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Research Article

Holographic Processing in Neural and Psychosocial Systems

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Keywords: Holographic processing; Neural microstructure; Gabor processing; Fourier processing; Quantum holography; Information processing; Sensory perception; Motor function; Purposeful action; Spectral domain; Psychosocial systems

Abstract

With his application of the physics of image and information processing in research on the brain, the late, world-renowned neuropsychologist, Karl Pribram, illuminated the inner workings of neural processes with his holographic approach. Pribram shows that both Gabor processing and Fourier processing are involved in processing in the neural microstructure, and that memory/retrieval, sensory perception, and motor function, can all be understood in the terms of holographic processing, which is extended, here, to purposeful action. In collaborative work, Bradley and Pribram applied Gabor processing to show how social communication in groups, via the field of affective attachment among members, distributes quantized holographic-like units of information about collective order to generate functionally effective patterns of organization.

In the fifteen or more years since this striking resemblance between holography and certain brain/behavioral processes was noted, much evidence has accumulated to show that what began as a metaphorical simile has been developed into a precise neurological model.

Such a theory is thoroughly grounded in the structures and functions of the microanatomical connectivity of the nervous system and provides a mathematically sophisticated formalism of the relationship between anatomy and memory structure.

... There is little remaining doubt that some brain processes are characterized by holonomic transformations that result in algebraic isomorphisms between image/object on the one hand and the holographic transform domain on the other Karl H. Pribram [1,2].

"Hidden behind the discrete and independent objects of the sense world is an entangled realm [quantum reality] in which the simple notions of identity and locality no longer apply." [3].... and at the scale in which we navigate our [4-D spacetime] world, is a hidden holographic universe in which are embedded the objects we perceive with our senses and actions. The enfolded realm spans all scales of inquiry from cosmic through brain processing to quantum fields Karl H. Pribram [4].

Prologue

Psychologist Karl Lashley was the late, world-renowned neuropsychologist Karl Pribram's mentor. Lashley conducted a lifetime of experiments teaching rats to learn a maze after which he surgically removed a portion of the visual cortex, in searching for the engram (the location of the memory image of the maze path). Despite surgical excision of almost all the visual cortex, the rats could still find their way through the maze! This left Lashley exasperated, a result for which he had no answer. After learning about Gabor's discovery of holographic organization, Pribram realized that the principle of distributed organization of information—namely, that information about an object (as a whole) is recorded at all points and locations throughout a field by the movement of energy—appeared to offer a way of explaining Lashley's paradoxical result. To resolve the paradox, Pribram had to venture deeply into the principles of holography—viz, the physics of image and information processing.

Introduction

As "sentient" creatures, we have awareness of feelings that signal, on a moment-by-moment basis, the disposition of our life experience. Our sensory perception, our movement, our thoughts and knowledge, and our plans and strategies for action "[come] to the mind in the form of *images*", neurologist Antonio Damasio writes. But he asks, "How do [our brains] come to create these marvelous constructions?"

… the neural activity that is most closely related to the *images we experience* occurs in the early sensory cortices and not in other regions. … whether [this] is engaged by perception or by recall of memories, *is a result … of complex processes operating behind the scenes*, in numerous regions of the cerebral cortex and of neuron nuclei beneath the cortex, in basal ganglia, brain stem, and elsewhere [5].

In the seven decades of research before his passing in 2015, Pribram delved in depth into "these complex processes operating behind the scenes". In his quest for understanding, Pribram found a viable approach in the physics of *image* [6] and *information* processing [7]. In his application of this approach, Pribram was able to show how neural processing of memory/retrieval, sensory perception, and motor function can all be understood in terms of holographic processing [8]. Building upon Pribram's approach, a model of holographic processing extends this to purposeful action.

The paper proceeds in three stages: first, the signal-processing and neural basis of holographic processing; second, its application to purposeful action and psychosocial organization; and third, a brief consideration of broader implications.

The brain as a 'pattern matching' computer

A crucial development in Pribram's work was a collaborative project, *Plans and the Structure of Behavior*, in which he and his co-authors and viewed brain processes in terms of computer processing [9]. Upon publication, the book stimulated a veritable revolution in brain science and psychology, facilitating the shift from behaviorism to a cognitive approach in which the animal or human interacted in their world with a *thinking* brain. Neural scientist Joseph LeDoux describes the utility of this approach:

Cognitive science treats minds like computers …. [It] has been very successful, and provided a framework that, when appropriately applied, provides an immensely valuable approach for pursuing the emotional as well as the cognitive mind [10].

Adopting the metaphor of a computer, Pribram and his collaborators viewed the brain as a programmable pattern-identifying and matching system [9]. Beginning by viewing neural processing as a "controllable thermostat"—viz, as a means of embodying, in systems logic, "*behavior [that] is controlled by the operations of an organism to fulfill an aim*", they moved to the circuitry of a *rheostat*,[1] because its logic was more appropriate for the brain as a regulator of a "*programmable, adjustable process*" [4]. This led them to view the basic logic of neural processing as a servomechanism (TOTE)[2] incorporating parallel processing with feedback and feed-forward control circuitry. A radical alternative to the dogma of behaviorism in psychology at the time, their approach was based on the postulate that the individual (animal or human) was *purposeful*, pursuing an "aim" or a "plan" in their interactions in the world (Figure 1). Today, this approach is known as cognitive science. Yet for Pribram, the computational metaphor remained provisional; the deeper issue was how distributed neural processing could generate stable images for memory, sensory perception, and purposeful action.

Feedback and feed forward regulation

Depicted in cybernetic terms, Figure 2 shows how Pribram viewed the brain as a control regulator for body systems' function and behavior. The baseline mode of the system (bottom circuitry) shows the brain's default 'setpoint' for system stability. It prompts this level of system behavior, which it regulates through feedback of input from internal and external sources, which is compared against the setpoint. A discrepancy between the two causes the brain to prompt the system to adjust its activity, accordingly, thereby restoring system stability. To change the level of body function requires establishing a new "setpoint" of system control (top circuitry). This is shown as the red 'feed forward' arrow by which the brain 'resets' system function to the new level. Locking this in requires *repeated cycles* of system activity at this level for it to become the "familiar" state and, thus, be instantiated in the neural architecture.

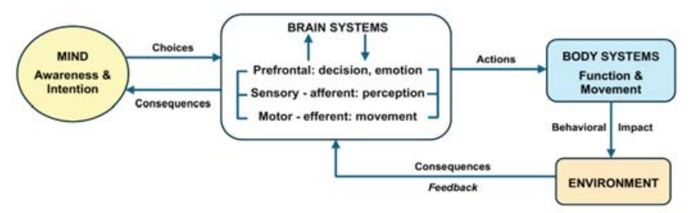


Figure 1: Schematic Showing Relations Among Mind, Brain, Body, and Environment Regarding Choices, Actions, and Consequences.
A highly simplified schematic of Purposeful Action (behavior in pursuit of an aim/goal). Highlighted is feed forward - feedback parallel processing of the primary Brain Systems involved in implementing and monitoring the actions of the Body's various systems, which, as behaviors, impact the Environment and result in various consequences. The consequences are perceived by sensory perceptual systems, and enable conscious adjustment of the choices which, in turn, produce modifications in motor control to change body function and movement, in adjusting behavior to better achieve the Plan. (© copyright, 2026, R. T. Bradley, Institute for Whole Social Science.)

[1] *Pribram [4] explains that "rheo is Latin for "flow"".*
[2] *The acronym "TOTE" signifies its four operations (Test-Operate-reTest-Exit). See Pribram [4] for a fascinating account of how Pribram and his collaborators used the metaphor of a "controllable thermostat" (as embodied in TOTE) to move neuropsychology from behaviorism to cognitive science.*

As a "novel" (new) situation is repeatedly experienced, these inputs are reinforced in the neural architecture as the 'familiar' (habitual) pattern and encoded as memory. In this way, the current reference pattern in the brain—its baseline setpoint—becomes modified, and the control circuitry is fed-forward to this 'new' setpoint. This shifts system activity to this new level (top circuit, Figure 2). From this point on, the system automatically strives to maintain a match with inputs that sustain the new level of activity, which is now the baseline setting [4].

Typically, this reset process occurs automatically and unconsciously. However, a *feed-forward* system reset process can be *intentionally induced*. This occurs as a pattern-matching operation in which the individual engages their mind to intentionally focus on a new emotional, cognitive, or behavioral target, a 'Plan'.

Purposeful action

Pribram defines a "Plan" as the "image of achievement" which precedes purposeful acts. This is a neurological *image* (an internal representation) of the "target" of achievement [11]. Hence, holding the new Plan in *mind* as the target of achievement induces the neural architecture to instantiate a *feed-forward* circuit as new patterns of input are *repeatedly* experienced, so that the match between target and repeated experience is stabilized as the new setpoint [8]. This is illustrated in Figure 3. A with the example of an intentional *reset* of the autonomic system using an emotional management technique which holds '*heart coherence*' in mind as the intended target[3]. While Figure 3B shows electrophysiological recordings from an individual to illustrate the self-initiated system reset process, the Institute of HeartMath has conducted many studies confirming self-induced shift to Heart Coherence in various populations [12,13]. This includes a field experiment involving 10th grade high school students (Experiment Group, N = 48; Control Group, N = 50) where the Experiment Group students shift to coherence produced statistically significant differences on all five measures of heart rate variability in an Analysis of Covariance (ANCOVA) [14]. The heart coherence example is used here as an illustrative case of intentional feed-forward resetting, *not* as part of the evidential basis of the holographic argument. Later, we'll come back to Pribram's concept of "image of achievement" to describe the holographic processing involved in such purposeful action.

