T-218

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Brain and the Composition of Conscious Experience

Of Deep and Surface Structure; Frames of Reference; Episode and Executive; Models and Monitors

Prologue

The resurgence of interest in 'consciousness' during the 1990s comes as somewhat of a surprise to one who in 1960 in *Plans and the Structure of Behavior* (Miller *et al.*, 1960) declared for a 'subjective behaviourism' and in Sigmund Koch's *Psychology: A Study of a Science* developed the theme as to how the data on subjectivity, our awareness of conscious experience, could be related to the behavioural and brain sciences. The occasion for these reports was the observation of disjunction between patients' verbal reports of their introspections and their behaviour. Subjectivity could not be ignored by a science of psychology. The chapter in *Psychology, A Study of Science* (Pribram, 1962), begins with a quotation from C. Judson Herrick's, *The Evolution of Human Behavior*:

> It does no good to declare that consciousness is a negligible epiphenomenon in the face of the fact that the most significant things people do are consciously motivated and consciously directed. One does not solve a problem by leaving out the troublesome factors....
>
> Defeatism is an unhealthy scientific attitude; it is, in fact, radically unscientific, for science has a legitimate interest in everything of which we have veridical experience. We have ample scientific evidence that a man's mental processes — his thoughts and emotions — are tied in with his physical behavior in lawfully ordered ways. If we do not know just how this is done, the thing to do is to try to find out by skillfully designed experiments. The answer will never be found if the plain facts of common experience are ignored and the mental factors of behavior are left out of consideration (Herrick, 1956, pp. 234–6).

Using six experimentally obtained results, my chapter discussed the methods by which such results and the observations in the clinic can be related to each other and how empirically-derived models can form the basis for theory construction. A quota-

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wrath, out of the garden of Eden for disobedience. The consequences of such dualism are stated succinctly in another quotation from Herrick, which ends:

> In our own culture the cleavage of the 'spiritual' from the 'natural,' which is a survival from the most ancient mythologies, has fostered popular ideologies of religious fanaticism, class rivalries, and political antagonisms that are biologically unfit and even suicidal because they result in social disintegration. Our ultimate survival is endangered as long as ideological fantasies that are incompatible with things as they are control individual and national patterns of behavior. We must somehow manage to heal this artificial dismemberment of the human personality before we can hope for a permanent cure of the present disorder (Herrick, 1956, pp. 416–20).

Given the concerns of the 1950s with subjective (conscious) experience, which lifted psychology out of its behaviourist straightjacket and initiated what is currently called cognitive science, why the renewed interest? I believe that there are several important developments that account for the renewal. The first is the availability of brain imaging techniques that can directly address the relation of brain processing to conscious experience, such as effort, attention, intention and thought in human subjects. Previously, the relation of subjectivity to brain function had to be inferred from verbal reports provided by brain damaged subjects and from animal experiments. Now the line connecting subjectivity and brain functioning is somewhat more direct.

A second reason for resurgence is quantum, and to some extent relativity, theory. Physicists have become aware of the critical role of observation in their empirical endeavours. Observation is a psychological pursuit. Physicists are therefore lending their not inconsiderable talents to resolving the mind–brain issue and have by this interest enlisted mathematicians (who do mathematics, which is a totally thoughtful, logical and therefore cognitive, psychological enterprise) and engineers (such as signal processor and computer scientists) in their endeavour.

Finally, the advances in molecular biology are being applied to neuroscience with the result that practical advances are being made in further bridging the mind/brain gap for the lay public. This public which includes the media, has never bothered much with the distinction between mind and brain and reflects the current ascendancy of a materialistic science. But materialism leads to a culture that has been split along C.P. Snow's division between science and humanities, a division that, as noted in the quotation from Herrick, has created havoc in the affairs of humankind. An alternative is a neutral monism based on the concept of in-formation — a form-within, which negentropically *organizes* energy. But this is another topic which I have taken up fully elsewhere (Pribram, 1986; 1997).

