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EN

FIGURING

Staring out into a dense canopy of branches, or at the white blindness of the frozen tundra, ancestral humans would have seen a variety of shapes overlapping with an irregular geometry. Contours and assemblages of leaves and bushes swaying in the wind to form combinations of intersecting shapes for a passing moment, before once again changing form.[I] Sinewy lines of trees contrasting against the open and infinitely receding horizon, like veins crawling across the skin of a clear sky.

The random fractal patterns caused by the entropic processes of nature – the wind that rustles trees, or the rain that slowly scoops out rocks – distort straight lines and surfaces into skeins of contorted and receding planes, jumbles of triangles and arcs.[II] Straight lines are topologically distinct.

The figure ⌞, for example, is more commonly found in nature than is the figure ⋌:

> L junctions are typically the result of contiguous contours, T junctions are the result of partial occlusions, and X junctions are the result of object surface adjacencies (such as stacks or tiling of objects or partial transparency ...[1]

The ability to detect the presence of ·· to process ¯¯¯·. is an evolutionary competence,[III] one for which homo sapiens are particularly apt – like counting or gossiping. We have evolved a remarkable ability to rapidly process these configurations;[IV] and it turns out, they are fairly invariant:

> the configuration distribution for natural scenes appears to be highly robust across very different environmental settings ... [W]hereas the distribution of geometrical shapes may well vary considerably across ecological settings, the distribution of topological shapes is much more invariant. Informally, nearly any environment with opaque, macroscopic objects strewn about (and thereby partially occluding one another) will possess strong correlations with this signature configuration distribution.

The capacity to visually process such scenes might in fact explain the shape of visual signs, including letters.[2] Their structure seems selected to match those found in nature, as Mark A. Changizi's research suggests. Visual signs seem to "disproportionately possess" such naturally common configurations, their structure optimized for visual recognition "because we have evolved to be competent at processing the configuration types found in natural scenes."[3] These configurations correlate closely with visual signs employed by humans.

These signs themselves have been subject to a process of selection that taps into our ability to recognize objects, including the ability to tell whether they are the result of human intervention.[V] "The lack of correlation between shorthand and visual signs and the lack of correlation between motor complexity and visual signs – suggest that visual sign topological shape is not strongly selected for the motor system." Rather, these are visual signs that humans have, through evolution, become particularly good at processing. The forms have of course been adapted to be distinguished or delineated on surfaces, such as papyrus, walls, or screens.[4] Easily seen and clearly detected.

This adaption has created a complex capacity for visual processing, in which the eye seems to process the shapes of letters with orthographic or syntactic complexity,[5] such that 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.[6]

COUNTING

The ability to distinguish or to divide objects according to their size brings with it a significant advantage: the biggest fish, the shortest climb, an even number of females. So far, so good. From there, things begin to get a bit complicated. From the simple equivalence of 1 apple is worth 6 grapes, it is not at all clear that 2 apples are worth ½ a peach, which would then be worth, at least at first deduction, 12 grapes.[VI] III does not necessarily follow from II – though "many" seems to follow clearly from more than II. Enumeration is, to put it plainly, not just mere counting; number evinces the size and shape of the things that inhabit the world.[7]

Herodotus, in his *History*, recounts an encounter between the Carthaginians and a tribe in Libya trying to sort this kind of thing out:

> There is a country in Libya, and a nation, beyond the Pillars of Heracles, which they are wont to visit,

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> where they no sooner arrive but forthwith they unlade their wares, and having disposed them after an orderly fashion along the beach, leave them, and returning aboard their ships, raise a great smoke. The natives, when they see the smoke, come down to the shore, and, laying out to view so much gold as they think the worth of the wares, withdraw to a distance. The Carthaginians upon this come ashore and look. If they think the gold enough, they take it and go their way; but if it does not seem to them sufficient, they go aboard ship once more, and wait patiently. Then the others approach and add to their gold, till the Carthaginians are content. Neither part deals unfairly by the other; for they themselves never touch the gold till it comes up to the worth of their goods, nor do the natives every carry off the goods till the gold is taken away.[8]

Till it comes to the worth is a rather glib way of putting it. What kind of counting is actually taking place here?

The oldest record of prime numbers (2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37 etc.) is believed to be the 25 000-year-old baboon bone found in the Congo in 1960:

> The Ishango bone is a 10-cm long curved bone, first described by its discoverer, Prof. J. de Heinzelin. He found the tiny bone about fifty years ago, among harpoon heads at a certain depth in stratified sand in the area of the Ishango fishermen village on the shores of the Semliki river, not far from the present border between Congo and Uganda. ... the bone carries 167 or 168 notches distributed in three columns along the bone length.[9]