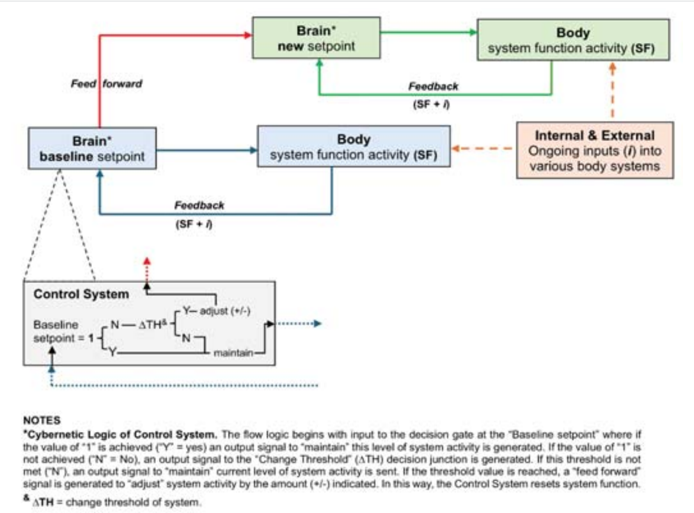


Figure 2: Logic of Brain as a Control Regulator for Body System Function Depicted in a highly simplified schematic form, is how the brain operates as a control system to regulate functions of the body. Note: the internal logic of the brain as a "control system" is depicted in cybernetic terms beneath the figure, in the gray shaded box. It shows the flow logic of inputs/outputs at the "Baseline Setpoint" and "Change Threshold of System" decision gates.
The baseline mode of the system is shown in blue (bottom circuitry), wherein the brain's baseline "setpoint" for system stability prompts this level of system behavior which it regulates through a feedback informational input to the brain—including that from internal and external sources, which is compared against the setpoint. A "mismatch" between the two causes the brain to prompt the system to adjust its function accordingly, to bring the system back to stability. To change the activity level of body function requires establishing a new "setpoint" of system control in the brain. This is shown as the red arrow by which the brain has "reset" the desired/target state of the system to new level of function, shown in green (upper circuitry). Establishment of a new level of system function requires repeated cycles of system behavior at this level for this behavior to become habituated—in Pribram's terms the "familiar" state (© copyright, 2025, R.T. Bradley, Institute for Whole Social Science.)

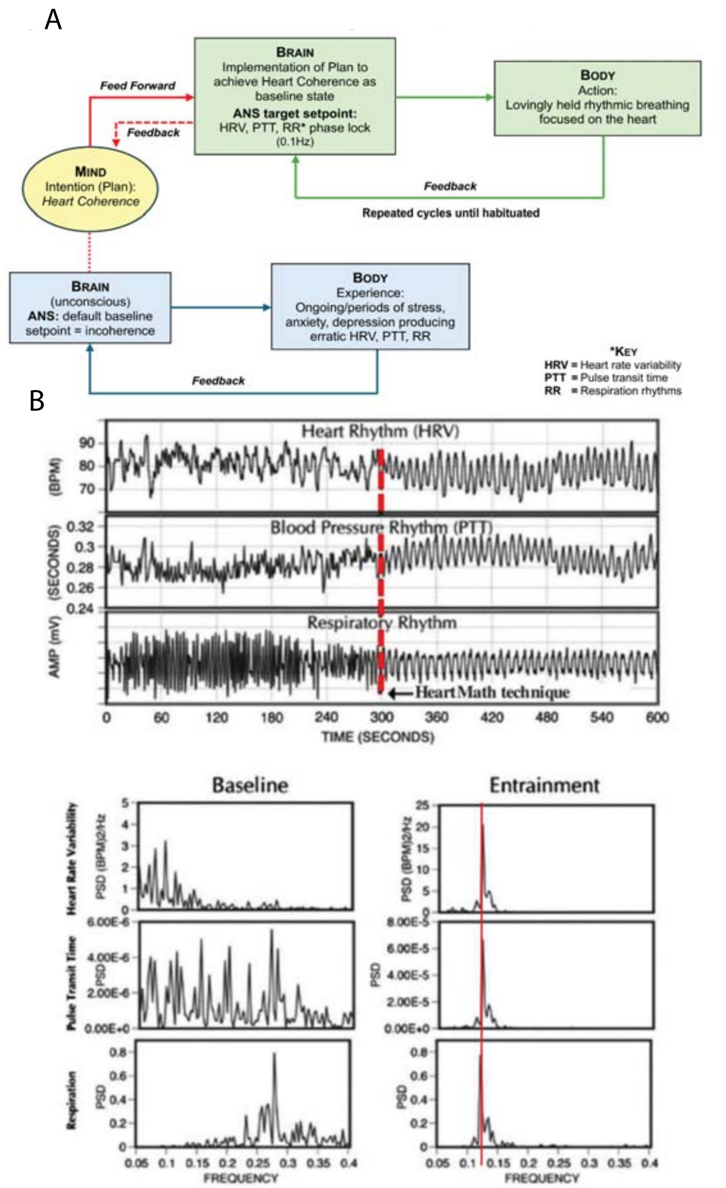
Neural processing

Pribram's research on the distributed (nonlocalized) organization of memory [11,15], the experiments by DeValois and DeValois [16,17] on vision, and Von Békésy [18] on audition, along with the results from other studies[4], provided a compelling body of evidence that memory and sensory perception were consistent with the principles of holographic processing [2].

In a 'eureka' moment, upon viewing Bernstein's [19] study from cinematographic recordings of waveforms from human subjects walking while wearing a black costume with white tape along arm and leg bones and white dots on joints, Pribram realized that neural representation of motor function, also, was processed holographically. Bernstein had used Fourier analysis and "*was able to predict each subsequent action accurately!!!*" [4]. In an experiment, involving passive movement of a cat's foreleg while recording electrical activity of single cells in the cat's motor cortex, Pribram found that "*These motor cortex cells responded to frequencies much as did the cells in the auditory and visual cortex*" [4], thus showing that motor function involved holographic processing in the *same* way as memory/retrieval and sensory perception.

Finally, while noting how useful the 'brain as a computer" metaphor was as an approach to research in designing experiments to show that sentient animals and humans were purposeful in their interactions with their environments, Pribram explicitly states that brain processes are *not* the same as computer processing:

[3] *The reader should note the feedback loop from the Brain to Mind (red dotted arrow), in Figure 3.A. This is to show how the individual can adjust their Plan in response to internal or external changes.*
[4] *Reviewed in Pribram [11].*



Entrainment During Psychophysiological Coherence. These real-time recordings show an individual's heart rhythm activity (heart rate variability pattern), pulse transit time (a measure of beat-to-beat blood pressure), and respiration rhythms over a 10-min period (**top graph**). At the 300-s mark, the individual used a HeartMath emotion self-regulation technique to activate the *psychophysiological coherence* state, causing these three physiological systems to come into entrainment. The **bottom graphs** show the frequency spectra of the same data on each side of the dotted line in the center of the top graph. Notice the graphs on the right show that all three systems have entrained to the same frequency (*0.12 Hz). (Adapted from Tiller et al. (1996), © Institute of HeartMath).

Figure 3: Example of Intentional Shift to Heart Coherence as a Feed Forward Process
A. The figure shows how an intentional shift to induce a state of heart coherence, when repeated daily, can reset the baseline setpoint for the psychophysiological system. By engaging the conscious Mind, the individual is able to intentionally shift their body's psychophysiological baseline function from a negative emotional state (e.g., stress/anxiety/depression, etc.) to a positive emotional state such as love, appreciation, gratitude, and so forth. Note: I have simplified the diagram by leaving aside the external environment; viz, its impact on the individual and the impact of their actions upon it. (© copyright, 2026, R.T. Bradley, Institute for Whole Social Science.)
B. These real-time recordings show an individual's heart rhythm activity (heart rate variability pattern—HRV), pulse transit time (PTT, a measure of beat-to-beat blood pressure), and respiration rhythms (RR) over a 10-minute period (top graph). At the 300-second mark (red dashed line), the individual used a HeartMath emotion self-regulation technique to intentionally activate the psychophysiological state—viz, to self-induce a change from a negative feeling of "frustration" to a positive feeling of "appreciation". The instant the coherence state is activated, an immediate shift to coherence is evident across all three systems as they are frequency-pulled by heart's rhythmic pattern into entrainment. This is shown in the graphs as a rapid change from an erratic, disordered (incoherent) heart rhythm pattern associated with "frustration" (left) to a smooth, harmonious, sine-wave-like (coherent) pattern induced by "appreciation" (right). The bottom graphs show the ECG electromagnetic spectra of the three recordings above. As is clearly evident, whereas the Baseline measure for each system (HRV, PTT, and respiration) is spread across the frequency spectrum (left), once the individual shifts into a sustained state of coherence, the spectra for the three systems have come into a state of entrainment at the same frequency (0.12 Hz; marked by the thin red vertical line)—viz, a state of system wide coherence. Research has consistently shown that the coherence state is associated with optimal psychophysiological function and performance [12,13](Tiller et al., 1996; McCraty et al., 2006, © copyright 2006, Institute of HeartMath; adapted and reproduced with permission.)

Our brain processes are not composed of input-output cycles. Rather, they are composed of interpenetrating meshed parallel processes: the motor systems of our brain work in much the same way as do our sensory systems. Our sensory systems depend on movement to enable us to organize the perception of images and objects [in terms of object constancy]. *Conversely, our brain's motor systems depend upon imaging the intended achievement* [as a target object] *of our actions* [4].

Holographic processes

In his magnum opus, *Brain and Perception* [8], Pribram presented his Holonomic Brain Theory[5] (which included mathematical formulations[6]) of these neural processes in terms of the physics of *image* and *information* processing[7]. I begin with Pribram's distinction between two forms of holography, Classical and Quantum[8]. While both encode structural information about an object as a whole in the movement of energy, Classical Holography captures a static image, whereas Quantum Holography records each moment as a continuing succession of 'snapshots'.

For clarity, five terms are used here in a specific sense. *Classical holography* refers to the recording of a stable interference pattern from which the structural organization of an object can be reconstructed. *Quantum holography* refers to Gabor's quantized treatment of information processing in which ongoing change is represented as a succession of minimum uncertainty units in joint time-frequency space. *Spectral domain* refers to the transform domain in which information is represented by frequency, amplitude, and phase, rather than by spacetime coordinates. *Logon* denotes Gabor's elementary unit of information, namely, a minimum jointly bounded time-frequency cell. And the term *Holoscape* refers to Pribram's response topography across overlapping receptive fields, which he rendered as contours or as a three-dimensional manifold.