In the context of this publication on blindsight, I want to address further the *brain* processes critically responsible for organizing our conscious experience. As in a previous related publication (Pribram, 1996), I am restricting myself to brain and conscious experience, not the fuller topic of 'consciousness' as this might be determined by genetic and environmental (e.g. social) factors, nor as it is defined in Eastern traditions and in esoteric Western religion and philosophy. For my thoughts on this broader topic the reader is referred to a recent publication (Pribram, 1997) prepared for the centennial celebration of Norbert Wiener's birth. That paper is entitled: 'What is Mind that the Brain May Order It?'

patients experience when a still appropriately functioning limb contralateral to the lesion is excluded from awareness. Here is a case history presented by a student in my class who is experiencing such 'neglect'.

From Mrs. C:

> I was doing laundry about mid-morning when I had a migraine. I felt a sharp pain in my left temple and my left arm felt funny. I finished my laundry towards mid-afternoon and called my neurologist. He told me to go to the emergency room. I packed a few things and drove about 85 miles to the hospital where he is on staff (the nearest was 15 minutes away). In the E.R. the same thing happened again. And again, the next morning after I was hospitalized, only it was worse. The diagnosis of a stroke came as a complete surprise to me because I felt fine, and I didn't notice anything different about myself. I remember having no emotional response to the news. I felt annoyed and more concerned about getting home, because I was in the process of moving.
>
> Not until several days later while I was in rehabilitation did I notice strange things happening to me. I was not frightened, angry or annoyed. I didn't feel anything — nothing at all. Fourteen days after I was admitted to the hospital, I became extremely dizzy, and I felt I was falling out of my wheelchair. The floor was tilting to my left and the wheelchair was sliding off the floor. Any stimulus on my left side or repetitive movement with my left arm caused a disturbance in my relationship with my environment. For instance, the room would tilt down to the left, and I felt my wheelchair sliding downhill of the floor, and I was falling out of my chair. I would become disoriented, could hardly speak, and my whole being seemed to enter a new dimension. When my left side was placed next to a wall or away from any stimuli, this disturbance would gradually disappear. During this period, the left hand would contract, and the arm would draw up next to my body. It didn't feel or look like it belonged to me. Harrison moved the left arm repeatedly with the same movement, and a similar behavior occurred, except I started crying. He asked me what was I feeling, and I said anger. In another test he started giving me a hard time until the same episode began to occur, and I began to cry. He asked me what I was feeling, and I said anger. Actually I didn't feel the anger inside but in my head when I began to cry. Not until I went back to school did I become aware of having no internal physical feelings.
>
> I call that arm Alice (Alice doesn't live here anymore), — the arm I don't like. It doesn't look like my arm and doesn't feel like my arm. I think it's ugly, and I wish it would go away. Whenever things go wrong, I'll slap it and say, 'Bad Alice' or 'It's Alice's fault'. I never know what it's doing or where it is in space unless I am looking at it. I can use it, but I never do consciously because I'm unaware of having a left arm. I don't neglect my left side, just Alice. Whatever it does, it does on its own, and most of the time, I don't know it's doing it. I'll be doing homework and then I'll take a sip of coffee. The cup will be empty. I was drinking coffee with that hand and didn't know it. Yet I take classical guitar lessons. I don't feel the strings or frets. I don't know where my fingers are nor what they are doing, but still I play.
>
> How do I live with an illness I'm not aware of having? How do I function when I'm not aware that I have deficits? How do I stay safe when I'm not aware of being in danger?

Mrs. C is obviously intelligent, attending lecture material, asking interesting questions. She is a widowed lady in her mid-fifties, enrolled in adult education, majoring in clinical psychology. She gets around splendidly despite Alice and despite a history of a temporary left hemi-paresis. The diagnosis was damage of the right temporal-parietal cortex confirmed by an abnormal EEG recorded from that location. The damage was not sufficiently extensive to show in a PET scan.

Placed in juxtaposition with blindsight, a simple conclusion can be reached: in humans, there are separate brain systems that organize allocentric (specifically, occulocentric) and egocentric (specifically, body centered) awareness. Damage to *sensory receiving systems* and, further, that *behaviour is disturbed by more forward lesions* — that led many eighteenth century neuroscientists to mislocate these primary systems (see the disputes between Ferrier, Goltz, Munk; reviewed by Ferrier, 1876).