We start off with a counting problem: 167 *or* 168 notches on the bone, in three columns along their length.[10] These columns are called M, G and D respectively, following the French (Left [*Gauche*], Right [*Droite*], and Middle [*Milieu*]).[11] The middle column, from top to bottom, contains groups of 3, 6, 4, 8, 9 or 10, 5, 5, and 7 notches; The G and D columns have four groups of 11, 13, 17, 19 and of 11, 21, 19, 9 notches respectively.[12] These are “consistent with a numeration system based on 10, since the notches are grouped as 20+1, 20–1, 10+1, and 10–1.” The first four groups of the middle column evince a form of duplication, or multiplication by 2.[13] It is the left, or G column, that contains the primes between 10 and 20, or 11, 13, 17, and 19 (a prime quadruplet). The frequency of these primes is calculated by the following formula:[14]

$$P_x(p, p+2, p+6, p+8) \sim \frac{27}{2}\prod_{p\geq 5}\frac{p^3(p-4)}{(p-1)^4}\int_2^x \frac{dx}{(\ln x)^4}$$

$$= 4.151180864 \int_2^x \frac{dx}{(\ln x)^4},$$

Prime numbers notched into the fibula of a baboon 25 000 years ago. What kind of counting is going on here?

> ... the Ishango number system would have involved the number 12 in particular. Now one of the many African counting methods, similar to the ones given above, uses the base 12: the thumb of a hand counts the bones in the fingers of the same hand. Four fingers, with each three little bones, evidently yield 12 as a counting unit. Also, each dozen is counted by the fingers of the other hand, now including the thumb, and the multiple 5×12=60 provides an additional indication of the often simultaneous occurrence of the duodecimal and sexagesimal base.[15]

The baboon at Ishango[VII] would have been hard pressed to keep up with this duodecimal system – the thumb counting out the three bones of each finger of the hand to twelve – but not entirely lost. Animals possess an *innate* sense of number. Many can sum sets of objects without actually counting: falling apples.[16] Bees can differentiate between varying quantities, whereas rhesus monkeys can match “the number of sounds they hear to the number of shapes they see,” while also differentiating between the larger of two flashing dots.[17] Elizabeth Brannon suggests this likely evolved from the need of territorial animals “to access the different sizes of competing groups and for foraging animals to determine whether it is good to stay in one area given the amount of food retrieved versus the amount of time invested.”[18] There might be, however, a threshold of number: salamanders can differentiate 1, 2, 3 flies, but not between 3 and 4.[19]

BLINKING

Every few seconds, nerve cells between the base and outer surface of the brain release the triangular muscle that elevates the upper eyelid (*levator palpebrae superioris)* as another muscle (*orbicularis oculi*) tenses involuntarily.[20] The eyes close and then suddenly reopen.[VIII] The skin around them draws into folds radiating from the angle of the eyelids, before the frontal ball of the eye is once again instantaneously exposed to light.[21] A black spot is inserted into the ongoing perception of the world for about 300–400 milliseconds – an abrupt *cut-to-black* repeated 7–15 times per minute, making up nearly ten percent of the brain’s waking hours.[22] The ostensible function of this largely imperceptible yet constant interruption of vision is to lubricate or clean the ocular surface, conjunctiva and the epithelium. This opening and closing is also a protective reflex – a response to anything suddenly approaching the face.[23]

None of this is either random or particularly obvious. Evolution has modulated the rapid closing and opening of the human eye to a particular amplitude and frequency.[24] Even after 24 hours in total darkness, the rate of blinking does not vary significantly from that while sitting in a well-lit room.[25] The fact is, the human eye blinks much more than it ought to.[26] The mean rate of other primates is nearly half of that of humans, for whom the frequency of blinking increases tenfold from infancy onward.[27] The human eye blinks at the metric end of sentences (waiting for punctuation),[28] or in implicit breakpoints during the attentive act of listening or looking. Sounds of a certain amplitude and pitch effect an increase, as do variations in dopamine levels.[29] Schizophrenics blink more often than patients with Parkinson’s.[30]

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The evolutionary advantage of this isn't entirely clear. Blink. Threat. *You're dead*.

> Imagine yourself as one of the early humans. You need to seek food and shelter to stay alive, but you also need to be wary of predators ... If a blink lasts nearly half a second, that half a second could be the difference between life and death. What, then, would be the evolutionary pressure to select for keeping our eyes closed longer than we need to? If we blink for nearly half a second every 3–4 seconds we spend over an hour and a half of our waking day with our eyes closed. Wouldn't there be a stronger pressure for keeping our eyes open?[31]

What accounts for the constant and imperceptible opening and closing of the human eye?[IX]

Each of the hundreds of daily blinks in fact function as a form of cognitive release. They disengage attention by momentarily deactivating the dorsal attention network that allocates focus to locations, objects, or features.[32] Cortical activity during these blinks include the regions of the brain associated with introspection.[33] The blink is not merely a black frame inserted into the pulsing film of experience, by the relaxing and contracting of complementary muscles. Each blink is both like an instant daydream and a second look.[34] Blink. Threat. *Focus*.