Classical and quantum holography[9]

Both forms of holography have their origins in the work of Nobel Laureate Dennis Gabor [6,7]. Holographic organization is a field concept of order in which energetically encoded information about the organization of a system—as a *whole*—is enfolded into the field and distributed, nonlocally, by the movement of energy to all parts and locations. The process occurs in spacetime as energy radiates, scatters, and diffracts from interaction with objects, creating an interference pattern that contains a tacit image encoded (in terms of frequency, amplitude, and phase) in the *spectral domain*, an invisible reality apart from spacetime. The nonlocalized distribution of information makes it possible to obtain a *static* image—a *hologram*—of the system's global organization from the *information* spectrally encoded in any part or location within the field, as illustrated in Figure 4.

The discussion involves two distinct realms—spacetime reality and the spectral domain—which are related, in that Gabor showed you can get from one to the other and back by means of a Fourier transform (FT) function, which means it is *invertible* [6]. Thus, a *Forward* FT ($\boldsymbol{F(k)}$) into the spectral domain, and an *Inverse* FT ($\boldsymbol{f(x)}$) back to spacetime[10]. At this point, no specifically quantum claim is required. The Fourier transform is invoked here as the formal mapping between the spacetime representation and spectral representation. As we will see, the quantum issue enters *only* when, following Gabor, *time and frequency are treated as conjugate variables* subject to his minimum uncertainty relation, thereby defining an elementary unit of information (a quantum) in joint time-frequency space. In short, although seemingly paradoxical, mutually exclusive domains, spacetime and the spectral domain are *complementary*: viz, while each embodies a different face of reality, they are unified by a specific physical mechanism of translation—the Fourier transform function.

A further distinction is needed. In what follows, holography is used in two related but different senses. In one sense, it refers to an experimentally grounded physical and signal-processing framework involving interference, spectral encoding, and transform relations. In the other, in a later section, it refers to a model for neural and psychosocial organization. In the latter case, *the claim is not that social systems literally perform optical holography, but that they may exhibit distributed, nonlocal forms of informational organization analogous to those found in holographic processing*.

These same dimensions, spacetime and frequency, are also the basis of Quantum Holography. Except here, drawing on

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[5]*See Pribram, 1991 [8], Lecture 2. In clarifying his usage of the word "Holonomic", Pribram writes "The term for the theory, holonomic, was first used by Hertz to describe linear transformations when they are extended into a more encompassing domain. I have here extended its meaning to cover the spectral domain. Holos refers to this domain and Nomos to the naming of the generalization" [8]*

[6]*These were coauthored with Kunio Yasue and Mari Jibu in seven "Appendices" to Brain and Perception [8].*

[7]*Gabor, 1948 and 1946, respectively [6,7].*

[8]*Pribram, 1991, Lecture 2 [8].*

[9]*This section draws heavily on material in Bradley [20] and Bradley and Torris [21].*

[10]*Notation. Let x denote spatial position, t time, k spatial frequency or wave number, and f temporal frequency. Let i = √-1. The function f(x) denotes a spacetime signal or image distribution, and F(k) its spectral representation. Unless otherwise stated, time is measured in seconds, temporal frequency in hertz, and spatial frequency in cycles per unit distance. The Fourier relations are used here in their standard signal-processing sense. In their general form, these transformations are given by the following equations:*

$$\text{Forward FT}: \boldsymbol{F}(\boldsymbol{k}) = \boldsymbol{F}_x\left[\boldsymbol{f}(\boldsymbol{x})\right](\boldsymbol{k}) = \int_{-\infty}^{\infty} \boldsymbol{f}(\boldsymbol{x})\boldsymbol{e}^{-2\eth ikx}\boldsymbol{dx}$$

$$\text{Inverse FT}: \boldsymbol{f}(\boldsymbol{x}) = \boldsymbol{F}_k^{-1}\left[\boldsymbol{F}(\boldsymbol{k})\right](\boldsymbol{x}) = \int_{-\infty}^{\infty} \boldsymbol{F}(\boldsymbol{k})\boldsymbol{e}^{2\eth ikx}\boldsymbol{dx}$$

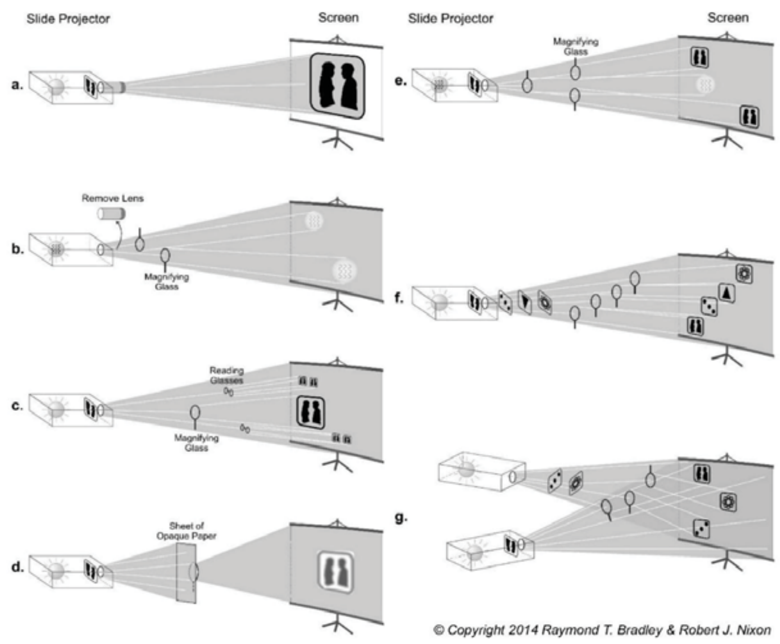

Figure 4: Demonstration of a Holographic Effect.
The normal setup for a slide projector (a) is shown first, with the image of a slide projected by the light emitted from the light bulb through (and focused by) the lens onto the screen. In (b) both the lens and the slide are removed, so that a cone of empty 'white' light is projected onto the screen—'empty,' in that no image of anything at all is apparent. However, holding a magnifying glass perpendicular and close to the projector, at the right focal length, reveals an image of the light bulb's filaments, wherever the magnifying glass is held in the plane of the light cone field projected into the screen. In short, the features of a source object (in this case the light bulb) are encoded as an image everywhere in the energy field emitted from that object. In (c) the slide is reinserted, but without the lens, so that the light passing through the slide appears on the screen as 'white' light; no features or image of the slide are visible. However, holding a magnifying glass and/or one or more pairs of reading glasses (each is a lens), an image of the whole slide can be retrieved for each lens, at the appropriate focal length, from anywhere within the cone field of the 'white' light—demonstrating that an image of the slide is encoded into the light's energy field. Covering most (~90 - 95%) of the magnifying glass lens with a sheet of paper, as shown in (d), the slide's image can still be retrieved from any position in the light cone field—demonstrating the property of information redundancy. The image's features are fuzzy, due to the reduced energy density storage capacity producing a loss in resolution. Yet the object as a whole is still discernible from the smaller amount of light energy passing through the tiny portion of the magnifying glass' lens not covered by the sheet of paper. In (e), an image of the light bulb's filaments and that of the slide can both be retrieved, at appropriate focal lengths, anywhere in the light field on the screen. This shows that the encoded information from the source object is preserved, even though the energy field from the light bulb has passed through the slide and encoded the slide's features as well. This principle of superposition—the recording and preservation of the features of all objects encountered by energy field emitted by an object—can be seen more dramatically in both (f) and (g). In (f), the images from multiple objects (in this case a stack four different slides ~1" apart) are simultaneously enfolded into the light field of energy, so that a clear image of all of the features of each object as a whole is retrievable from any position in the 'empty' field of white light by holding one or more magnifying glasses at the appropriate focal length/s. Preservation of object/image integrity over multi-field interactions is illustrated in (g), using two slide projectors. When the light fields from two projectors, passing through different slides (a stack of two slides in the top projector and one slide in the other), are simultaneously projected, so that their light fields overlap as they travel to the screen, a clear image of the features of the object depicted in each of the slides is retrievable from any position in the overlapping light cones. By holding a lens (magnifying glass or reading glasses) at the appropriate focal length, the images of all objects in the slides can be retrieved—either separately, using a single lens, or simultaneously, with multiple lens at the appropriate focal length/s. While not shown, an image of the source object (the light bulb's filaments) can also be retrieved, despite the light's journey through all of those objects on its path to the screen. Finally, the same experiment can be repeated with a movie projector, in which each picture frame in the movie film is analogous (but not equivalent) to a quantized unit of information—a logon—in quantum holography, as described below. (© Copyright 2014, Raymond T. Bradley & Robert J. Nixon, Center for Advanced Research; reproduced with permission.)

the mathematics of Heisenberg's principle of uncertainty[11], Gabor [7] treats the two as orthogonal coordinates in which measurement precision on one ordinate is obtained at the cost of total *uncertainty* on the other. However, when *conjoined*, as conjugate variables, the coordinates create a phase space in which minimum values on both can be mathematically determined (Figure 5A). The phase space is Gabor's elementary unit of information, a *quantum* of information—the *logon*, which defines the minimum amounts of energy, frequency and space/time required to encode a feature element of a signal for communication with fidelity. Since certainty can be obtained only by minimizing uncertainty on both ordinates, the minimum measurement of the signal in time *and* frequency is given by *Dt Df* **= ½**, which defines an *elementary unit of information*—approximately half a cycle [7][12]. More

[11]*Which is defined as ΔpΔx > h, where Δp is the uncertainty of momentum, Δx is the uncertainty of location, and h is Planck's constant. For a discussion of Heisenberg's 'uncertainty principle' in English see, W. Heisenberg, Remarks on the origin of the relations of uncertainty, in: W. Price and S. Chissick (eds.), The Uncertainty Principle and Foundations of Quantum Mechanics. A Fifty Years' Survey, J. Wiley & Sons, London, 1977 [23], pp. 3–6. For the original publication in German see, W. Heisenberg, Uber den anschaulichen Inhalt der quantentheoretischen Ki ¨ nematik und Mechanik, Z. Phys. 43 (1927) 172–198.*

[12]*In the Gabor elementary function, Δt denotes temporal spacing, Δf frequency spacing, j the temporal index, k the frequency index, and a the width parameter of the Gaussian window. The Gaussian modulation constrains the function so that analysis remains localized rather than extending without bound across the spectrum. In Fourier space, the minimum area is defined by the following Gaussian-modulated complex exponential functions, which is known as the Gabor Elementary Function (ϕjk(t)):*