Object Centered Frames of Reference

Allocentric and egocentric 'spaces' constitute frames of reference within which behaviour becomes organized. These two are not the only frames for which separately localized brain systems can be identified. Another set of systems deals with the perception of entities. In vision these are, e.g., objects and colour; in audition they are, e.g., phonemes and tones. It is characteristic of entities that they remain invariant over transformations. For example, object constancy derives from operations that can be described in terms of mathematical group theory (Hoffman, 1978; Pribram, 1991). Colour constancy derives from operations on double opponens processing (DeValois & DeValois, 1993; Zeki, 1993).

I did not realize the devastating effect on conscious experience that damage to a constancy system would produce until I read 'The Case of the Colorblind Painter' presented by Oliver Sacks in *An Anthropologist on Mars* (1995), The painter, whose colour constancy system was selectively damaged, was not left with just a colourless black/white visual world; he was left with a muddy, hazy experience. Should the damage be to *object* constancy, what might the visual world appear to be?

When we performed an experiment on size constancy, Ungerleider, Ganz and I (1977) showed that monkeys who had their peri- and prestriate cortical systems removed responded to the retinal image size of a pattern (a square), and failed to take the distance of the pattern into account. Extrapolating to object constancy, one would expect that a person would fail to recognize an object when its perspective changed. Turnbull (Turnbull & McCarthy, 1996; Turnbull, 1997; Turnbull *et al.*, 1997), describe just such a patient. For this patient, every perspective of an entity entailed its own 'meaning': its separate potential usefulness and relationship to other perspectives.

Other Reference Frames and the Relations Between Them

Taken a step further, other frames of reference can be identified. A categorical and a propositional frame are the most obvious. Just as perspectives are grouped to construct invariances that are identified as entities, so entities can become grouped into categories. Eleanor Rosch (1975), has performed a series of experiments showing how categories are constructed around a kernel, a prototype. And Martha Wilson (1987) has shown, using monkeys, that with respect to visual entities, the inferotemporal cortex is critical to the formation of prototypes. Furthermore, she has provided a model for the operation of this prototype system (see also the review by Pribram, 1991, Lecture 7).

Edelman (1989), has constructed his theory of consciousness around the operations that produce categories. Others (e.g. Freud, 1895; Eccles, 1958) have invoked propositional utterances as the basis of conscious experience. A propositional frame of reference uses entities and categories to construct proposals, naming entities and categories and predicating their relationship to one another.

At this propositional level of experience we can go back and identify the distinction between allocentric and egocentric frames and suggest that this distinction synaptodendritic processing web — patches that are organized by experience (see Alkon *et al.*, 1996, for review). What follows is from *Languages of the Brain* (Pribram, 1971), pp. 104–5:

> Any model we make of perceptual processes must thus take into account both the importance of . . . subjective experience, and the fact that there are influences on behavior of which we are not aware. Instrumental behavior and awareness are often opposed — the more efficient a performance, the less aware we become. Sherrington noted this antagonism in a succinct statement: 'Between reflex action and mind there seems to be actual opposition. Reflex action and mind seem almost mutually exclusive — the more reflex the reflex, the less does mind accompany it.'
>
> The reciprocal relationship between awareness and behavior is perhaps best illuminated by the psychological processes of habit and habituation. If an organism is repeatedly exposed to the same situation, is placed in an invariant environment, two things happen. If he consistently has to perform a similar task in that environment, the task becomes fairly automatic, i.e., he becomes more efficient. The organism has learned to perform the task; he has formed *habits* regarding it. At the same time the subject habituates: he no longer produces an orienting reaction; he no longer notices the events constant to this particular task in this environment. His verbal reports of introspection, his failure to move his head and eyes in the direction of the stimulus, and electrophysiological measures such as galvanic skin response, plethysmography and EEG, all attest to the disappearance of orienting when an unvarying situation is repeated. . . . However, habituation is not an indication of some loss of sensitivity on the part of the nervous system but rather the development of a neural model of the environment, a representation, an expectancy, a type of memory mechanism against which inputs are constantly matched [Sokolov, 1960; Pribram, 1971; Thompson, 1986; Grandstaff & Pribram, 1972]. The nervous system is thus continually tuned *by* inputs to process further inputs.
>
> The habitual performance of the organism also results [of course] from neural activity. . . . So the question is: What is the difference between the two kinds of neural activity that make awareness inversely related to habit and habituation?