There are various ways to test the rate and reflex of these passing daydreams and double takes. Experimental set-ups employed have included: irritating the eyes with cigarette smoke, ("the subject was given a cigarette to smoke and instructed to hold it continuously between the lips."); measuring the blinking periods of a cocainised eyeball; making the subject watch episodes of Mr. Bean on video to measure the rate of blinking (which is strangely convergent, since subjects *blinked at the same time*)[35]; and experimentally producing "sudden and impotent anger," to increase the frequency of blinks.[36]

With an increase in anger, the frequency of blinking also increases in relation to vergence, so that eyes fixed on a near point blink faster than those moving from one point to another, or with the eye following a moving object while the head remains still.[37] This allows the eyes to follow movement in its periphery though the head remains stationary. "It requires requires extraordinary effort and attention to focus the gaze perfectly sharply on a definite point of the visual field even for 10 or 20 seconds," wrote Hermann von Helmholtz in his *Treatise on physiological optics* (1866).[38] This "wandering of the gaze" consisted of continual miniature eye movements we now know as microsaccades: rapid shifts a couple of times per second, like sudden jerks of the eyeball even while fixed.[39] The eye never stops moving. Our visual perception relies on this retinal image motion.[40] These sudden jerks of the eye ensure that we see a non-moving image, the eye moving even as the scene itself remains still.[41]

A striking aspect of the movement of many birds, such as chickens and pigeons (who blink at rapid rates), is a distinctive bobbing back and forth of the head *while* moving.[42] "Like many other birds, pigeons show a very characteristic motion pattern during walking, running and landing flight: the head appears to move rhythmically forwards and backwards,"[43] as Nikolaus F. Troje and Barrie J. Frost describe.

In order to determine the exact character of this movement, Frost put male white Carneaux pigeons on a treadmill, and filmed them using with a 16 mm camera:

> It was found that the pigeons quickly adapted to the treadmill apparatus and could be readily induced to walk when the motor speed was set to an average walking speed ... Head-bobbing records were made by motion photography with a Bolex Hi 16 reflex 16 mm camera using Kodak Tri-X film typically shot at 64 frames/s. Head, breast, wingtip and foot positions were measured by projecting single frames of the movie, at exactly twice life size, onto a tracing paper screen with a LW Photo-Optical Data Analyzer Model 224–A projector equipped with a frame counter and single frame advance mechanism.[44]

Like Muybridge slowing down the movement of the human gait,[X] or the gallop of a horse to empirically confirm its movement, Frost found that the head-bobbing of pigeons in fact consists of two phases. In the first phase, the head is "locked" in space, relative to the body moving forward; in the second, the head "thrusts," rapidly, in order to catch up. Jerking back and forth, the pigeon tries to hold onto a retinal image of the world, hurling forward toward it a split second later. The "hold" phase allows the pigeon to stabilize this retinal image, taken at the point in space where its head was previously relative to the forward-moving body – adding, in the process, information about depth from parallax.[45]

On the treadmill, Frost could get the pigeons to walk without bobbing, in fact, by equalizing the speed of the belt with their walking. Slowing down the speed of the treadmill made the pigeon's head push so far forward that the pigeon "eventually toppled over."[46]

NOTING

Gazing up at the sky one November evening in 1572, the astronomer Tycho Brahe noted "a new and unusual star," in the heavens above:[XI]

> (I)n the evening after sunset, I was contemplating the stars in a clear sky.
>
> I noticed that a new and unusual star, surpassing the other stars in brilliancy, was shining almost directly above my head; and since I had, from boyhood, known all the stars of the heavens perfectly, it was quite evident to me that there had never been any star in that place of the sky, even the smallest, to say nothing of a star so conspicuous and bright as this. I was so astonished of this sight that I was not ashamed to doubt the trustworthyness of my own eyes. But when I observed that others, on having the place pointed out to them, could see that there was really a star there, I had no further doubts.

This new star ("nova") appeared just outside the distinctive W-shape of the constellation Κασσιέπεια, or Cassiopeia, one of the 48 constellations identified by Ptolemy.[47] The significance of the blinking presence did not escape

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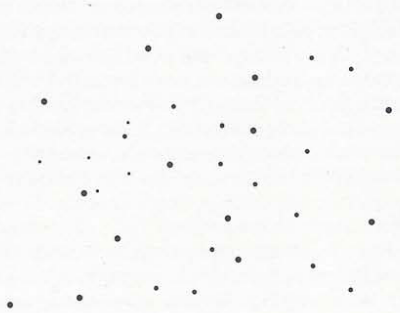
Brahe. This new star, shining as bright as Venus, was "a miracle indeed," since it had never previously been seen before our time, in any age since the beginning of the world." Brahe's star, described in his *De nova et nullius aevi memoria prius visa stella* (Concerning the Star, new and never before seen in the life or memory of anyone) published in 1573,[48] evinced a new event in the supposedly immutable, fixed heavens of Aristotle.[49] It remained visible in the night sky for nearly 16 months before declining in brightness and eventually disappearing. We now know Brahe's *stella nova* as SN1572, or Tycho's Supernova, 15 000 light years from earth, and one of a few explosions of a dying star ever noted in historical records as observed with the unaided eye.[50]

Noting, Brahe's new star tells us, is a distinct feature of knowing – and we never know what to look for until we see it, be it a sleeping man on a high-speed train or the movement of waves breaking continuously against a rock.[XII]



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