ϕjk(t) = exp[-π(t-jΔt)2/α2] exp[2 πikΔf (t-jΔt)]

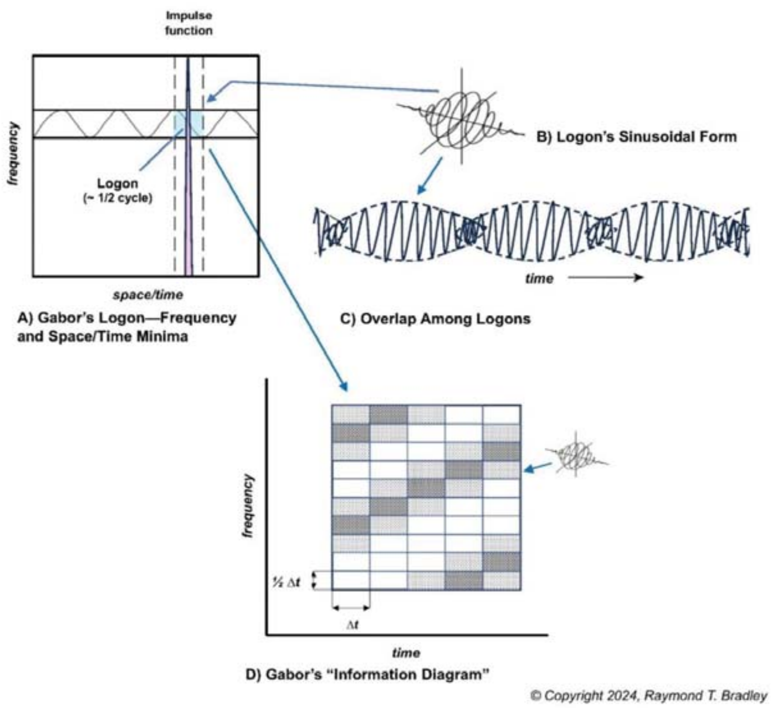

Figure 5: Basic Features of Gabor's Elementary Unit of Information—the Logon
A) The minimum amounts of frequency and space/time (shaded rectangle) required to encode a signal, which Gabor called a logon. B) The logon's 3-dimensional sinusoidal form which emerges from the real (cosine) and imagined (sine) components of the complex Gabor waveform—Gaussian modulated (Adapted from MacLennan [36](1994, Figure 10, p. 11) and used with permission). C) The "overlap" of logons wherein the information from a given logon is spectrally enfolded into adjacent logons. D) Gabor's "Information Diagram" per his "expansion" method for grouping ensembles of logons to capture the entire signal [7]. The pattern of shading, diagonally across the cellular matrix, represents the 'peaks' and 'troughs' morphology of waves of energy. (From Bradley [20](2024a, Figure 2; © copyright, R.T. Bradley 2024; reproduced with permission.)

precisely, the logon is *not* merely a metaphorical snapshot. It is Gabor's minimum jointly bounded time-frequency unit for representing a signal feature with finite fidelity. Thus, the term "snapshot" is employed, both by Pribram and me, only as an aid to understanding.

In Gabor's mathematics, the phase space is Gaussian modulated ("windowed"/ constrained) to prevent spectral progression to infinity. Gabor's reasons for using a Gaussian envelope to modulate the elementary signal are given in his paper, "Communication Theory and Physics" [22]:

One can represent an arbitrary signal in an infinity of ways as a linear function of certain "elementary" signals, associated with the individual cells. There is however one description of particular interest, in which the elementary signals are harmonic functions, modulated with a "Gaussian" signal [,] i.e. they have envelopes of probability shape. These share with other functions the property that their Fourier transforms have the same shape, but they are *unique in the respect that the product of their "effective" duration and of their effective frequency width is the smallest possible for any function* [22].

Viewed in three dimensions, the logon has a sinusoidal form which emerges from its cosine and sine components (Figure 5B). Communicated as a succession of quantized 'snapshots,' logons overlap (Figure 5C). The overlap means there is spectral enfoldment of information among adjoining logons, creating, in Gabor's words, an *"overlap of the future"* [7], an important property we'll come back to. Finally (Figure 5D), the logon is shown as a 'cell' in Gabor's "Information Diagram", which is the basis of his "expansion" method for measuring/ capturing the "entire signal" for communication[13]. The pattern of shading shown in the figure, diagonally across the cellular matrix, represents the 'peaks' and 'troughs' morphology of waves of energy. Signal fidelity in communication requires millions of logons (each cell in the information diagram matrix = a single logon, a quantum of information). Elsewhere [22], Gabor calculates the amount of energy required for each logon—viz, the *minimum* energy required for transmission of a *single* unit of information—which he determines to be "about *a hundred million photons per information cell* in order to define amplitude and phase of the signal to 1% each [!]" As if he was anticipating Pribram's work, Gabor concludes, "The interesting feature of this result is its *generality,* it applies to the unknown processes in the *nervous system* as well as to *electrical communications*" [22].

This is how Pribram explains it:

Gabor's mathematical formulation [of the elementary function] consisted of what we now call a "windowed"

[13]*The recent work by Nishiyama, et al. [24], and their use of "binary holograms" appears an example of a 'lost opportunity' to utilize the power of Gabor's "expansion method" and his "information diagram" [7].*

[Gaussian modulated] Fourier transform, that is, a "snapshot" [the logon] (mathematically defined as a Hilbert space) of the [frequency] spectrum created by the Fourier transform which *otherwise would extend spectral analysis to infinity*. … The Gabor function provides the means to place these communication patterns within coordinates where the spectrum is represented on one axis and space-time on the other. *The Fourier transform lets us look at either space-time or spectrum; the Gabor function provides us with the ability to analyze a communication within a context of both space-time and spectrum* [4].

Accordingly, the term quantum holography is used here in a restricted sense. It refers to Gabor's quantized information formalism *grounded in minimum uncertainty relations*. It does *not* imply that every neural or psychosocial process discussed below is itself a quantum event in the strong physical sense. Where ordinary transform relations and receptive-field filtering suffice, the explanatory basis remains signal processing.

With these distinctions in place, the next question is how such signal-processing principles are instantiated in neural tissue.

Receptive fields in the neural substrate

The features of the objects of perception are encoded in the interference of oscillations of energy as tacit information (spectra) and processed by the neural substrate in receptive fields composed of densely interconnected networks of dendritic fibers [8] (Figure 6A). In various experiments, Pribram and his collaborators found that neural response spectra in receptive fields could be "systematically described," in graphic form, as three-dimensional manifolds rendered by plotting spatial frequency against temporal frequency (Figure 6B). Importantly,

It was then *demonstrated that these manifolds could be derived from Gabor-like functions*, indicating that *somatosensory processing is consistent with the physics of conventional signal processing theory*[14].

The conjoint operation of adjoining receptive fields creates ensembles of logons, each of which is an *element of a feature processing channel* and for which the limits of information processing fidelity are set by Gabor's principle of minimum of uncertainty. Essentially, the operation of ensembles of logons occurs in the same terms as Gabor describes in his expansion of an "arbitrary signal in cosine-type and sine-type elementary signals" [7] (Figure 5D).

Neural processing over these adjoining receptive fields creates a "transneuronal manifold" which Pribram visualizes as a "holoscape" (Figure 6A) embodying Fourier coefficients (amplitude, frequency, and phase). Together, the coefficients define the relations between oscillations, and therefore spectrally encode the stimulus object's spacetime features in physical form. "These components are quantified as Fourier coefficients. *The ensemble of such coefficients, when embodied in physical form, becomes palpable as an optical hologram*" (Figure 6B) [8].

Processing in the neural microstructure requires a "constraint" to prevent spectral progression to infinity and thus enable translation of the spectrally encoded data into imagery along spacetime coordinates:

Note that we are dealing with dendritic patches limited to one or a small congregation of receptive fields … [so that] the transformation is limited to a single or small patch of receptive fields. By definition, therefore, the Fourier transformation is *constrained*, windowed, making the transformed brain event a [Gabor] wavelet [4].

This is a crucial point, for without the operation of a constraint "window" on the neural processing of spectra, there would be *no* physical means by which the energetically encoded information from objects could be rendered into imagery along spacetime coordinates. In other words, we would be *blind*—unable to perceive the spacetime features of an object—because our perceptual experience would be confined solely to the spectral domain, as David Bohm points out [25].

Pribram goes on, "Wavelets are not instantaneous numbers. As their name implies [,] wavelets have an onset slope and an offset slope. Think of a musical tone: you know a little something about where it comes from and a little as to where it is leading" [4]. In addition to the onset and offset slope of the wavelet, there is an overlap among successive wavelets as logons. This suggests a basis for *anticipatory aspects of sensory processing*, insofar as the overlap among successive wavelets carries structured information across adjacent intervals. It arises from "interference" in the overlap among logons, which reflects their spectral enfoldment and which as a Fourier series extends to infinity (Figure 5C). In Gabor's words:

Though the overlapping of the elementary signals may be of small practical consequence …, we have seen that *we could not carry out the expansion into elementary signals without taking into consideration also the "overlap of the future"* [7].

Adjustable neural 'lens'

In his final book, *The Form Within* [4], Pribram clarifies that Gabor information processing and Fourier image processing are *both* involved in neural processing. Also, the 'constraints' on processing in the microstructure substrate of receptive fields are affected by "*cognitive* influences", and that the *prefrontal* cortex (which processes decision and emotional regulation) is implicated in the change to Fourier processing:

[14]Quotes from SantaMaria, et al. [26]: 158; italics added.