Nerve impulses and graded potential changes (hyper- and depolarization) occurring within a dendritic web are two kinds of processes that could function reciprocally. A simple hypothesis would state that the more quickly the patterns of signals arriving at synapses are transduced into patterns departing from the web via axons, the shorter the duration of the design occupying the processing web. Once habit and habituation have occurred and a throughput has been established within the processing web, behaviour becomes 'reflex'. By contrast, the more persistent designs of graded polarizations are coordinate with awareness. The hypothesis carries a corollary: nerve impulse patterns *per se* and the behaviour they generate are unavailable to immediate awareness. Thus, even the production of speech is 'unconscious' at the moment the words are spoken.

The distinction between neural circuits composed essentially of axons when a rapid throughput has been established in the web and processing in the web is important and not ordinarily acknowledged.

Neurons are ordinarily conceived to be the computational units of the brain. Thus the majority of processing theories since the seminal contribution of McCulloch and Pitts (1943) have taken the axonal discharge of the neuron, the nerve impulse, as the currency of computation.

However, there is more to processing than these models indicate. Not only are axonal-dendritic synapses that connect neurons subject to local influences in these

> The spatiotemporal patterning of these cooperative processes... [involve] ionic shifts... with extrusion of potassium ions and ionic binding on extracellular mucopolysaccharide filaments. If we focus our attention not on the membranes of single neurons, but upon charge density distributions in the tissue matrix of neurons, glial cells, and mucopolysaccharide processes, we can envisage a complex, three-dimensional volume of isopotential contours, topologically comprised of portions of cellular membranes and extracellular binding sites and constantly changing over time (Thatcher & John, 1977, pp. 305–6).

There is more. Dendrites are fitted with spines that resemble little cilia, or hairs, protruding perpendicularly from the dendritic fibre. These spines have bulbs at their endings, knoblike heads that make contact with teledendrons, the branches of axons and with other dendrites to form synapses. Activity in teledendrons and in dendrites such as those stemming from axonless neurons produce depolarizations and hyperpolarizations in the dendritic spines. The postsynaptic effects are ordinarily invoked chemically and can be modified by other chemicals that act as regulators and modulators (see Pert, 1997, and Jibu *et al.*, 1996), The following paragraphs to the end of this sections are adapted from *Brain and Perception* (Pribram, 1991, pp. 85–7).

Shepherd, Rall, Perkel and their colleagues (see, e.g., Coss & Perkel, 1985; Perkel, 1982, 1983; Perkel & Perkel, 1985; Shepherd *et al.*, 1985) modelled the process whereby these postsynaptic events occurring in spine heads interact. The issue is this: the stalks of the spines are narrow and therefore impose a high resistance to conduction (active or passive) toward the dendritic branch. Spine head depolarizations (as well as hyperpolarizations) must therefore interact with one another if they are to influence the action potentials generated at the axon hillock of the parent cell of the dendrite. The interactions (dromic and antidromic) among dendritic potentials (by means of which the signal becomes effective at the next stage of processing) thus depend on the simultaneous activation of both pre- and postsynaptic sites. According to Shepherd and colleagues (1985), several advantages accrue from this form of activation:

> First the relative efficacy of distal dendritic inputs would be greatly enhanced. Second... the transients within the model spines and dendrite are rapid and do not have the slow, low amplitude time course of synaptic potentials recorded experimentally at a distance from the cell body. Within the distal dendrite, information might thus be processed through precise timing of specific inputs to different neighboring spines.... These precise interactions would greatly increase the complexity of information processing that can take place in distal dendrites (p. 2194).

The activation of interacting polarizations occurs in parallel, is distributed and discontinuous: 'Thus, the active propagation... was discontinuous and resembled in this respect the saltatory conduction that takes place from node-to-node in myelinated nerve' (Shepherd *et al.*, 1985, p. 2193).

A prime virtue of this enhanced complexity is the potential for selectivity allowed by such a process:

> ... it has been shown that [post]synaptic polarization in a spine head can spread passively with only modest decrement into a neighboring spine head. If the neighboring spine is presynaptic, transmitter release could be evoked (p. 2192).

Thus effects on the presynaptic neuron can occur, effects critical to selectivity in learning (see e.g., Freud, 1895; Hebb, 1949; Stent, 1973).

vate *any* isocortical region by stimulating the hippocampal cortex. The finding was so striking that MacLean (1990) developed the theme of a schizophysiology of cortical function.

