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Thought and knowledge: A neurophysiological view

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The Ohio State University, 1987

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THOUGHT AND KNOWLEDGE:
A NEUROPHYSIOLOGICAL VIEW

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
The Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Kathleen S. Farber

*****
The Ohio State University
1987

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The relationship between mind and brain has long been a subject of debate. Elemental to the various positions in this debate is the existence and role of the mind-brain components in the process of intellectual and neurophysiological development. A critical question centers on how the mental and the physical relate to one another. R.W. Sperry (1980) characterizes the three currently dominant positions in this debate as the materialistic-behaviorist, the dualistic-interactionist, and the mentalistic-monist.

To use more familiar terms, Sperry is laying out possible positions with respect to mind-brain relationships. The materialistic-behaviorist would claim the existence of brain only, with mind being an unnecessary fabrication. All mental functions can, in this view, be accounted for in neurophysiological terms. There is no need to invoke the concept of mind at all.

The dualist interactionists, such as Popper and Eccles, claim that mind exists separately from brain and that mind functions in concert with the physical structures of brain to yield consciousness. This position is seen by Sperry as being dualistic, in that both mind and brain exist relatively independently of one another. Sperry, however, favors a view more in line with monism. The dualist would claim that
conscious experience can exist apart from the brain, affirming that independent mental and physical worlds do in fact exist. They accept notions of a conscious afterlife as well as other supernatural phenomena. In contrast, monism denies conscious mind existing independent and apart from the brain (Sperry, 1980, p. 195).

Sperry's position is that mind and brain are mutually interdependent, hence the position is monistic. He suggests that mind or the mental phenomena of mind cannot be accounted for only by examining the electrophysiological events of brain function. Mental phenomena are seen as forces that are "more potent in brain dynamics than are the forces operating at the cellular, molecular, and atomic levels" (Sperry, 1980, p. 196). He contends that as we experience something, the mental phenomena that emerge causally influence brain activity, actually pulling the brain to higher levels of functioning. Sperry's position is one in which mind and brain cannot be explained independently.

There are many similarities between Sperry's position and that of Popper and Eccles. Both, for instance, reject the behaviorist, materialist, and reductionist notions in the view that all mental processes can be accounted for in neurophysiological terms. Sperry is also in agreement with Popper and Eccles regarding psychophysiological interaction, with "the view that subjective experience as an operational derivative and emergent property of brain activity plays a prime causal role in the control of brain function" (Sperry, 1980, p. 197).
Both the Sperry and the Popper-Eccles positions view the mind and not neural machinery as providing the unity of conscious experience, putting "mind back over matter" (Sperry, 1980, p. 198). Further, in both positions we see a discussion of "emergent hierarchic controls." Matter is therein viewed as a progression of ever-widening spheres, from the atomic to the molecular to the cellular (in the case of living matter) to the organ/organismic. Specific physical, chemical, and electrical laws govern action at each level, with controls or boundaries exerted on the lower levels by the level immediately superceding it. The molecule sets the bounds of atomic movement, the cell that of the molecule, and the organ/organism that of the cell. In the case of the brain, physical properties give way to the "mental". Electric, atomic, molecular, and cellular actions exist consistent with physical laws, but these processes are "superceded by other configurational forces of higher-level mechanisms." In the case of human brains, the abilities commonly referred to as perception, cognition, reason, and judgment, to name a few, set operational bounds and direction for the inner physical-chemical forces (Sperry, 1980, p. 199). The central concepts, then, of the Sperry and the Popper-Eccles positions are that causal control is exerted downward from (higher) emergent mental functions over (lower) neural entities, and that the mental and the neural are events of different types and subject to different laws and forces.

The fundamental difference that Sperry sees between his position and that of Popper-Eccles lies in the question of determinacy versus indeterminacy. Popper-Eccles (1977) see the mind-brain relation as indeterminant and unpredictable. They suggest that the conscious self
has supernatural origins and is something that survives death of the brain, therefore, separating the mind and the brain. Sperry sees conscious phenomena as emergent functional properties of brain processing that exert an active control and even determine the flow patterns of cerebral excitation (1980).

When physical or mental elements, be they atoms or concepts, are arranged in the same way and under the same conditions, the same outcome emerges. This outcome, therefore, is determined, caused, by the above arrangement. If such is the case, the outcome is also predictable, in principle if not in practice. Where Popper and Eccles see the mind as "prime mover" or "first cause" (Popper and Eccles, 1977), Sperry sees it as "a tremendous generator of emergent novel phenomena that then exert supercedent control over lower-level activities" (Sperry, 1980, p. 200). These new phenomena are high level entities or reconfigurations of inner (subjective) experience that operate according to their own cerebral dynamics. Reconfigurative or creative mental processes are not indeterminant, but are self-determinant (Sperry, 1980).

Sperry does not deny that there are external and internal controls on behavior, but contends that the "self determinants" in human beings "include the stored memories of a lifetime, value systems, both innate and acquired, plus all the various mental powers of cognition, reasoning, intuition, etc." (Sperry, 1980, p. 200). Here Sperry is using determinism in the sense that our decisions and choices are influenced and perhaps even determined by our inner self, by our experience.
To summarize, Sperry uses the illustration of a wheel rolling down a hill, carrying its atoms and molecules with it. The course of atomic and molecular travel in terms of time, space, and ultimate destination is determined by the properties of the wheel as a whole, in conjunction with the forces of the environment impinging on the wheel.

One can compare the rolling wheel to an ongoing brain process or a progressing train of thought in which the overall properties of the brain process, as a coherent organizational entity, determine the timing and spacing of the firing patterns within its neuronal infrastructure. The control works both ways; hence, mind-brain 'interaction'. The subsystem components determine collectively the properties of the whole at each level and these in turn determine the time/space course and other relational properties of the components. (Sperry, 1980, pp. 201-202)

Sperry's illustration however, is incomplete because the example does not account for or include transformations that occur because of experience. A better illustration is that of an individual down-hill skiing. The first time a person skis down a hill and hits a patch of ice disaster usually results. The skier inevitably falls, slides into a tree, or has some other fearful experience. Because of this experience the skier usually tries to incorporate some other method of dealing with the ice patch, if only to ski more slowly and cautiously.

What one gets from Sperry is a view of brain functioning based in neurophysiology, but guided by mind, conscious activity, thought, or what Sperry calls "holistic 'mental' properties" (p. 198). This study will address the following questions: What, exactly, are these "holistic 'mental' properties?" How do they form? Can one tell when a particular holistic mental property has formed? If so, how? How, if at
all, do the answers to these questions bear on a more general theory of
motivation, cognition, and learning?