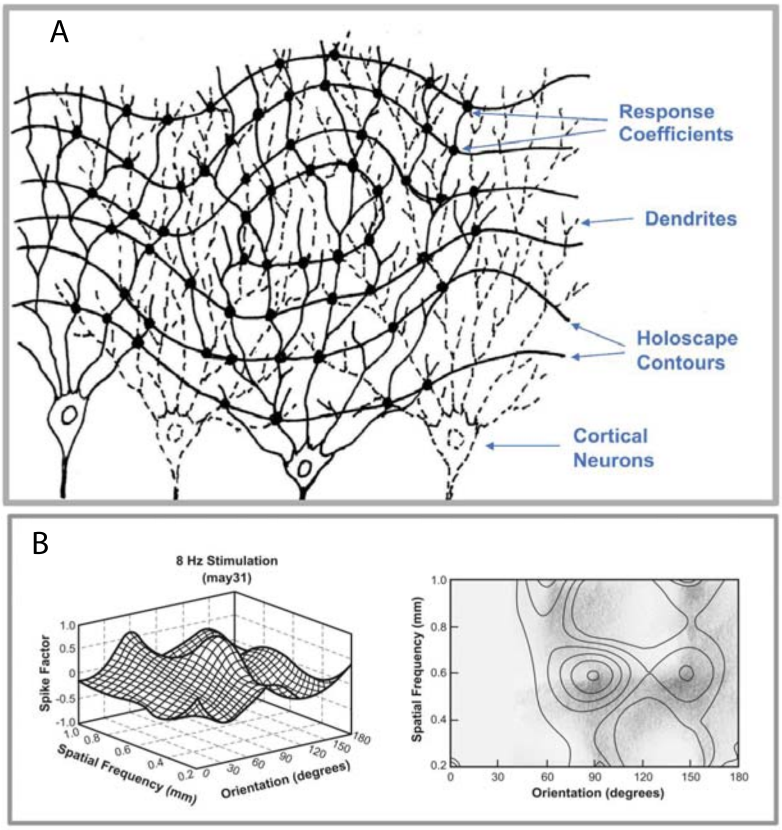

Figure 6: A: Neural Microstructure: Pribram's "Idealized Portrait of a Holoscape". B: Three-Dimensional Response Manifold and Associated Contour Map ('Holoscape') of the Barrel Cortex in Rats.
A) Pribram's "Idealized Portrait of a Holoscape," shows overlapping dendritic receptive fields in which response coefficients of identical value are plotted as a series of contour lines which increase in value toward the center, to create a three-dimensional, knoll-like form. B) Pribram and his collaborators found a similar morphology in the response field in the barrel cortex of rats in an experiment stimulating the rat's whiskers in different orientations and spatial directions. Of note, is that the response manifold displays sinusoidal Gabor wavelet-like form—left. The term "holoscape" is used in Pribram's sense to denote the organized response topography generated across overlapping receptive fields. It refers to a manifold of response coefficients, often displayed as contours or as a knoll-like three-dimensional form, and not to a separate ontological domain. (Both figures adapted and redrawn from Pribram [4]; reproduced with permission from Bradley, 2024a; © copyright, R. T. Bradley.)

The form of receptive fields is not static. ...receptive field properties are subject to top-down (cognitive) influences from higher-order brain systems. Electrical stimulation of the inferior temporal cortex changes the form of the receptive fields to enhance Gabor information processing, as it occurs in communication processing systems. By contrast, electrical stimulation of the prefrontal cortex [decision and emotional regulation] *changes the form of the receptive fields to enhance Fourier image processing .... The changes are brought about by altering the width of the inhibitory surround of the receptive fields. Thus, both Gabor and Fourier processes are achieved, depending on whether communication and computation or imaging and correlations* [respectively] *are being addressed* [4].

This is vitally important, for it means that the constraint "window" can be *adjusted*, much like a *lens*, to enhance *signal* processing via the inferior temporal cortex (Gabor processes) or modulated under top-down cognitive influence, by way of the prefrontal cortex, to enhance *image* processing (Fourier processes)—a key point we will come back to. While a more complex, nuanced process in reality, the logic of these operations in the neural microstructure is shown in Figure 7.

Purposeful change: Holographic feed forward processes

What follows is a theoretical extension of Pribram's framework to purposeful action. Armed with the principles of holographic processing and their application to neural processing, and drawing on earlier work [27,28], the processes of purposeful action can be described in the terms of the two kinds of holography. Not only does this fit with Pribram's research, but holographic processing has enormous efficiencies (Figure 4) which arise from the *spectral* nature of the processing entailed (see the blue shaded boxes in Figure 8). While space constraints permit only a highly condensed overview, I have compensated with a more detailed depiction of the processing logic and description of processing at each phase of the process in Figure 8.

Returning to Pribram's notion of a Plan as a neurological "image of achievement", for the individual, a Plan is the *means* of achievement: *a mentally constructed target object to which the consequences of a program of action are directed, and against which the results of actions are compared* [8]. There are

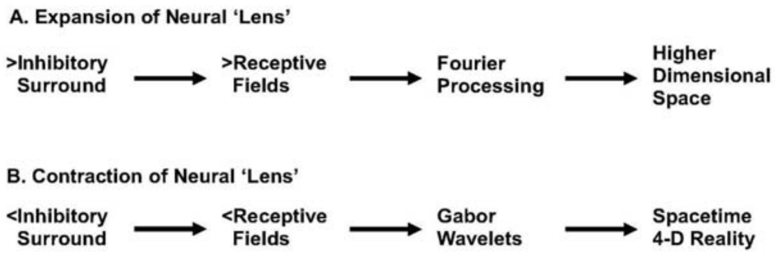

Figure 7: Adjustment of Neural 'Lens'.

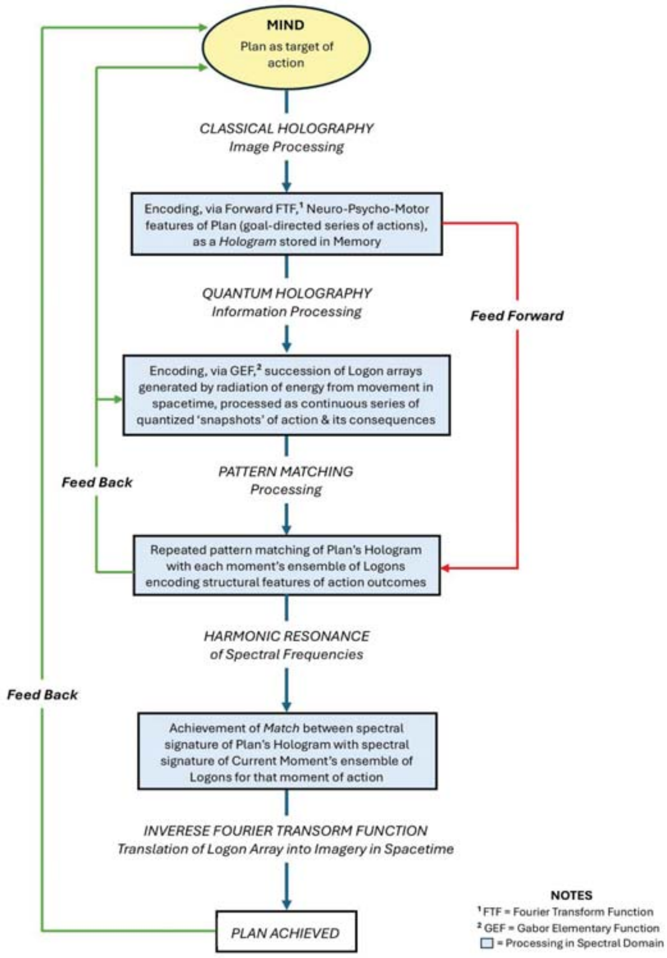

Figure 8: Holographic Processing of Purposeful Action. (Adapted and redrawn from Bradley, 2004, Figure 4.8, © copyright, 2026, R.T. Bradley; reproduced with permission [29])

two key elements here. One is the Plan, which, to be effective, has to be stable, viz, visualized in the Mind as an object of *constancy*. The second element involves actions and their consequences which, by nature, are dynamic and *changeable*.

Thus, because Classical Holography records an *image* of an object that is static, it is the neuro-psycho-energetic processing means by which a mental Plan is encoded as a *hologram* and stored in memory as *stable* representation. By contrast, because Quantum Holography encodes, in ensembles of logons, the structural features of object movement in spacetime as a continuous succession of quantized 'snapshots' (like the individual frames in a video/movie), it is the neuro-psycho-energetic means by which *movement* (behavior and its consequences) is encoded and perceived by sensory perceptual systems.

Putting the two together in a pattern matching process, in which the hologram of the Plan is the *reference image* against which each moment's quantized 'snapshot' of that moment's movement in spacetime is compared, the process repeats until a *match* in spectral signatures of the two is achieved. The match signals that the individual's action at that moment has achieved the Plan.

Summary

Perceptual input from sensory experience is encoded, via a holographic process, in the interference spectra of oscillations of energy and processed by adjoining receptive fields in the neural substrate, which are constrained by an inhibitory surround. Essentially, these microprocessing patterns (Pribram's "holoscape") consist of ensembles of logons, each of which is a feature processing channel. The constraint window on neural processing in the micro substrate of receptive fields is *adjustable* and can be *willfully* changed—expanded to enhance Fourier processing; contracted to enhance Gabor processing. This provides the conscious means for changing the brain's 'lens' in the neural substrate—viz, to focus attention to the 4-D existential world of spacetime, shift focus to the spectral domain of Fourier processes Finally, purposeful action can be understood as a holographic pattern-matching process, in which the hologram of the Plan is the *reference image* against which each moment's quantized 'snapshot' of that moment's movement in spacetime is compared until a *match* in spectral signatures of the two is achieved.

Information processing in psychosocial systems

A word of caution is needed before proceeding. The argument in this section is not that social systems literally instantiate optical holography, but that their organization may be modeled using distributed informational relations analogous to those found in holographic processing.

My own journey of scientific discovery also began with a paradox. As a graduate student at Columbia University, New York, in the mid-1970's, I participated in a largescale, longitudinal study of 60 urban communes—10 selected from six major metropolitan areas in the US (Atlanta, Boston, Houston, Los Angeles, Minneapolis-Saint Paul, and New York) [29]. The primary focus of the study was to map the structure of social relations, on a number of different relational 'contents', among all adult members (> 15 years old) in each group for the three waves of data collection (1974 - 1976) of the study. We developed a "Relationship Questionnaire" to measure each individual's perceptions of their relations with each member of the group, as a set of discrete dyads [29-31].