On the other hand outputs are plentiful to the amygdala, to the *n. accumbens septi* and to other subcortical structures via the fornix. Confirmation of the difference between input (encoding) and output (decoding) operations involving the hippocampal formation has recently come from studies in humans using fMRI (Gabrieli *et al.*, 1997), Encoding into memory was found to activate the para-hippocampal cortex (including the entorhinal cortex which receives input from the remainder of the isocortex), whereas decoding (retrieval) was found to activate the subiculum which - provides the major *subcortical* output of the hippocampal region via the fornix' (p. 265).

The subcortical nuclei do not have the laminar structure of cortex and so are poor candidates for the point to point match a computer would ordinarily be conceived to implement. On the other hand, a match could readily be achieved if the comparison would involve a distributed stage, much as when a holographic memory is used to store and retrieve information (for instance with holofishe). It is the evidence that a distributed store is, in fact, built up in the hippocampal formation during learning that makes this sort of model plausible.

Landfield (1976), and O'Keefe (1986), have developed this sort of model. O'Keefe reviews the evidence and describes the model as follows:

> Attempts to gain an idea of the way in which an environment is represented in the hippocampus strongly suggest the absence of any topographic isomorphism between the map and the environment. Furthermore, it appears that a small cluster of neighboring pyramidal cells would map, albeit crudely, the entire environment. This observation, taken together with the ease that many experimenters have had in finding place cells with arbitrarily located electrodes in the hippocampus, suggests that each environment is represented many times over in the hippocampus, in a manner similar to a holographic plate. In both representation systems the effect of increasing the area of the storage which is activated is to increase the definition of the representation.
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> A second major similarity between the way in which information can be stored on a holographic plate and the way environments can be represented in the hippocampus is that the same hippocampal cells can participate in the representation of several environments (O'Keefe & Conway, 1978; Kubie & Ranck, 1983). In the Kubie and Ranck study the same place cell was recorded from the hippocampus of female rats in three different environments: All of the 28 non-theta cells had a place field in at least one of the environments, and 12 had a field in all three environments. There was no systematic relationship amongst the fields of the same neurone in the different environments. One can conclude that each hippocampal place cell can enter into the representation of a large number of environments, and conversely, that the representation of any given environment is dependent on the activity of a reasonably large group of place neurones.
>
> The third major similarity between the holographic recording technique and the construction of environmental maps in the hippocampus is the use of interference patterns between sinusoidal waves to determine the pattern of activity in the recording substrate (see Landfield, 1976). In optical holography this is done by splitting a beam of monochromatic light into two, reflecting one beam off the scene to be encoded and then interacting the two beams at the plane of the substrate. In the hippocampus something similar might be happening.... The beams are formed by the activity in the fibers projecting to the hippocampus from the medial septal nucleus (MS), and the nucleus of the diagonal band of Broca (DBB).

Pioneering work by Petsche, Stumpf and their colleagues (Stumpf, 1965) showed that terms of a spacetime constraint on a sinusoid — such as the Gabor elementary function, the constraint is embodied in the inhibitory surround of the field. Enhancing the surround enhances processing in configuration coordinates; diminishing the surround enhances the sinusoidal (spectral domain) aspects of processing. Thus, the development of scanpaths operates on the inhibitory process that characterize the fluctuations of the polarizations of the dendritic connection web.

The frame of reference in this model is the *path* through the maze that is to be instantiated. Extrapolating from this example, frames of reference are not to be considered to be static — rather they are dynamic processes optimizing a fit to ongoing sensory and central (brain) activity. With regard to object-centred reference frames, Palmer (1983) describes the process as follows.

> The reference frame hypothesis makes use of the underlying transformation group in a somewhat different way. Rather than ignoring properties that vary over the transformations of the group, it assumes that the effects of transformations are neutralized by imposing an 'intrinsic frame of reference' that effectively 'factors out' the transformation, thereby achieving shape constancy. The 'intrinsicness' of the frame simply means that the frame is chosen to correspond optimally with the structure of the figure rather than being imposed arbitrarily (pp. 275–6).