The Study

The theoretical model proposed parallels Sperry's mentalistic
monism, in that mind and brain are seen as interactive and mutually
dependent. Yet there does appear to be a causal priority, with mind
pulling brain in an ever-expanding spiral to greater and greater
cognitive power. As is the case with Sperry, the mental operations
ultimately "supervene" brain processes. If this is the case, and if
there is mind-brain interaction, then this interaction can be explored.

Although aspects of mind are somewhat elusive and hard to define, by
examining the nature of holistic mental properties one may be able to
more clearly understand mind-brain interaction. One way to do this is
by viewing these holistic mental properties as resulting from the
perception of coherence. In this study coherence is seen as a quality
or a condition of being integrated and organized. The suggestion is
that the perception of coherence occurs when experiences are organized
by the mind and the brain. One also experiences a feeling of pleasure.
This achievement of organization and the resultant feeling of pleasure
lead to meaning for the organism and contribute to the emergence of a
holistic mental property.

The motive for this shaping or organizing of information comes out
of problematic situations in which one experiences vagueness and the
inability to make sense or create meaning. These states are referred to
as incoherent states, result in feelings of displeasure and confusion, and are the motive force behind human acts. If there is no perception of incoherence and the resultant feeling of displeasure, there is no motivation to reshape or reconfigure experience. If one looks at motivation in this sense one begins to understand aspects of the nature of holistic mental properties as they relate to cognition, to coming to know.

Motivation then, is crucial to the development of holistic mental properties, because a sense of coherence is established only if there is a felt need to do so. How then does one organize information in a way that a sense of coherence is established and knowledge is gained? What mental and neurophysiological processes facilitate the establishment of the perception of coherence? Once established, what empirical evidence might there be that this perception has become a part of the nervous system?

Theoretical Bases

In order to understand mind-brain interaction, this study will examine the relationships of motivation, cognition (including reflective thought), and neurophysiological processes. These elements are the "configurational forces" (Sperry, 1980) that influence the creation of holistic mental properties of mind.

The primary theoretical bases for this study are found in relationships between and among Donald Meyer's theory of motivation rooted in neuropsychology, John Dewey's notion of 'reflective thinking',
Michael Polanyi's concept of 'tacit knowing', and specific event-related brain potential research. The exploration starts with motivation arising out of states of incoherence, moves to processes directed at resolving those incoherent situations, and ends with speculation regarding how one might employ empirical research to test hypotheses generated by the theory as constructed herein.

As an organizational guide, Chapters II, III, and IV will closely examine Meyer's, Dewey's, and Polanyi's theories (respectively) as they relate to mind-brain interaction. The works of these three theorists serve to illuminate Sperry's concept of the mind-brain relation in which consciousness is conceived to be emergent and causal. Specifically, Meyer gives insight into motivational forces rooted in the central nervous system. Dewey ties this notion of motivation to cognition, in that he describes a process of thinking that links the initial motivational state to its resolution via reflectivity. Polanyi enlarges and enhances the conception of cognition by showing the means to and the nature of the informational content with which one thinks.

Meyer's work is chosen because it frames this study neurophysiologically; his theory of motivation (moving from incoherence to coherence) is based on the workings of the brain. Meyer suggests that the brain is concerned with the organization of behaviors and is content if the behaviors are perceived to be well organized.

Dewey's work has been selected because coherence is central to his concept of reflective thought (Dewey, 1933). Reflective thought involves units that are linked together so that there is a sustained movement to a common end. The origin of reflective thinking is some
perplexity, confusion, or doubt; and the outcome of reflective thinking is the establishment of a sense of coherence—the situation is unified and whole.

Finally, Polanyi's idea of tacit knowing is used because it is concerned with the content of thinking, including reflective thinking. In Polanyi's view every kind of human knowing involves reconstructing experience into a coherent entity; an appreciation of order as opposed to randomness is basic to humans. His use of subsidiary and focal awareness as elements of tacit knowing provides an underlying scheme for how the organism reconfigures information so that it becomes meaningful. Meyer, Dewey, and Polanyi are employed, then, to explore the integration of motivation, reflective thinking, and tacit knowing, respectively, into a theory of knowing and thinking.

Chapter V provides a review of empirical research on the P300, a brain wave of particular interest here, as it may provide neurophysiological evidence relevant to the theoretical assertions of Meyer, Dewey, and Polanyi, as well as to the central questions of this study. The sixth and culminating chapter then provides a synthesis of these ideas, suggests empirical research questions that test hypotheses emanating from the emerging theory, and highlights educational suggestions drawn from the study. What follows is a brief introduction to concepts and processes from Meyer, Dewey, Polanyi, and (event-related potential) brain research that relates to mind-brain interaction and to the formation of emergent holistic mental properties.
Meyer and Coherence

The link provided by Meyer lies in his conception of motivation. He claims that humans have one and only one universal motive—to seek coherence—and that humans are motivated and driven by states that are perceived as incoherent or vague. Said another way, motives, regardless of their sources, are states which are perceived as vague. These states are unstable and result in behaviors or acts that may or may not be pleasing. If the acts have a high degree of organization, they are perceived as coherent and result in a feeling of pleasure. If the acts are not nicely put together, they are not perceived as coherent, but as incoherent, and result in a feeling of displeasure. Everyone, for example, has experienced something like the pleasure of the perfect golf swing or tennis stroke, as well as displeasures similar to the sloppy slice or the over-the-fence backhand. Most have also experienced hunger, a state that is hard to describe. At best hunger can be described as vague, uneasy, or even painful. A resolution to the incoherent state of hunger is eating, a most coherent act.

One may think of cognition or thinking in a similar manner. In this sense cognition occurs as a result of perceptual incoherence, and thinking acts that resolve incoherence will result in some intrinsic reward and be perceived as pleasurable.

Dewey and Reflection

Dewey's connection lies in providing a cognitive process that begins with a motive state similar to that discussed by Meyer (incoherence) and
progresses through a series of operations that lead ultimately to resolution of that motive state (coherence).

