carries scientific weight.

Examples of the use of such eidolons in psychophysics already exist. We especially appreciate the groundbreaking work in the Rosenholtz group[47]. As a simple illustration of the use of eidolons we successfully implemented tarachopic conditions in normal observers[45].

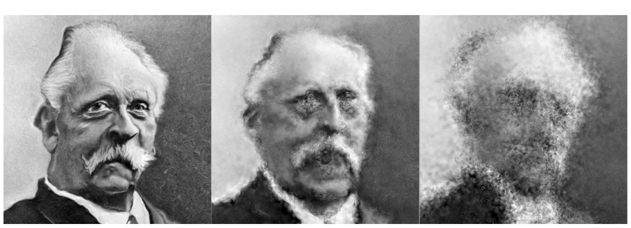

Figure 22. *In these figures the reach is four times the grain, both reach and grain are constant. The coherence is (from left to right) 0.95, 0.70 and 0.10. As the coherence decreases, details start to diffuse and local structure becomes undefined.*

Figure 23. *This is the result of the application of a fractal dislocation field, the reach is varied from smallish at left, to larger at right. If the dislocations are appreciable the image tends to fall apart.*

Acknowledgments
Where I use the first person ("I" short for "the first author (JK)"), this means that I'm prepared to take the brunt for a stupidity alone. I thank my co-authors for graciously letting me, at least a few times.

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References
[1] Liliana Albertazzi, editor. *Handbook of Experimental Phenomenology: Visual Perception of Shape, Space and Appearance*. Wiley–Blaclwel, 2013.

[2] Jakob J. von Uexküll. *Theoretische Biologie*. Springer, Berlin, 1928.

[3] Jan J. Koenderink. Ontology of the mirrorworld. *Gestalt Theory*, 37 (2):119–140, 2015.

[4] Jason W. Brown. *Self and Process*. Springer-Verlag, New York, 1991.

[5] Gottfried W. Leibniz. *Nouveaux Essais sur l'entendement humain*. Librairie Hachette, Paris, 1898 orig. 1765.

[6] Tommy T. Poggio, Vincent V. Torre, and Christoph Koch. Computational vision and regularization theory. *Nature*, 317:314–319, 1985.

[7] Richard Feynman. *The character of physical law*. MIT Press, Cambridge MA, 1965.

[8] Whitman A. Richards. How to play twenty questions with nature and win. AI Memo 660, M.I.T., 1982.

[9] Erwin Schrödinger. *Mind and matter (Tarner lectures, 1956)*. Cambridge University Press, Cambridge UK, 1958.

[10] Giambattista Vico. *The New Science of Giambattista Vico*. Cornell UP,, Ithaca, 2 edition, 1968 orig 1744.

[11] Jan J. Koenderink. The all seeing eye? *Perception*, 43:1–6, 2014.

[12] Donald Hoffman. The interface theory of perception: Natural selection drives true perception to swift extinction. In M. Dickinson, S. Tarr, A. Leonardis, and B. Schiele, editors, *Object categorization: Computer and human vision perspectives*, pages 148–165., Cambridge, UK, 2009. Cambridge University Press.

[13] Jan J. Koenderink. Vision as a user interface. In B. E. Rogowitz and T. N. Pappas, editors, *SPIE Proceedings: Human Vision and Electronic Imaging XVI*, volume 7865, pages 1–13, 2011.

[14] Eleanor H. Rosch. Natural categories. *Cognitive Psychology*, 4(3): 328–350, 1973.

[15] Euripides. Helen (412 BCE). URL `http://classics.mit.edu/Euripides/helen.html`.

[16] David C. Lindberg. *Theories of Vision from al-Kindi to Kepler*. University of Chicago Press, 1976.

[17] Luitzen E. J. Brouwer. Essentieel–negatieve eigenschappen. *Koninklijke Nederlandsche Akademie van Wetenschappen, Proceedings of the section of sciences*, 51:963–964, 1948.

[18] Simon Stevin. *De Thiende*. Christoffel Plantijn, Leyden, 1585.

[19] URL `http://www.pi-world-ranking-list.com/index.php`.