More generally, Smolensky describes the relationship between surface (memory retrieval in his example) and deep (storage) structure as follows:

> The concept of memory retrieval is reformalized in terms of the continuous evolution of a dynamical system towards a point attractor whose position in the state space is the memory; you naturally get dynamics of the system so that its attractors are located where the memories are supposed to be; thus the principles of memory storage are even more unlike their symbolic counterparts than those of memory retrieval (Smolensky, 1988, p. 12).

To summarize: using language as an example, we are rarely if ever aware of how we speak or write or read. Rather it is the contents that derive from the process that constitute our experience. That experience is formed at least at two levels: a semiautomatic perceptual (and motor) skill that allows us to cope readily with circumstance; and an awareness of that coping which intrudes whenever fluidity in processing becomes jeopardized. Both levels operate within a set of mutually embedded reference frames. Experienced conscious awareness emphasizes one frame to the temporary exclusion of the others much as when a fluent multilingual speaker uses one language at a time. Reference frames, like languages, are surface structures that address a deeper distributed process. The surface structures, the reference frames, are conceived to be embodied in brain circuits; the deep structure in the synaptodendritic web within these circuits. Embedding of frames indicates that the same neural elements can partake of several circuits (Hebb, 1949/61); it is the pattern of connectivity that determines the reference frame. The synaptodendritic web is composed of patches that are modified by experience. Modification is determined not only by the processes and contents of experience *per se* but also by another form of processing which is organized by brain systems different from those that organize reference frames.

Episodic Experience

These other systems are located, in a sense, at the opposite 'end' of the brain. The systems include the anterior poles of the frontal and temporal lobes and the limbic forma-

> drawing at the beginning of a session, and his tutor said that we needed to begin to work and he countered 'this will be quick'. Unsurprisingly, he finished his drawing at his normal pace. He somehow seems to use such terms correctly without any experiential appreciation of them. (Modified from Letter written by Richard Ahern on 19 March 1995, addressed to Karl H. Pribram. For a complete description, see Ahern *et al.*, 1998).

Note that TK has no difficulty whatsoever in processing entities or allocentric and egocentric space. His categorical and propositional skills are so well developed that he can use these 'semantic' processes to veil his deficit in 'episodic' processing to some extent.

Episodic processing organizes experience not according to invariant frames (as defined above), but according to covariations among events. Covariations are 'parsed' into episodes, (de)marked at both ends by a 'stop' constituted of an orienting response. Orienting is ordinarily accompanied by visceroautonomic arousal, arousal which fails to occur after amygdalectomy (Pribram *et al.*, 1979; Pribram, 1991, Lecture 8). In the absence of this visceroautonomic arousal, habituation of the orienting response fails to occur and the organism (monkey or human) continues orienting to a repetition of the event. There is no closure; experience is ever novel and never familiar.

Seizures originating around the amygdala produce experiences such as *déjà vue* (a feeling of familiarity in a strange place) and *jamais vue* (a feeling of estrangement in what should be a familiar place). When the seizures are prolonged, an entire experienced episode fails to become encoded into the person's retrievable life story. As an example, one Friday I was accompanied by a young psychologist to my car after having lectured at Napa State Hospital in California. I wished her a happy weekend, and she said that she looked forward to it because of a party the group was having. The following week, she and others of the group were again accompanying me to my car, and I asked how this young lady had enjoyed the party. She answered that she had become overly tired and had fallen asleep and not gone to the party. The others in the group turned to her in surprise — they had all seen her, seemingly enjoying her attendance, 'a bit spaced-out because, perhaps she had had a bit much to drink'. On examination it turned out that the young lady had psychomotor seizures due to an epileptic focus in the region of her medial temporal lobe. In extreme instances, when this part of the brain is not just temporarily out of commission, but is permanently injured as in TK, experience simply never engenders the feeling of familiarity. What remains is an encoding of experience in reference frames. *Inter*personally the impaired transaction feels strange (estranged).

As to how a 'stop' process that marks an episode might operate, I have for years suggested to my laboratory colleagues that the marking could work somewhat like pagination in a computer program, or setting a bandwidth in a content-addressable holographic-like memory. This would account for the effect of priming and the intrusive retrieval of material by a subject with 'memory loss' due to excessive alcoholism, as in Korsakoff's syndrome, or in HM, who has had both amygdala and hippocampus bilaterally removed (Weiskrantz *et al.*, 1974). The suggestions need to be modelled in a PDP type program to understand more fully the observations.