When a situation arises containing a difficulty or perplexity, the person who finds himself in it may take on a number of courses. He may dodge it, dropping the activity that brought it about, turning to something else. He may indulge in a flight of fancy imagining himself powerful or wealthy, or in some way in possession of the means that would enable him to deal with the difficulty. Or, finally, he may face the situation. In this case, he begins to reflect. (Dewey, 1933, p. 102)

The reflective process serves an individual’s quest for coherence (Hoover, 1984). This reflective process is based in Dewey’s notion that the need to resolve vague or problematic encounters is part of the nature of humans. The idea of reflective thinking can be seen as a special, directed, conscious form of thinking that is intended to get optimal results in resolving an incoherent situation (Hoover, 1984). Reflective thinking is a particular kind of thinking which functions to yield greater reliability in establishing coherence (Hoover, 1984). Dewey states that the function of reflective thinking is to transform a situation in which there is experienced obscurity, doubt, conflict, disturbances of some sort, into a situation that is clear, coherent, settled, harmonious. (1933, pp. 100-101)

Reflective thinking is a method of thinking which allows one to adapt when faced with a problematic situation. It is a method of moving effectively from the unsettled to the settled, where the settlement is optimal relative to the problem at hand and the end in view. According to Dewey, "the nature of the problem fixes the end of the thought, and the end controls the process of thinking" (1933, p. 15). In reflective
thinking, each suggested solution must stand rigorously true to its pertinence to the problem. Thinking reflectively entails finding not just any solution or apparent resolution to the difficulty. Thinking reflectively incorporates the search for optimal effectiveness in resolving the incoherence, the difficulty. Once the incoherence is resolved and experience has been consciously reconstructed, new questions arise and inquiry can proceed along lines previously obscure.

Dewey does not discount other forms of thinking, but suggests that reflective thinking is most reliable because it includes a conscious and directed effort to establish belief upon a firm basis of evidence and rationality. With the notion of conscious, directed effort leading to grounded belief, Dewey allows one to view operationally Sperry's notion that consciousness is emergent and causal. In brief, reflective thinking is a process that leads to meaning, learning, and further inquiry - increased consciousness. Consciousness, then, emerges progressively and makes possible (causes) the continuation of the intellectual quest. In Dewey the learning that occurs as a result of reflectivity is rewarding, and this learning allows new problems to come into conscious awareness.

The discussion in Dewey of reflective thinking as opposed to thinking in other, more impulsive ways begs the idea of a continuum, from exceedingly impulsive thinking to habitual reflection. The continuum is based on the degree of consciousness or awareness of the factors involved and employed in thought, in other words, a continuum of less to more consciousness.
Polanyi and Tacit Knowing

Reflectivity is not the only way to resolve problematic situations. Other modes of thought, less comprehensive, systematic, or in depth, may also yield the perception of coherence. One of Polanyi's contributions to the overall theory becomes evident here. According to Polanyi, every kind of human knowing, from perception to scientific observation, includes an appreciation of order as contrasted to randomness and of the degree of that order (1957, p. 38). Every kind of human knowing involves a reconstruction or reorganization of experience into a coherent entity (Polanyi, 1975). This perception of coherence results from the active shaping and integrating of information which brings about the meaning and the quality of an experience that allows this information or experience to be learned, to become known. Polanyi refers to this phenomenon as the tacit power by which all knowledge is discovered, and once discovered, is held to be true (1957, 1975).

Once a tacit structure is established, once information has become tacit, the contents of that structure (tacit information) can then be recast into thought or some practical use. For example, one can recognize someone's face without recognizing the particulars of that person's face. But once one has established this recognition, one can begin to depict just what it is that makes up the uniqueness of that individual's physiognomy. Or, to use a different example, once one realizes what a paint brush does, one begins to analyze the properties of the brush that will be most suitable for what one is painting. These two aspects of knowing, the "knowing what" and the "knowing how", have a similar structure and neither is ever present without the other.
(Polanyi, 1966, p. 7). Here one can see the basic structure of tacit knowing, two different kinds of awareness of things: subsidiary awareness and focal awareness.

When one uses a paint brush to paint a house or a picture, one attends to both the brush and the object to be painted, but quite differently. One watches the effects of the strokes on the house or the picture, but one does not attend to the handle or to each bristle of the brush as it covers the house, the canvas. One, of course, is very aware of the feeling of the brush in the palm and fingers. The feeling guides the effective handling of the brush, and the attention given to the house or the canvas is given to this feeling also, but in a different way. The difference is that the feeling of the brush in the hand and its contact with the house or the canvas is not the focus of attention, but rather the instrument of attention. This instrument, or subsidiary, is not watched in itself; one watches something else while keeping intensely aware of this feeling of the brush. The object of the painting, the house or the canvas, is the focus of attention because of the feeling or awareness of the brush in one’s hand. Further, one knows the feeling in the palm of the hand by relying on it for attending to the brush for painting the house, the picture. One has a subsidiary awareness of the feeling in the hand which is merged into the focal awareness of the stroking of the brush to paint the house or to create the picture.

The grounds of all tacit knowing are items or particulars (subsidiaries) that one is aware of in the act of focusing attention onto something else (Polanyi, 1975, p. 34). This is the functional
relation of the subsidiaries to the focal target. This relation establishes or allows a "from-to" knowledge of the subsidiaries. One knows the subsidiaries by relying on awareness of them in attending to the focal target. One has a knowledge of them as they appear functionally in establishing the object of focal attention. In the above example of the human face, one relies on awareness of its features for attending to the characteristic appearance of the face as a whole. Once the subsidiaries, the awareness of facial features and other relevant environmental cues, are brought to bear on the face as a whole and recognition results, one has constructed an entity perceived to be coherent. One has come to know the face. This integration of information then becomes a part of one's tacit repertoire of usable knowledge.

Event-Related Potential Research

Although the establishment of the perception of coherence and the ensuing emergence of a holistic mental property may not always result in overt observable behavior changes, there may be neurophysiological evidence that there is a change in the organism when these phenomena occur. (The reader is reminded that coherence in this study is a subjective quality; there is not yet objective verification of what coherence is.) Current event-related potential (ERP) research has yielded a particular brain response which consistently occurs under conditions where organizing acts are required. This research seems to indicate that the brain is concerned with the forms of behaviors it
assembles, and that the brain will repeat those behaviors if the signals it receives indicate that the acts have a high degree of structure. The brain is content, so to speak, if it believes that behaviors are organized.

The brain response associated with the completion of organizing acts occurs approximately 300 milliseconds after the presentation of a stimulus event. This response, the P300, is a potential recorded from the cerebral cortex and is seen as a large, positive-going waveform. The P300 is probably the ERP waveform that has been studied more than any other. This is because the P300 invariably occurs during cognitive activity as opposed to the earlier ERPs (1-70msec) that are stimulus-bound (ERPs that occur whether or not the subject is attending to the task and are not significantly modulated if the subject is anesthetized).