Of the 46 communes from which 'usable' relational data were collected, my analysis revealed, in a dramatic way for "power" relations in some groups, a *paradox* of measurement when sociograms were constructed from relational data of dyadic perceptions (Figure 9A)[15]. *From the data collected about perceptions of parts—dyadic relations—an image of the organization of the whole—group's social structure—was obtained.* This suggested that group structure—collective consciousness—was organized in a holographic-like manner in which information about group order was encoded and distributed throughout a field of collective 'energy' to all members. In a 'crude' test of this 'holographic' hypothesis, I used membership turnover as a bio-psycho-social mechanism that could disrupt the perpetuation of group order through time. Insofar as, empirically, this was 'true', it would constitute evidence *against* the hypothesis of holographic social order. But what I found is that *coherent collective order persisted despite high levels (>150% in a year) of membership turnover*:

Using membership turnover as analogous to the removal of cortical tissue in experiments on brain function [and memory], [I] found that a commune's ability to maintain a coherent order of power over time is *not* affected by the aggregate level of turnover or a change of (sociometric) leader/s (Bradley, 1987: 269; italics added).

Moreover, a coherent image of such group order appeared to be associated with group survival (Figure 9B). Further investigation, using triadic analysis of the relational structure of charismatic[16] and noncharismatic communes, revealed that the triadic[17] profiles of "Loving" and "Power" relations differentiated the two systems. Finally, the difference in triadic profiles of Surviving and Non-surviving groups appeared strongly interconnected as a *balanced coupling* directly associated with future survival (Figure 9C). Pondering these findings, Pribram and I collaborated on a series of works[18] in an effort to explain the endogenous processes involved.

The result was a Theory of Social Communication that draws on the principles of energy conservation and self-organization and Gabor's [7] concept of information—*minimum of uncertainty*—to describe how the moment-by-moment processing of information generates stable, effective forms of collective organization [31]. Here, too, the term quantum holographic is used by analogy to Gabor's quantized information formalism and not as a claim that social communication is literally an optical or quantum-mechanical process. There is space for the briefest summary.

[15] *For the details of the measurement and operational procedures see Bradley, 1987 [28], Chap. 8 and Appendices A – C.*

[16] *The presence of charisma in a commune was measured from the extensive interviews, field observations and other qualitative data in relation to the following operational logic: first, there had to be evidence of group held beliefs that a leader (alive/dead) held "extraordinary powers", and second, that these "powers" were believed to originate from "supernatural origin". If both conditions were met, a commune was classified as "charismatic" [29] (see Bradley, 1987, Chap. 2 for the concept of "charisma" and the details of measurement and its validation).*

[17] *The "triadic profiles" were derived from a structural analysis of the relational structure of each group in terms of Holland and Leinhardt's [32] 16 isomorphism classes for digraphs with g = 3 (that is, the triad types). For the triadic analyses conducted in both my original study [29] and that with Pribram [30,33], a subset of seven triad types was used (the symmetric 102, 201, and 300 triads for "loving" and later for "flux"; the asymmetric 021C, 021D, and 030T triads for "power") [31]. These served as local indictors of macro structural features of global structure which emerged when sociograms were constructed for the 46 communes. See Bradley [29], Chap. 6, and Appendices A through C for the details.*

[18] *Bradley & Pribram [30]; Bradley & Pribram [30]; Pribram & Bradley [33].*

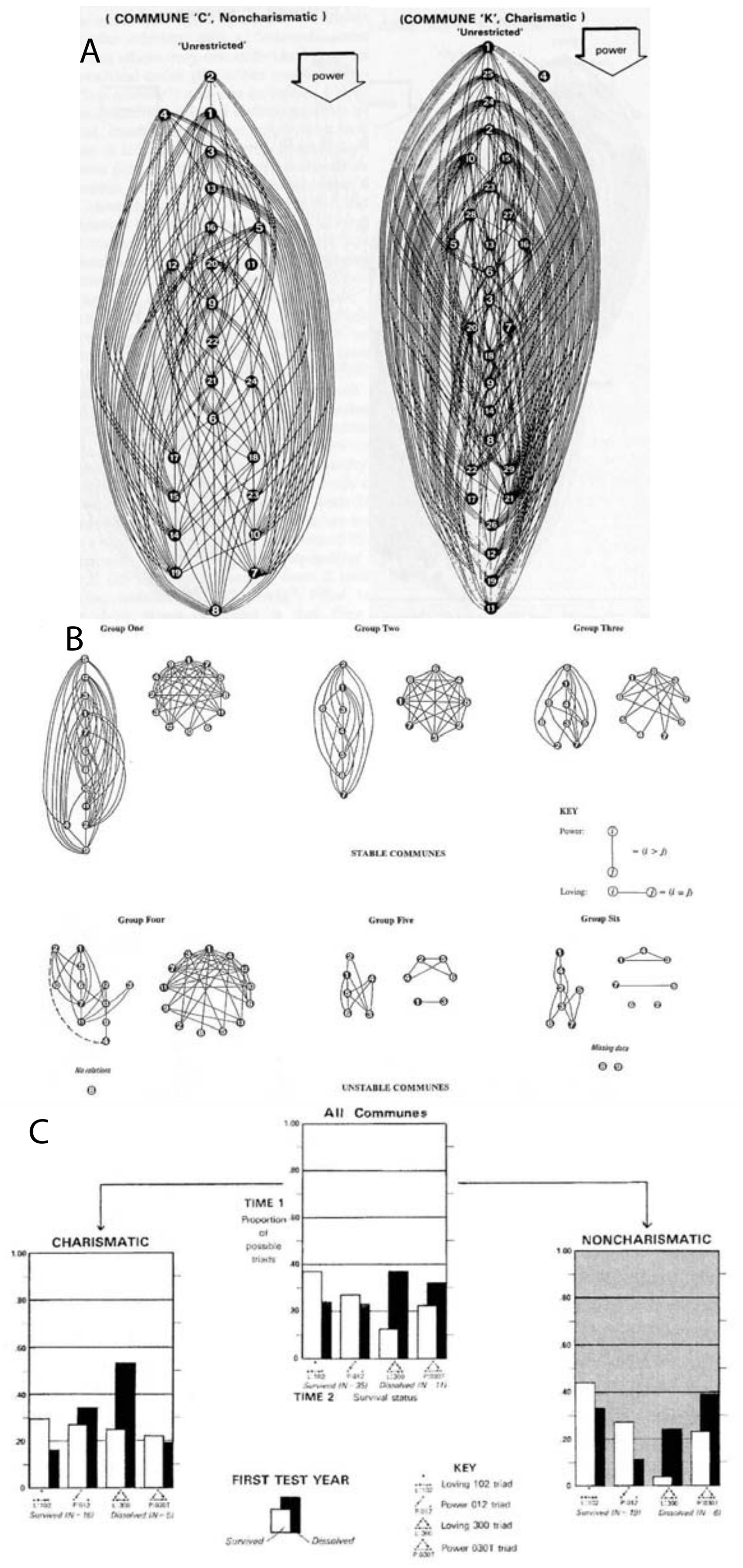

Figure 9: A: Sociograms of Dyadic Perceptions "Power" Relations in a Non-charismatic and a Charismatic Commune.
In the sociograms, individual members are represented by the black dots (the numerical digits are unique codes to identify each group member) and the lines connecting pairs of black dots relations. In Commune C (left), there are 24 members interconnected in a transitively hierarchy of "Power" relations with 15 distinct levels; in Commune K, comprised of 29 members, there are 21 distinct levels! The reader is reminded that this 'emergent' order of a coherent structure (no cycles, conflicts, or isolated cliques) is constructed from perceptions of discrete dyads; no mention of "group structure" was made in the Relationships Questionnaire [28,31](see Bradley & Pribram, 1998, Table 2, page 38, or Bradley, 1987, Appendix B, page 329).
(Source: Bradley, 1987, Figures 8.1 and 8.2, respectively, © 1987 R. T. Bradley; reproduced with permission [28,31].)
B: Examples of the Structure of "Loving" and "Power" Relations in Six Communes (Time 1), by Survival Status 12 Months Later.
(Source: Bradley & Pribram, 1998, Figure 1, © 1996 R. T. Bradley; reproduced with permission [31]).
C: Triadic Structure of "Loving" and "Power" Relations for Charismatic and Noncharismatic Communes at Time 1 by Survival Status 12 Months Later.
(Adapted from Bradley, 1987, Figs. 7.4 and 7.5, (c) R. T. Bradley, 1987; used with permission.)

Theory

Translating Gabor's ordinates of energy frequency and space/time constraint to the dimensions of affective energy and social control, respectively, in social systems, we began with the supposition that the principles of quantum holography could elucidate the energy-based processes of communication and action in collectives. In what follows, activation of bio-affective energy is *Flux,* and implementation of social constraint on members' potential action is *Control*. The primary proposition is that stable collective organization is a function of the degree of interconnectedness between the two as a *balanced coupling*.

Energy is a measure of the means, the fuel, for maintaining organization in the face of challenge (novelty) or changing order in the face of inertia. Energy is also the medium for information processing, the medium for encoding and relaying communication among the elements of a system.

Collective organization entails a mutually beneficial relationship of *collaboration*—of individuals *working together* in pursuit of a shared purpose. To collaborate entails work (as physical behavior and interaction), and work requires a supply of biological *energy*, which is provided by the individuals as they expend their energy in interacting and activity toward a common outcome.

Membership establishes a bond of affective attachment[19], which the group activates to mobilize each individual's biological propensity for action—viz, the *potential* for expending energy. Collaboration also requires social constraint: that each individual's expenditure of energy in action be regulated, coordinated, and directed toward the group's objective, and *not* be dissipated in other useless activity.

The collaborations within the group that form the communication system are formed by the interpenetration of relations among members organized along two dimensions, in which the values allocated in each dimension define points in a *socioaffective field* (Figure 10B). The values on the horizontal dimension represent *Flux*, the amount of activation of *bio-affective energy* (potential energy) in the group. This field is the energetic medium through which transmission of *all* interactions within the group occurs. *It provides the ontological means by which members sense and 'read' each other's actions.*

The values on the vertical dimension represent the amount of *Control*, the degree to which each member's behavior is regulated by an ordered network of hierarchical constraints exercised at that location. By differentially constraining the paths by which individuals expend their energy, both with respect to specific locations in space and with respect to particular moments in time, the hierarchy of controls *in-form*—viz, *give shape to* [35] the organization of collective action. Thus, the interaction between flux and control operates as a communication system that generates and distributes units of information throughout the collective.