> normal adults. It does not depend on the character of the intrinsic normal rhythms and is as large and extensive with the eyes open as shut. In children, however, and in mentally disturbed patients, the E-wave is often elusive and variable; above all, it is extremely sensitive to social influences.
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> As already mentioned the E-wave arises always and only during sensory-motor association, but both the sensation and the motion may be of quite a subtle nature. In the simplest case the presentation of a conditional stimulus in any modality, followed by an imperative stimulus in another modality, evokes an E-wave following the primary conditional responses and lasting until the moment when the imperative response would have occurred.
>
> The striking feature of the E-wave is that it appears, as it were, to submerge the imperative response, and terminates very abruptly at the instant when the latter would have subsided. The typical sawtooth waveform of this phenomenon is remarkably like that of the time-base of an oscilloscope, rising steadily toward a maximum value over a time determined by the established stimulus interval, and dropping suddenly to zero. The duration of the E-wave as studied systematically so far is several seconds, but in some subjects the potential difference seems to be sustained much longer during 'extinction' trials when there is no imperative stimulus to act as a 'fly-back' trigger. Sometimes there is even a suggestion of a staircase or 'Treppen' effect when conditional stimuli are presented at intervals of a few seconds without reinforcement to subjects with a very slow rate of extinction. Since the E-wave presumably represents depolarization of the apical dendritic plexus, the possibility of 'recruitment' in such a mechanism would be interesting to study in more detail. The subjects who have shown signs of this effect are highly suggestible and easily hypnotized (Black and Walter, 1963),; the capacity to maintain a high and even cumulative level of expectancy may be typical of this disposition, and may depend on some idiosyncrasy of the electro-chemical relations in the superficial cortical levels (Walter, 1964, pp. 310–13).

Episodic processing and its working memory component (especially when considered as short term memory) have often been considered to precede semantic processing (what has been discussed here as processing involving reference frames). The clinical evidence presented indicates, however, that episodic and semantic (referential) processing can effectively proceed independently of one another although the brain systems that organize these processes do, of course, ordinarily interact. Thus ordinarily, episodic awareness uses referential systems and referential systems become modifiable by virtue of input from the episodic systems.

Summary

Weiskrantz's, Stoerig's and Cowey's distinction between reflexive, phenomenal and consciously accessible processing becomes, according to the analyses presented here, a distinction between automatic, referential (semantic) and episodic executive processing. Automatic, reflexive, processing occurs whenever a neural circuit has become thoroughly established with a minimal synapto-dendritic delay. Referential, phenomenal, processing is semi-automatic but easily accessible to monitoring when shifts among reference frames are initiated within circuits, either 'spontaneously' or by some more organized sensory or central input.

Executive monitoring comes about when frontolimbic processes become addressed, thus producing delays that allow shifts among reference frames in the systems of the posterior convexity. Ordinarily such shifts are included within episodes marked with a beginning and an end (a function of the amygdala), and by re-

Neither process is easy but we have attributed a misplaced concreteness (and therefore labelled them the easy problems) to the downward process and have been suspicious of relativistically (relationally) reached conclusions. Nonetheless, science needs both types of knowing: concepts such as feedback (homeostasis) in biology and relativity in cosmology are indispensable (see Granit, 1970, for their indispensability in understanding the motor systems of the brain).

I believe the misplaced concreteness of downward analysis comes from the faith we have in deductive reasoning. Such reasoning is logically tight and solid. But, of course, it depends for its 'truth' on the axioms from which the reasoning takes off. Inductive, synthetic reasoning is relativistic, loose, in the sense that complementary schemes (frames of reference) can organize the experiences. Abductive reasoning (Peirce, 1934), has the virtue of helping to choose among frames by comparing one inductive scheme with another derived from outside the experiences from which the first derives. Induction and abduction thus overcome the Gödelian constraint imposed by deductive systems. Reductive systems can only formalize what we have *chosen* to be 'true'. (I have always been intrigued by viewing the concept 'formalizing' as dipping our ideas into formalin to harden them much as we do brains, so we can slice them up more readily).

My trials in essaying these 'explanations' of conscious experience end much as did my previous paper relating to this topic (Pribram, 1996): the dictionary holds that to experience means to try; conscious experience occurs when I try and in this endeavour, my trying has indeed been tried.

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