For example, the P300 is seen in the frequent versus infrequent stimuli or "oddball" paradigm. In this paradigm a subject is presented stimuli from two categories, one that occurs frequently, (such as 80 percent of the time) and one that occurs infrequently (such as 20 percent of the time). The subject is then asked to count the stimuli from one category. Large P300 waves reliably occur when subjects are presented with and respond to the less frequent stimuli; and, the rarer the stimulus, the larger the P300 amplitude (Donchin, 1977). But it has been found that the omission of an expected stimulus will also yield a P300 waveform (Picton et al., 1974). The oddball paradigm has many versions and for a time was the most popular P300 paradigm used.
The results of the oddball paradigm research led to the labeling of the P300 as the brain wave associated with the element of surprise or unexpected event (Donchin, 1981). This interpretation for the occurrence of the P300 has been accepted for the most part by brain researchers. However, there is other evidence that leads one to believe differently. Desmedt (1977, 1979, 1980) seems to present evidence that the P300 is a reflection of a postdecision closure activity. In his view, this wave signals the end of a cognitive epoch and thereby clears neural pathways for further processing.

Kutas and Hillyard (1980) also seem to present results in conflict with the "surprise" interpretation. In a sentence-reading task, subjects were presented sentences that were completed either congruently or incongruently. Congruent sentences ended with words appropriate to the meaning of those that preceded it, and incongruent sentences ended with words inappropriate to the beginning of the sentence. For example, a congruent sentence might be, "It was his first day at work." An incongruent one is "He spread the warm bread with socks." Their data showed a P300 related to the congruent sentences and an N400 related to the incongruent. One would assume surprise to be associated with the incongruent ending, eliciting a P300. But, instead of a P300, the researchers found an N400 elicited by the semantically inappropriate endings. The P300, on the other hand, was found in congruent situations.

Given the Desmedt and the Kutas and Hillyard results, a number of questions arise. Is the P300 the neurophysiological indicator of the resolution of a motive state? In other words, does this brain response
reflect the subjective quality experienced when the perception of coherence is established? Or is this brain response indicative of some other organizational aspect of mind-brain interaction?

Position Summary

The non-dualistic positions of Sperry, Meyer, Dewey, and Polanyi allow one to examine the questions of mind-brain interaction. They all suggest that the mental and the physical relate and interact with each other. Intimate connections are seen between subjective experience and cognition. The initial feelings that an experience engenders influence and motivate later experiences of learning and cognition. Further, if mind and brain function in concert with each other, then empirical observation of this interaction might be possible. Specifically, I am proposing a theoretical model (presented verbally and graphically) to link the various components of this motivation/cognition process, along with hypotheses for possible studies designed to test some theoretical connections proposed in the model.

In such a model, neurophysiological processes of the brain function according to physical, chemical, and electrical laws. Yet superceding "mental" processes operate in conjunction with the physical. Mental processes, such as holistic mental properties, pull the brain to greater schematic adequacy and complexity, leading to higher levels of consciousness.

The ensuing chapters are arranged to explicate the major theorists--Meyer, Dewey, and Polanyi--as they relate to the nature of motivation
and cognition; to review and synthesize critical neurophysiological research; and to integrate the separate theoretical and empirical information into a "mind-driven" cognitive theory. Chapters II, III, and IV are devoted to the theoretical works of Meyer, Dewey, and Polanyi, respectively, concentrating on constructs and processes that illuminate how we come to know. Chapter V includes a selective review of event-related potential brain research that enhances the theoretical construction and also suggests ways to test hypotheses generated by that theory.

Chapter VI represents a synthesis of two through five, presenting an integrated theory of motivation and cognition. The chapter also explores possible empirical research questions that might test relationships among components of the theory. In addition, the educational and pedagogical significance of this theoretical and empirical work is addressed.
CHAPTER II
INCOHERENCE AND COHERENCE

The starting point for explicating a mind-driven model of cognitive functioning is with the organism itself, with its neurophysiological make-up. The work of Donald Meyer lays the foundation for the emerging theory in that he sees motivational forces rooted in the central nervous system. His theory of motivation suggests that the brain is concerned with the form and organization of acts, and that the degree of organization or structure--coherence--of those acts plays a major role in the functioning of the cognitive system.

This chapter begins with an explanation of several concepts central to Meyer's theory--coherence, incoherence, motivation, and learning. The whole of Meyer's theory hangs on an understanding of these critical terms and of how they relate to one another. The chapter then moves to the two laws at the heart of Meyer's theory--the law of coherence and the law of reactive inhibition. The culmination of the chapter lies in the interaction, through example, of those two fundamental laws.

Meyer has not defined coherence in some fixed sense; he uses the term in a variety of ways and often attributes different meanings to the term. His ideas then remain somewhat unclear and ambiguous. However, because Meyer's work incorporates the structure and functioning of the central nervous system at both the micro and macro levels, the basic
tenents of his theory allow one to begin to examine mind-brain issues. It is important to note that most theories of mind and brain give credence only to the chemical and electrical firings of the brain when explaining functions.

Throughout Chapter II the text will remain true to Meyer's theory of coherence. This study is in agreement with Meyer that the tendency to organize information is characteristic of the mind and the brain. For purposes of clarification and consistency as this study proceeds, perceptual coherence is defined as a quality or condition of being integrated that is sensed by the organism.

Perceptual Coherence and Incoherence

Coherence and incoherence are determined by the level of prediction afforded a perceiver by the information contained in a message. A percept is maximally coherent if the information in a part of a message will permit one to predict every feature of the message as a whole and maximally incoherent if no level of prediction is afforded the perceiver. Percepts relatively high in coherence are typically described as "clear, unmistakeable, and unforgettable", and those highly incoherent seem "vague, confusable, and unrememberable" (Meyer, 1980, propositions XI and XII). The terms 'coherence' and 'incoherence' apply to any act, regardless of whether it be perceptual, muscular, or thoughtful. For example, listening is an act of perceiving, running is a muscular act, and drawing a conclusion is an act of thinking. Despite
the obvious differences between these acts, the pains and pleasures that they each can give obey the same fundamental laws.

In terms of perceptual acts, motivation can be viewed as being determined by the ratio of signal to noise in the message. The higher the noise level, the greater the incoherence experienced by the perceiver. Since this incoherence is unpleasant, the perceiver is moved to search out the signal, resulting in increased coherence and hence pleasure. Motivation persists either until the message is discovered or until the perceiver no longer receives the message. The motivation stops when "the percept of the signal is maximally coherent within limits set by the nature of the message and of the perceiver's nervous system" (Meyer, 1980, proposition XXIV).