Because the units are energetic, in that information is enfolded in the movement of affective energy within the collective, Pribram and I use Gabor's [7] concept of information to describe them. It is expected, therefore, that the operation of hierarchical *Controls* on the relations of affective energy generates information as a moment-by-moment description of the collective's internal organization, encoded in terms of both structure (spatial-temporal position) and *Flux* (distribution of energy). The succession of descriptions within space-time and spectral coordinates is in terms of ensembles of *logon-like* units of information. These are enfolded into the field of affective attachment and communicated throughout the collective, via a holographic-like process, to all group members, thereby giving shape to the collective's organization on a moment-by-moment basis. Thus, the information exchange that characterizes communication can be described as *quantized*. In short, *the interaction between a network of affective bonds and a hierarchy of social controls operates as a quantum-holographic-like information processing system that informs the transformation of potential energy into a stable order of effective collective work*.

However, there are limits on the amount of information generated by flux and control that can be processed efficiently. Amounts that fall outside the limits–amounts that either exceed the communicative processing capacity, or amounts that are insufficient to *inform* the collaborative activation and expenditure of energy–increase the likelihood of endogenous disorganization and result in collective dysfunction and instability.

Functional (and thus stable) organization requires a certain minimum amount of energy, and also that a minimum of direction be given to the expenditure of that energy. If these minimum values for communication are not met, *dysfunction* results and non-viable or unstable states of order are created. Beyond the threshold of these minima, the range of low values for stable organization narrows progressively from many different loosely coupled combinations of *flux* and control to a close complementary coupling involving high values of both. Finally, in terms of Figure 11, there is a *discontinuity* (a jump) in the values defining functional organization, giving rise to a pattern of extremely high values that create the potential for system *transformation*. When energy activation is maximized, stability is problematic and requires an equivalent level of control–a tight, one-to-one coupling between *flux* and control.

[19] *There is evidence that the heart's radiant field of energy is implicated in these bonds of affective attachment—see Bradley (2024c) [34].*

Evidence

Of the extensive analyses we conducted, two, in particular, provide compelling evidence of the utility of our holographic approach. The first was an analysis of the information processing capacity in relation to group survival. A measure of the *Total Amount of Information* processed by a collective at a given moment in time was computed by summing and averaging for each group the incidence *Flux* and *Control* triads at Time 1. The values for all groups were then grouped into 0.10 intervals and, holding these values on this measure constant at Time 1, the sample was partitioned by *Survival Status* with the distribution of *Survivors* and *Non-survivors* plotted on a time series of bar charts at 12-month intervals—viz, from Time 2 through Time 5 (Figure 10A).

In terms of results, two patterns stand out. One is the 'bell-shaped' curve for "All Communes" at Time 1 at the top; 67% of the groups fall within one standard deviation of either side of the mean (0.569). The second is that this bell-shaped distribution *devolves* over time into two contrasting patterns that are virtually the *inverse* of each other by Time 5: a 'single-peaked' distribution for the 22 *Survivors* with its mode in the 0.500 – 0.599 interval; a bi-modal distribution for the 24 *Non-survivors* with its 'trough' in this same interval. The difference in survival rates between the two groups on the 0.500 – 0.599 interval and those groups outside this range is statistically significant (chi-square = 6.695, p = 0.010). Taken together, the two patterns appear to mark the *bounds* of a region *where the probability of stability is maximised*. Thus, it would appear that the amount of information in the intervals *above* 0.599 was *excessive* in terms of processing capacity, whereas in the intervals *below* 0.500 it was *insufficient* to sustain a viable collective.

The second analysis began with a Scatter Plot of the groups in the coordinate system formed their values on *Flux* and *Control* at Time 1, with Survival Status 24 months later indicated by a black dot for *Survivors* (N = 29, 63%), and a hollow dot for *Non-survivors* (N = 17, 37%) (Figure 10B). A triangular pattern of the distribution of groups, oriented along the main diagonal of *Flux* and *Control*, is evident. The three diagonal lines mark the thresholds of four alternating bands of *Surviving* and *Non-surviving* communes. To perform statistical analysis, groups above the second line were aggregated into one category—Nonoptimal, Upper Region (N = 15, 33%). A second category—Optimal, Mid Region, was constructed for the groups between the bottom two lines (N = 25, 54%). The third category was groups below the bottom line—Nonoptimal, Lower Region (N = 6, 13%). The differences in the rates of instability, by Time 3—24 months later, between the three groupings are statistically significant (chi-square = 15.641, p = 0.0004).

Since it was possible that other sociological variables [29] may statistically explain the three survival groupings, identified by *Flux* and *Control*, Discriminant Function Analysis was conducted to rule these factors out and confirm the veracity of the results above. Along with *Flux* and *Control*, eight sociological variables[20] with limited missing data were used as independent variables for the stepwise multivariate analysis. Table A, in the Appendix, presents the results of this analysis.

Of the ten variables analyzed in the stepwise procedure, *only* two—*Flux* and *Control*—had sufficient statistical power to meet the minimum for entry (F-statistic = 0.50). *Flux* entered at Step 1 and *Control* at Step 2 (Wilks' Lambda coefficient = 0.517, p < 0.0000, and 0.214, p < 0.0000, respectively). The 'Test of Difference' between all four pairs of groupings of the three Optimality categories was highly statistically significant (F-statistics ranged from 14.246 to 64.451, p < 0.0000 for all pairs of groupings). While two discriminant functions were constructed, Canonical analysis revealed that Function 1 had, by far, most of the discrimination power (Squared Canonical Correlation = 0.786, Percent of Variance explained = 99.99%, Eigenvalue = 3.674). Together, the two Discriminant Function constructed from *Flux* and *Control* were able to correctly classify 44 (96%) of the 46 communes into their correct Optimality category. Prediction rates for the three categories were: 25/25 (100%) groups for the Optimal-Mid Region category, 14/15 (93%) for the Nonoptimal-High Region, and 5/6 (83%) communes in the Nonoptimal-Low Region. These prediction rates were substantially higher than the prior probabilities (0.54, 0.33, and 0.13, respectively).

Overall, taken together, these results provide a compelling empirical basis for the Model of Communication and its relation to collective action presented in Figure 11. These findings do not by themselves prove holographic processing in a literal physical sense; rather, they indicate that the proposed framework captures a nontrivial and predictive structure in the data.

Summary

The theory postulates that social constraints (*Control*) over the activation and distribution of affective energy (*Flux*) result in social communication by way of quantized (*logon-like*) units of information, which enfold a *holographic*-like description of the collective's endogenous organization. Distributed throughout the collective, these units of information *inform* the moment-by-moment expenditure of energy to create functionally effective patterns of collective organization. Evidence from the data presented is generally consistent with the theory.

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[20]These are: Admission Requirements, Extent of Authority, Affiliated to a Larger Organization, Mean Commune Age, Degree of Ideological Consensus, Mean Proportion of Old Group Members—joined before 1973, Formal Rules, and Group Size—# adult members > 15 years old. See Appendix, Table A for the univariate statistics.

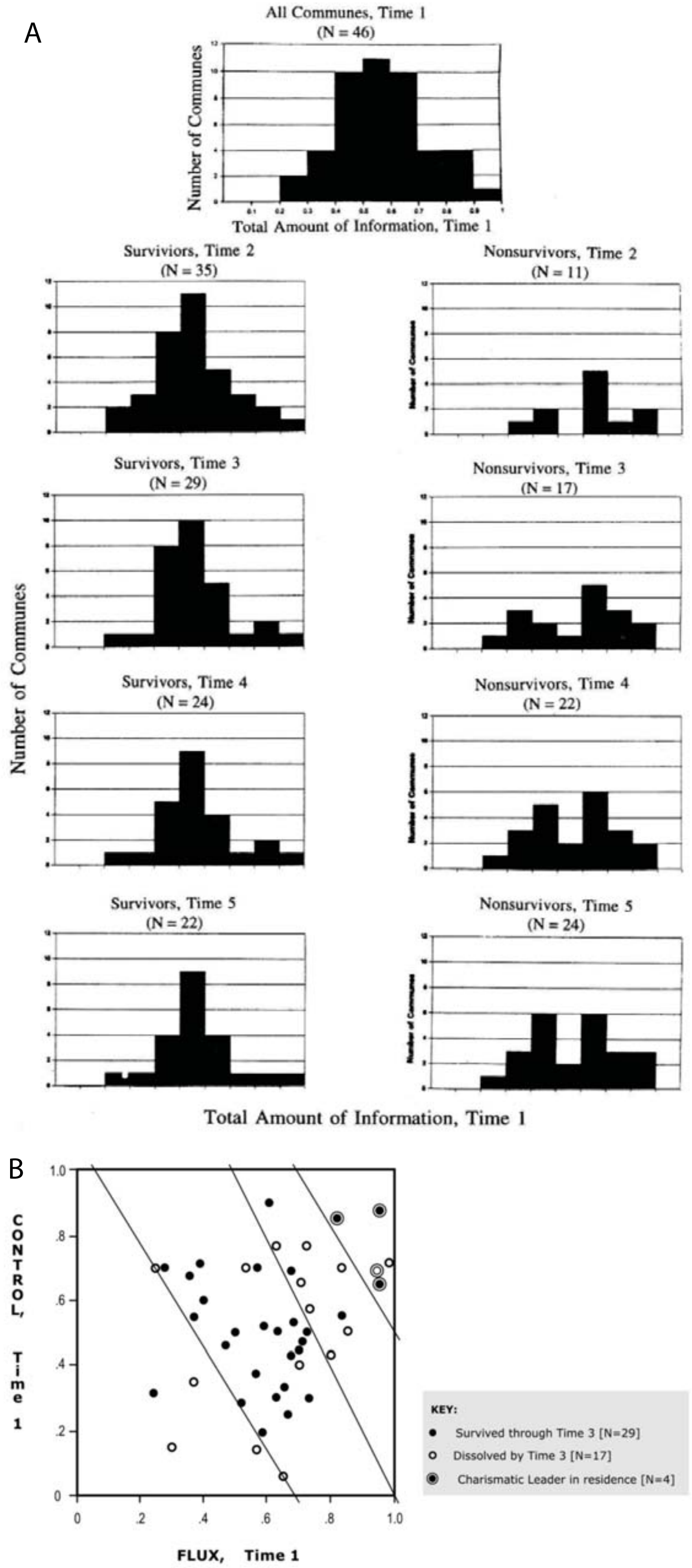

Figure 10: A: Bar Charts of a Time Series Distribution of Communes on Total Amount of Information (Time 1), by Survival Status (Time 2 through Time 5). (Source: Bradley & Pribram, 1998, Figure 5, © 1996 R. T. Bradley; reproduced with permission [31]).
B: Scatter Plot of Flux and Control at Time 1, by Survival Status 24 Months later.
The three diagonal lines mark the thresholds of four alternating bands of Surviving and Non-surviving communes oriented along the main diagonal. To perform statistical analysis, groups above the second line were aggregated into one category—Nonoptimal, Upper Region (N = 15, 33%). A second category—Optimal, Mid Region, was constructed of the groups between the bottom two lines (N = 25, 54%). The third category were groups below the bottom line—Nonoptimal, Lower Region (N = 6, 13%). (Source: adapted from Bradley and Pribram (1998) Figure 7, © 1996 R. T. Bradley; reproduced with permission [31])

Table 1: Summary of the Principal Features of Holographic Processing Across Physical, Neural, and Psychosocial Levels.