[20] Minor White. The perennial trend. *PSA Journal*, 29(7):17–21, 1963.

[21] Robert Frost. *Stopping by Woods on a Snowy Evening*, chapter Stopping by Woods on a Snowy Evening. Henry Holt and Company, Inc., 1923.

[22] Matt Davis. Aoccdrnig to a rscheearch at cmabrigde uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. [...]. MRC: Cognition and Brain Sciences Unit Cambridge University, 2012.

[23] S. Jayaraman, S. Esakkirajan, and T. Veerakumar. *Digital Image Processing*. Tata McGraw Hill Education, 2009.

[24] Felix A. Wichmann, Doris I. Braun, and Karl R. Gegenfurtner. Phase noise and the classification of natural images. *Vision Research*, 46:1520–1529, 2006.

[25] Leon D. Harmon and Bela Julesz. The recognition of faces. *Scientific American*, 229(5):71–82, 1973.

[26] H.H.Nasse. Depth of field and bokeh. Technical report, Carl Zeiss, Camera Lens Division, march 2110.

[27] Victor Rosenthal. Cognition, vie et… temps. *Intellectica*, 16:175–207, 1993.

[28] Hermann Lotze. *Medicinische Psychologie oder Physiologie der Seele*. Weidmann'sche Buchhandlung, Leipzig, 1852.

[29] Harry E.Burton. The optics of Euclid. *Journal of the Optical Society of America*, 35:357–372, 1945 orig. ca.300BCE.

[30] Hermann von Helmholtz. *Physiologische Optik*. Leopold Voss, Leipzig, 2 edition, 1892.

[31] Arthur Eddington. *The nature of the physical world (1926–27 Gifford lectures)*. MacMillan, 1928.

[32] Jan J. Koenderink, Andrea J. van Doorn, and James T. Todd. Wide distribution of external local sign in the normal population. *Psychological Research*, 73(1):14–22., 2008.

[33] Lars Arendt-Nielsen and Peter Svensson. Referred muscle pain: basic and clinical findings. *Clin J Pain*, 17(1):11–19, 2001.

[34] Vittorio Benussi. *Psychologie der Zeitauffassung*. Winter, Heidelberg, 1913.

[35] Jan J. Koenderink. The structure of images. *Biological Cybernetics*, 50(5):363–370, 1984.

[36] Jan Koenderink, Andrea van Doorn, Baingio Pinna, and Johan Wagemans. Boundaries, transitions and passages. *Art and Perception*, 4(3):185 – 204, 2016.

[37] Judea Pearl. Causal inference in statistics: An overview. *Statistics Surveys*, 3:96–146, 2009.

[38] James J. Gibson. The ecological approach to the visual perception of pictures. *Leonardo*, 11:227–235, 1978.

[39] Roberto Casati and Achille Varzi. *Parts and Places: the structures of spatial representation.* MIT Press, Cambridge MA, 1999.

[40] Robert F. Hess. Developmental sensory impairment, amblyopia or tarachopia. *Human Neurobiology*, 1:17–29, 1982.

[41] John D. Mollon and A. J. Perkins. Errors of judgement at greenwich in 1796. *Nature*, 380:101–102, March 1996.

[42] Ernst Mach. *Beiträge zur Analyse der Empfindungen*. Verlag von Gustav Fischer, Jena, 1886.

[43] Wilhelm Wundt. *Grundzüge der physiologischen Psychologie*. Engelmann, Leipzig, 1902.

[44] Jan Koenderink, Whitman Richards, and Andrea van Doorn. Blow-up: a free lunch? *i-Perception*, 3:141–145, 2012.

[45] Jan J. Koenderink, Andrea J. van Doorn, Matteo Valsecchi, Johan Wagemans, and Karl Gegenfurtner. Eidolons: Novel stimuli for vision research. *Jornal of Vision*, accepted, 2017.

[46] Jan J Koenderink. The . of awareness. *Perception*, 45(9):969–972, 2016.

[47] Benjamin Balas, Lisa Nakano, and Ruth Rosenholtz. A summary-statistic representation in peripheral vision explains visual crowding. *Journal of Vision*, 9(12)(13):1–18, 2009.

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