With respect to muscular behaviors, such as dancing, swinging a sledge hammer, or eating (which also happens to be a primary drive), the quality of performance of the acts depends upon notions of relative coherence or incoherence. A muscular act performed poorly or slovenly is punishing because, according to Meyer (1980), the perceptual consequences of such performances are relatively incoherent. When a muscular behavior is performed well, smoothly, the perceptual consequences are coherent and therefore pleasing. The energy expended in the performance of the act is only of marginal concern.

An additional factor in the performance of those muscular acts related to primary drives is the relative coherence or incoherence of the drive state itself. The drive is motivating because it is incoherent, unpleasant; and the consummatory behavior that reduces the drive is rewarding because, and only because, its perceptual
consequences are more coherent than those of the drive itself. In the case of primary drives, then, both the quality of performance of the muscular act (e.g., eating) and the fact that the act replaces a less coherent drive state (e.g., hunger) account for the rewarding features of such acts.

Finally, thinking acts follow the same general motivational laws (Meyer, 1980). When one perceives thoughts to be coherent, one calls those thoughts "understandings". Any act of thinking that results in understandings, or that improves upon and enhances earlier understandings, is rewarding. Those thinking acts that do not result in understandings, that do not result in increased coherence, are unpleasant and punishing. Acts of thinking are learned if they result in greater coherence (understandings) and are not learned if they do not, independent of the uses to which such understandings might be put in the future.

Upon close inspection of the above three categories of acts--perceptual, muscular, and thoughtful--one finds essentially the same processes at work. Coherence is associated with the ratio of signal to noise, with coherence varying positively with the perceiver's recognition of the signal at the expense of noise. This was stated clearly by Meyer with respect to perceptual acts, as might be the case when one is requested to pick a familiar voice (signal) from among several other unfamiliar ones (noise). Incoherence is high until that familiar voice is located and the others "blocked out". At that point, the perceiver has increased the signal-to-noise ratio, thus increasing coherence and experiencing pleasure. The signal/noise metaphor might
also be used to illuminate the parallels with the other two types of acts.

In the case of muscular acts, dancing smoothly, rhythmically, and with a minimum of unnecessary and irrelevant effort (signal) will lead to more coherent and pleasing perceptual consequences than would dancing littered with arrhythmia and abrasiveness (noise). In like fashion, thoughtful acts that result in drawing meaningful inferences from conversation, that is, that cull out the signal from the noise, result in greater perceptual coherence than do thoughtful acts that fail to make meaningful inferences, thereby confusing signal and noise. Dancing well and inferring meaningfully are rewarding because and only because they result in greater perceptual coherence, independent of other potential future outcomes of such acts.

The Law of Coherence

According to Meyer (1980), human beings have only one motive, although it appears in many forms. That universal motive is to seek coherence. States that are perceived as incoherent or vague will be resolved by an act that is perceived as coherent. An act is anything that the organism does which has a perceptual consequence. The feelings with respect to the outcome of an act are pleasant if, and only if, the act results in enhancement of perceptual coherence. The feelings are unpleasant if the act has resulted in a reduction of perceptual coherence. In other words, humans behave or act to achieve and experience clear perceptions and pleasant feelings.
Meyer contends that biological drives, such as hunger or thirst, and personal "drives", such as love, are governed by the same set of fundamental laws. He proposes that these basic laws govern the organization of behavior. The first law of Meyer's theory is the law of coherence. There are three basic elements to understanding the law of coherence. The first is that motives, regardless of their source, are states which result from perceived vagueness. Second, one experiences the perceived vagueness as unpleasant. Third, the law of coherence asserts that these states are inherently unstable and, because they are unstable, result in attempts to resolve the instability which may or may not be pleasing. The behaviors will be pleasing only if the behaviors have a higher degree of organization than prior behaviors. Hunger, for example, is a state that is perceived as vague and is experienced as unpleasant. Hunger also produces behaviors such as eating and drinking which are experienced as highly pleasurable acts because they are particular patterns of behavior that have a high degree of structure.

Acts or behaviors that are pleasing because they have a high degree of organization, once initiated, will persist and please as long as they continue to be highly-differentiated, smoothly performed behaviors. The law of coherence is not concerned with the notion that behaviors may have important future consequences. Future consequences have almost nothing whatsoever to do with whether one will find one's behaviors of the moment enjoyable or punishing. In other words, feelings of pleasure or displeasure with something one has done are determined by whether or
not the act performed was perceived as a coherent pattern of behavior.

According to Meyer,

> The law of coherence implies that it simply doesn’t matter whether the behaviors we engage in are good for us, bad for us, trivial or stupid so long as the brain is content in its belief that the behaviors are nicely put together (1980, p. 18).

There are many examples to illustrate the law of coherence. The law is clearly illustrated when accounting for coping with itches. When one has an itch she scratches it, which actually makes matters worse in the long run. The act of scratching gives enormous satisfaction at the time it is performed. Why should that be so when a scratch by itself has unpleasant consequences? Why should one enjoy, at least while one is itching, doing something that mutilates the body?

Scratching of itches, then, is uninterpretable in terms of the notion that biological motives either have a purpose of self-preservation or of propagation of the species. Certainly many actions do fulfill these two purposes, but the future consequences of what one is doing at any given moment do not control one’s actions at that moment.

Then how does the law of coherence account for the fact that people like to scratch an itch even though the act is punitive? An itch is a relatively vague percept. Having an itch is not unlike being hungry; they both are motivating, yet the specific acts that satisfy them are different. Thus, when one is stung by a mosquito, he knows where he has been stung. The sting is not nearly as unpleasant as the itching that ensues. When the itch begins, it spreads and becomes progressively diffuse. He then finds himself driven or compelled to do something, and the something he does is scratch the itch.
The pain of the bite and the itch that follows are both products of the same perceptual system. Physiological studies have shown that if an itch-producing substance is spread upon the skin, sensory neurons that innervate the skin will transmit signals at low and irregular rates (Meyer, 1980). Further, studies have shown that when subjects' skin is weakly stimulated with electrical pulses that are separated by a few seconds, they report a perceptual effect that is essentially the same as the itch one feels after being stung by the mosquito. However, if the same set of neurons is stimulated by a somewhat stronger and faster set of electrical pulses, the perceptual effect is no longer reported as an itch, but as a "prick". The difference between an itch and a prick is that the itch is incoherent, motivating scratching behavior, whereas the prick is experienced as coherent (Meyer, 1980).