Aspect	Summary Description
Basic Conception	Holographic processing refers to the encoding, distribution, and recovery of structural information through spectral relations rather than by direct point-to-point pictorial representation.
Classical Holography	In classical holography, a stable interference pattern records information about the whole object, such that structural features can be reconstructed from the hologram.
Spectral Domain	The spectral domain is the domain in which information is represented in terms of amplitude, frequency, and phase rather than ordinary spacetime coordinates.
Fourier Transform	The Fourier transform provides the invertible relation between spacetime representation and spectral representation, allowing translation from one domain to the other and back again.
Quantum Holography	In Gabor's formulation, time and frequency function as conjugate variables. Their joint minimum defines an elementary information unit in phase space, thereby introducing a quantized account of information processing.
Logon	The logon is Gabor's elementary unit of information: a minimum jointly bounded time-frequency cell sufficient to encode a feature element of a signal with fidelity. Logons occur in succession and may overlap, yielding spectral enfoldment across adjacent units.
Constraint or Windowing	Spectral processing must be constrained or windowed to prevent progression to infinity. In Gabor's elementary function this is achieved by Gaussian modulation; in neural processing it is achieved by the limited patch of adjoining receptive fields.
Neural Implementation	In the neural microstructure, information is processed across densely interconnected receptive fields. Their conjoint operation creates ensembles of logons and a transneuronal response manifold structured by Fourier coefficients.
Holoscape	Pribram's holoscape is the organized response topography generated across overlapping receptive fields, often visualized as contours or a three-dimensional manifold. It expresses the structured geometry of neural spectral processing.
Functional Significance	The framework implies that perception and communication depend not only on localized signals, but on distributed spectral relations in which information about the whole is enfolded across overlapping processing units.
Psychosocial Extension	At the psychosocial level, the holographic model is used to suggest distributed, nonlocal forms of informational organization. The comparison is structural and processual, not a claim that social systems literally perform optical holography. This conception helps separate physical mechanisms from higher-level analogy.

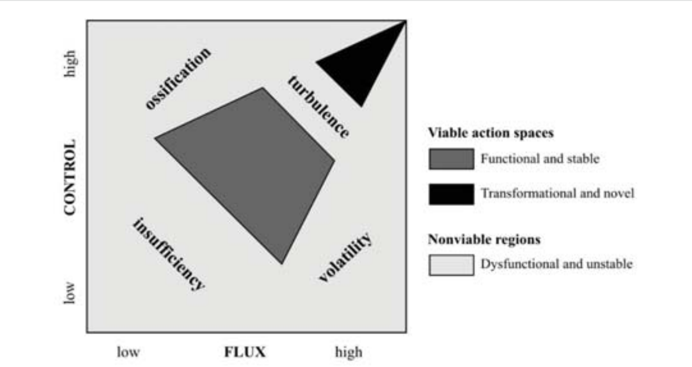

Figure 11: Model of Communication and Action States of Collective Organization.
The model was based on an interpretation of the results of the various statistical analyses and abstracted into two generalized regions of Viable Action Spaces and Nonviable Regions, and then further delineated into subregions by coordinate values on Flux and Control. (Source: redrawn from Bradley and Pribram [31] Figure 11, © 2004 R. T. Bradley; reproduced with permission.)

Conclusion

Pribram's successful use of the physics of image and information processing to describe neural processes in the brain inspired my own application of holographic principles to understand communication in social collectives. This, in turn, led to our collaborative work on a quantum holographic approach to social communication. In this work, thus, the perspective of a physical image and signal processing framework has been employed to elucidate key aspects of neural processing and, as a psychosocial analogy, distributed communication in social groups and its relationship to stable, functionally effective collective action. By way of summing up these applications of a holographic approach, Table 1 presents a concise synopsis of the key aspects of holographic processing addressed in this work.

Speculative broader implications

Beyond this, I have employed Gabor's property of 'overlapping logons' (viz, their spectral enfoldment, the "overlap of the future") to provide a physical mechanism for encoding 'future foreknowledge' in a signal, as measured repeatedly in intuition studies of precognition/presentiment [20,21]. In this context and that of research on states of 'higher consciousness' [24,38-41], Pribram's discovery of an adjustable neural 'lens' in the micro substrate is relevant. He shows that the inhibitory surround of receptive fields can be *intentionally* adjusted: narrowed for Gabor processing to focus on the 4-D spacetime world; expanded for Fourier processing access to the spectral domain of nonlocal communication. Is Pribram's discovery, the neural 'lens' that enables neuro-psycho-physical access to the realms of 'higher consciousness'?

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Discriminant Function: Univariate Statistics

Variable	Optimal — Mid Region Mean	Optimal — Mid Region SD	Nonoptimal — Upper Region Mean	Nonoptimal — Upper Region SD	Nonoptimal — Lower Region Mean	Nonoptimal — Lower Region SD	Total Mean	Total SD	Wilks' Lambda	Univariate F Ratio	Pr.
	Optimality Groupings										
(N)	(25)		(15)		(6)		(46)				
Admission requirements[a]	1.96	.93	1.87	.99	2.00	.89	1.93	.93	.997	.062	.940
Extent of authority[b]	1.52	.51	1.47	.52	1.33	.52	1.48	.51	.985	.326	.723
Affiliated to a larger organization[c]	.48	.51	.33	.49	.33	.52	.41	.50	.978	.484	.620
Control	.457	.178	.688	.136	.286	.231	.510	.218	.603	14.156	.000
Flux	.581	.149	.802	.122	.396	.174	.629	.196	.517	20.055	.000
Mean group age, years	3.36	1.91	2.20	1.08	2.67	1.51	2.89	1.69	.899	2.413	.102
Degree of ideological consensus[d]	1.40	.50	1.47	.52	1.00	.00	1.37	.49	.908	2.174	.126
Mean propn. old members[e]	.46	.29	.48	.34	.41	.35	.46	.31	.995	.117	.890
Formal rules[f]	1.40	.50	1.40	.51	1.50	.55	1.41	.50	.995	.101	.904
Group size[g]	9.20	4.44	8.20	2.08	8.67	2.73	8.80	3.59	.984	.358	.702

Note: SD, standard deviation; Wilks' lambda, *U*-statistic; pr., statistical significance with 2 and 43 degrees of freedom.
[a]Admission requirements: 1 = if room/see individual; 2 = trait required/group ready; 3 = trial membership/novitiate required/group closed
[b]Extent of authority: 1 = none/a little; 2 = some/a lot
[c]Affiliated to a larger organization: 0 = not affiliated; 1 = affiliated
[d]Degree of ideological consensus: 1 = a little/some; 2 = a lot/unity
[e]Mean propn. old members = proportion of adult members who joined commune before 1973
[f]Formal rules: 1 = none/few; 2 = some/many
[g]Group size = number of adult members (≥ 15 years old)

Variable	Step	Wilks' Lambda	Pr.	Minimum D^2	Pr.	Equivalent F	Pr.
Flux	1	.517	.0000	1.656	.0070	8.011	.0070
Control	2	.214	.0000	6.028	.0000	14.245	.0000

*Maximum significance of *F*-statistic to enter = .050; minimum significance of *F*-statistic to remove = .100.

Summary of Stepwise Analysis*
Test of Differences Between Pairs of Groupings After Step 2

Pairs of Groupings	F-statistic	Significance*
Optimal/Nonoptimal — Upper	43.848	.0000
Optimal/Nonoptimal — Lower	14.246	.0000
Nonoptimal — Upper/ Nonoptimal — Lower	64.451	.0000

*With 2 and 42 degrees of freedom.

Canonical Discriminant Functions

	Function 1	Function 2
Canonical Correlation	.887	.002
Squared Canonical Correlation	.786	.0005
Percent of Variance	99.99	.01
Eigenvalue	3.674	.001

Unstandardized Canonical Discriminant Function Coefficients

	Function 1	Function 2
Control	6.080	3.546
Flux	7.652	−3.574
(Constant)	−7.911	.440

Table 21.3c. Discriminant Function ... Classification Results

Actual Group	Predicted Group: Optimal — Mid Region N	%	Nonoptimal — Upper Region N	%	Nonoptimal — Lower Region N	%	Total N	%
Optimal — Mid Region	25	100.0	0	0.0	0	0.0	25	100.0
Nonoptimal — Upper Region	1	6.7	14	93.3	0	0.0	15	100.0
Nonoptimal — Lower Region	1	16.7	0	0.0	5	83.3	6	100.0
Total	27	58.7	14	30.4	5	10.9	46	100.0
Prior Probability		.54		.33		.13		100.0

Table A: Discriminant Function Analysis of Optimality Classification of Communes: Univariate Statistics, Stepwise Analysis, Canonical Discriminant Function, and Classification Results.
(Source: adapted from Bradley and Pribram (1997), Tables 21.3a through 21.3c, pages 477- 478.)

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APPENDIX

TABLE A(above)

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