This phenomenon occurs because pain mechanisms have two distinguishable components; "one is a slow fiber, protopathic system and the other is a fast-fiber, evecritic system" (Meyer, 1980 p. 13). The protopathic system enables one to make fine tactile discriminations and also allows one to perceive fast or bright pains. When one scratches an itch hard enough to feel a bright pain, the scratch has an immediate salubrious effect of inducing a clear experience. This is partly due to the intrinsic coherence of the signals in the fast-fiber system, and in part due to the fact that the propagation in the fast-fiber system is accompanied by an inhibition or suppression of conduction by the slow-fiber system. The overall effect is a replacement of a spatially and temporally disordered or random signal pattern with a more organized
pattern that is perceived as clear or sharp and, therefore according to the principle of coherence has a pleasing effect (Meyer, 1980).

A special case of the illustration of the law of coherence can be seen in the principles of visual-form perception. Meyer suggests that seeing provides its own rewards, regardless of whatever further uses one may make of the facts that are obtained in the process. To begin to understand this notion, Meyer suggests that one take note of one's moods on a gray winter day. Everything one looks at tends to look the same. Nothing appears to be clear and distinct. Edges of objects are not sharp and defined. Under such conditions one usually finds oneself unhappy with longings for bright, sunny weather. Why does this occur?

According to the law of coherence, a gray day will be bothersome for essentially the same reason that having an itch is bothersome; they both result in or are themselves vague percepts. "Our eyes are built to pick out the edges in a scene, and to discard much of the information that is picked up by receptors that are stimulated by the spaces that the edges enclose" (Meyer, 1980 p. 14). When the edges themselves are indistinct this visual process is thwarted. When the process is inefficient one's eyes send the brain cluttered visual messages. Instead of enhancing the differences (or signals) in a pattern of light, which would yield a simplification of the transmitted message, the eyes see very little detail or clarity. Everything appears as "pretty much the same". This effect is not always debilitating but can be if the scenes one looks at have no detail at all (Meyer, 1980).

A classic study by Hebb et al. (1954) illustrates how the visual system strives for form and clarity. In their study, human volunteers
experienced minimal external sensory stimulation. The subjects were asked to wear translucent masks to cover their eyes and to keep their heads in U-shaped pillows to attenuate sound. They also were requested to wear soft gloves and long cardboard cuffs on both hands and lower arms and were instructed to lie on a soft bed within an airconditioned cubicle. The only interruptions were for meals and restroom breaks, at which time the subjects still wore the apparatus but were helped by the experimenters.

The subjects, who were graduate students, thought that the time spent during the experiment would be profitable and rewarding. However, the subjects soon discovered how difficult their task was. Although the subjects thought they could complete unfinished work, they rapidly discovered that they could not think clearly. They also experienced visual and auditory hallucinations. The visual hallucinations began as dots, progressed to geometric patterns, and then were replaced by percepts of squirrels or dinosaurs (Hebb, 1954).

The Hebb et al. study indicated that the brain's visual system will not simply rest but will continue to perform visual functions if deprived of the guidance it normally receives from the world via patterns of light. The functions of the visual system, which are the same as the functions of other control neural mechanisms, are to perform operations which permit particular patterns of behaviors to emerge. In the Hebb et al. study the patterns of behavior that emerged were percepts of different types of forms. Thus, from the perspective of the law of coherence, also a law of forms, the geometric shapes, squirrels, and dinosaurs would be explained as nicely-integrated percepts.
experienced in order to achieve coherence. Even in the absence of external stimuli the mind continues to seek coherence by patterning and shaping information.

Other studies support this notion. Fantz's (1961) studies indicate that humans have an inherent capacity to perceive form to confer order and meaning on their environment. He studied chicks before they had any real experience with food and found that, when presented with eight objects of graded angularity from sphere to pyramid, they pecked at preferred forms for hours on end. Circles were preferred over triangles. Among the circles the chicks consistently selected a sphere over a flat disk. Fantz's results provide evidence that the chicks have an innate ability to perceive shape and dimensionality. Further, the chicks use this ability in a meaningful way by selecting, without learning, those objects most likely to be edible: round, three dimensional shapes about the size of grain or seeds. Fantz also found that human infants from one to fifteen weeks old showed a definite preference for certain forms. For example, the human infants looked mostly at a "real" face and largely ignored a scrambled face.

Chimps also prefer good form. Schiller (1952, cited in Meyer, 1980) found that chimps will selectively attend to figures in which pieces have been left out, and will mark those places as if the figures as presented were defective.

Significantly, the Gestalt school of psychology proposed that the underlying perceptual unit is the form (Hearst, 1979). Percepts are products of events within the brain that tend to go forward until the organization of the percept is eventually completed (Meyer, 1980). This
principle is termed the law of good figure, or Pragnanz (Wertheimer, 1959). The law implies that "properties of parts depend upon the relation of the parts to the whole; part qualities depend upon the place, role, and function of the part in the whole" (Wertheimer, 1959, p. 5). Therefore, unclosed figures are not as "good" as closed ones because closed figures are perceivable without interruptions in the flow of the process of perceiving (Meyer, 1980).

According to Meyer the law of coherence, when applied to the process of perception, is not essentially different from the law of Pragnanz. The only difference in the two is that Wertheimer's law is regarded as a law of perception, whereas the law of coherence applies the same reasoning to other kinds of motivated acts. The law of coherence, stated again, is that acts are rewarding if the acts have a high degree of structure, no matter whether the act is the construction of a percept or a movement. Thus, the law of coherence asserts that the chimp that fills in the gaps in visual figures is driven to that behavior by the same kind of motive that prompts a thirsty dog to drink.

The Law of Reactive Inhibition

Although the law of coherence accounts for some behavior, there are aspects of experience and behavior that cannot be explained by this principle. If the law of coherence were the only law of motives, one would be caught in a trap. That is, if a coherent act supplies its own reward or reinforcement, why then should such an act ever be succeeded or replaced by another? The principle answer to this question is
supplied by the law of reactive inhibition, which governs the functions of almost every subcomponent of the central nervous system.

The law asserts that acts which are initially perceived as coherent, regardless of the nature of the act, will lose their coherence if repeated. This results in a reduction in the probability that an act will be performed in exactly the same way again. This bias against repetition increases as a function of 1) how coherent the act is and 2) how often and rapidly the act is repeated.

The simplest illustration of the law's operation is explained by the flexor reflex seen in a paraplegic animal or human whose spinal cord and brain connection has been injured. The legs will still respond by withdrawing if a pin is applied to the sole of the foot. But, after repeated stimulation of the foot, the flexor reflex will fail to occur, or the leg will withdraw, but all of the muscles of the leg will be involved in the process. Thus, if a flexor reflex is fatigued, it will fail; but before it fails the precision of the reflex will deteriorate. This effect is described by neurophysiologists as irradiation, and Meyer contends it is similar to the reaction of a human being who must do the same thing over and over again. What happens when a person fatigues is actually that the nervous system changes its mode of operation. The change begins as soon as the system has completed an act and develops until the system fails to operate.

To understand this process of irradiation, which is a consequence of reactive inhibition, consider the neural mechanisms involved in the knee jerk and flexor reflexes. These extensor and flexor behaviors have been studied in detail for clues to the operations of networks of neurons
(Meyer, 1980). The knee-jerk reflex extends the leg with a jerk if the
tendon that lies just below the kneecap is tapped. In contrast to the
flexor reflex, the knee-jerk reflex will show few signs of wearing out
or tiring if it is repeatedly evoked. The neural mechanisms of the
knee-jerk reflex consists of sensory neurons that form direct
connections with neurons that operate our muscles. In the pathway there
are no other neurons that transmit signals from a tap on a tendon to
neurons whose signals command the muscles to contract and, in this case,
extend the leg. In contrast, signals from a prick to the foot, which
causes the flexor reflex, activate neurons which are termed
interneurons. The interneuron is wholly contained in the spinal cord
and activates other neurons that control muscles whose contractions will
bend a leg's joints, causing a withdrawal of the leg. Therefore, since
the flexor reflex network involves interneurons and the knee jerk reflex
network does not, and since this reflex is subject to fatigue whereas
the knee-jerk reflex is not, it would appear that the fatigue reaction
involves the interneurons.

Meyer suggests that the interneurons are components of loops that
detect the operation of a neuron and then, after a very brief interval
of time, transmit signals to the neuron which serve to increase the
charge across its membrane. This process is termed reactive inhibition
because the neuron that is affected, the interneuron, is the neuron that
prompted the loop to operate, and because the increase in the charge
across its membrane makes it less sensitive, inhibiting further
immediate action. This is but one of several forms of inhibition that
illustrate the nervous system's bias against repetition.
Another illustration of this bias is seen in the phenomenon called successive induction. When walking one alternately extends and flexes one's legs. These acts are antagonistic, and the neural mechanisms which put them together are related in a manner such that one, and only one of them can operate at any given instant. In other words, when one movement is in operation the other is inhibited. This is a type of reciprocal inhibition. When coupled with the principle of reactive inhibition, reciprocal inhibition explains why extending one's leg makes it easier to cause it to flex at a later point in time--the neural mechanism of extension will then be fatigued. As an example, if one pinches the hindpaw of a cat whose spinal cord and brain connection is injured, the leg will be withdrawn and extended, then withdrawn and extended once again. This phenomenon is termed "spinal stepping" and results from a change in the balance between the functions of antagonistic systems. When either the flexion or the extension reflex succumbs to reactive inhibition, the other reflex is released. Although spinal reactions allow for illustrations of the laws of inhibition, the same laws are seen in operation in many kinds of acts.

Operations of the law of reactive inhibition can be found in the study of visual perception. When a simple visual figure is presented in a way that its features always stimulate the same set of visual receptors, the figure is perceptible at first but then fades very quickly (Meyer, 1980). These types of visual figures are indicative of maximally coherent percepts, and according to the law of reactive inhibition are most subject to a bias against repetition. The fading of these figures takes place so quickly because they can be seen in no
other way. When looking at a Necker cube, no matter how hard one tries
to focus on a particular edge, the image will change. The same effect
seems to occur with all ambiguous visual patterns. The longer one looks
at one specific aspect of the pattern, the less coherent the percept
becomes and the greater the reward for a relacement of that percept by a
percept of another specific aspect of the pattern.

The effect of reactive inhibition is also apparent in performances
of movements. Meyer's favorite demonstration of this phenomenon occurs
when he challenges a student to write the letter "d" (or any letter) on
the board in exactly the same way as many times and quickly as she can.
After having done four or five of them the student asks if that is
enough, and Meyer urges her to continue and even more quickly. The
effects, then, of the repetition of the act become increasingly
dramatic. After approximately forty such acts the letter is hard to
recognize and the person performing the act is not smiling. Repetitious
work, regardless of whether a small or large amount of muscular energy
has been expended, inevitably results in deterioration of the act and
punishment for the person who performs it.

Interestingly (especially for educators), Meyer suggests that
repetitious acts can be continued by tiring individuals because
effortful behaviors which are not ordinarily effortful become so due to
reactive inhibition of the neural system that guides or forms the acts,
not due to neural mechanisms that "energize" other behavioral
mechanisms. Repetitious acts, regardless of their nature (not
delineating between physical and mental) inevitably lose their
precision. It does not matter whether that act is looking at something,
listening to something, or splitting a load of kindling wood. The
tiredness or boredom that results from repititive acts is punishing
because repeated acts deteriorate and the feelings which accompany this
process have no mechanism of their own (Meyer, 1980), only one’s
perceptions of the fact that the behaviors are becoming less coherent
than they were.

The Interaction of the Laws
of Coherence and of Reactive Inhibition

The law of reactive inhibition and the law of coherence are
fundamental to explaining behavior. While the law of coherence accounts
for the pleasure experienced after performing a highly organized act,
the law of reactive inhibition accounts for the motive state which
arises from the deterioration of an act. This motive state, a perceived
incoherence, is punishing and sets the stage for learning other kinds of
acts. Acts will be learned if, and only if, they result in enhanced
perceptual coherence. An act, if coherent, has rewarding perceptual
consequences, and those are the consequences which determine whether the
act will be repeated. Acts will be rewarding if, and only if, they are
more coherent than the acts which preceded them.

For Meyer, the notions of reward and punishment are wholly intrinsic
in nature (1980), which is different from the classical and operant
conditioning notions of learned responses. Classical conditioning
theory, based on Pavlovian procedures, concluded that learned responses
occur because of a pairing of conditioned and unconditioned stimuli.
However, this conclusion is based upon the notion that rewards or reinforcers are extrinsic consequences of responses. Meyer asserts that one is in error if one assumes that the environment is filled with rewards and punishments. An illustration of this assertion is seen in one of Pavlov's digestion studies. In this study, he wanted to collect gastric juices from the stomach of dogs for use in the treatment of people with diseases of the stomach. Pavlov had found that the juice is secreted when a dog is given food. To avoid contamination of the juice by food, he cut the dog's esophagus in two so that when the dog would chew and swallow the food, the food could be caught before it passed into the dog's stomach. The remarkable result was that the dog did not eat unceasingly. Rather, it would eat a meal and then pause before it would eat again, acting the same as a normal dog would.

Adolph (cited in Meyer, 1980), using procedures similar to Pavlov's, found that drinking will satisfy a thirsty dog regardless of whether the water is ingested or not. According to Meyer, both of these investigations show that acts, in these illustrations, eating and drinking, will continue for a time and will then end regardless of whether the behaviors have served to do the subjects any good. As observed it does not matter even whether the acts serve to initiate a process that corrects an impending homeostatic need. The acts are repeated because they are more coherent than the states that they inhibit and replace and result in intrinsically rewarding perceptual consequences. Hence, the acts will be learned. If Pavlovian procedures are followed, a conditioned response will be established provided that the unconditioned stimulus will serve to elicit a coherent response.
The notion then that acts, if coherent, are rewarding and hence learned, implies that motivation is not extrinsic, but explicitly intrinsic. In other words, a stimulus itself is never motivating, but an act that it elicits can be if the act is incoherent. One cannot motivate anyone to do anything, but one can provide stimulus conditions which result in actions by humans which are incoherent and hence, are intrinsically motivated to seek coherence. To illustrate, Tolman and Honzik (cited in Meyer, 1980) used two sets of rats. One set of rats was put in a maze and allowed to wander as they pleased. The other set was kept out of the maze for the first trial. Tolman et al. then deprived the rats of food and began to reward them with food that was placed in one of the chambers of the maze. The group of rats that had previously been in the maze learned the path to the goal box containing the food much more quickly than the other group of rats. This finding suggests that even while the rats were supposedly unmotivated (no food situation) they learned the floor plan of the maze.

This result is in keeping with Meyer's theory. The learning did not require an extrinsic motive, for a rat that is put into a strange situation already has a motive to find out what the place is like. Most people's perspective would be that the learning "didn't get them anything"; but, as Meyer has shown, the external reward has nothing to do with satisfaction. The satisfaction is a result of knowing because knowing is more coherent than recognizing that we do not know. Human beings need and desire to know.

Coming to know, the attainment of perceptual coherence, is rewarding in and of itself. When one comes to know, one has integrated into a
whole previously disparate components of an act. When the act is performed in the future, all components of the act do not have to be consciously thought about. Once the organism has learned the act, has organized the components of the act into a coherent whole, the organism has greater control over the entire act and can better predict the outcome of the act. This allows the organism to perform the act smoothly. This state of increased control and prediction over the components of the act and the smooth performance of the act as a whole is intrinsically rewarding. While it is true that the newly learned acts may enable the organism to gain extrinsic rewards, it need not do so. The intrinsic motive of achieving coherence is what is necessary to spur the learning process, not the gaining of external rewards.

If there is no motive to seek coherence, then no learning will occur. Acts are learned when they serve as vehicles for reducing perceived incoherence (Meyer, 1980). Therefore, motivation and cognition are inseparable because the motive state (vague or confusing states resulting in a condition of perceived incoherence) is an absolutely necessary condition for cognition. "The human organism tries to establish internal harmony, consistency, or congruity among his opinions, attitudes, knowledge and values" (Festinger, 1964, cited in Meyer, 1980). By resolving incongruities, incoherences, and by establishing perceptual coherence humans come to know and to make meaning. This is true even though the meaning may be wholly subjective.
Summary

By addressing the interaction of the mind and the brain, this study explores how humans acquire knowledge. By examining relationships between and among theories of motivation, cognition, and neurophysiological processes, we come to understand how this interaction influences the development of knowledge. Different theorists' ideas that explicate the workings of the mind and the brain are pulled together to present a unified model of how we come to know. In this chapter Donald Meyer's work is discussed. He presents a theory of motivation that is based on the workings of the brain.

Meyer suggests that the brain is concerned with the organization of behavior and is pleased if behaviors are well organized or "coherent". The motivation for shaping behaviors stems from incoherence; a state which is perceived as vague or confusing, is experienced as unpleasant, and results in unstable or sloppily arranged behaviors.

Behaviors that are highly organized are prone to be reactively inhibited, or to lose their coherence if repeated. Reactive inhibition is due to a change in the activity of interneurons in synaptic transactions. While the principle of coherence accounts for the pleasure one experiences after performing a highly organized act, the principle of reactive inhibition accounts for the motive state which arises from the deterioration of an act. In other words, humans strive for coherence and, once coherence is achieved, repetition of those coherent acts yields reactive inhibition. This reactive inhibition
clears the neural pathways for new acts aimed at achieving new coherence.

Meyer further suggests that coherent acts will be learned. This applies to any act, mental or physical, that results in enhanced perceptual coherence. Hence, he implies that motivation is intrinsic and that a stimulus itself is not motivating, but an act that it elicits can be if the act is incoherent. Once the act has been learned, has been organized into a coherent whole, the organism has greater control over the act and can better predict the outcome of the act.

Dewey's process of reflective thinking, a process centering on inference or induction, is also concerned with prediction. His process of reflective thinking is intended to optimize coherence by arriving at the most strongly warranted conclusion or response to an incoherent, or problematic situation. This notion of warrantability or predictability is what distinguishes reflective thinking from ordinary modes of thought. As will be seen in the next chapter, suggestions and ideas are transformed into working hypotheses and finally into intelligent action through reasoning, imagination, and testing in the world. At the end of true reflectivity, the individual should be better able to predict the outcomes of her behavior.

Dewey's idea of reflective thinking carries Meyer's notions further and breaches the gap between the subject or the organism and the environment. Prediction for Meyer is a function of central nervous system activity; the internal, subjective experience of the person determines the nature and quality of behavioral outcomes. Dewey is concerned more with the transaction between the organism and the
environment. For Dewey, it is the initial dissonance in the subject/environment transaction that provides the motive state for action. Through the reflective process, this dissonance is reduced until there is harmony in the transaction, leading to a sense of integration and perceptual coherence. Dewey describes a process of thinking that links the initial motivational state (incoherence) to its resolution (perceptual coherence) via reflectivity, and it is to this process that the next chapter turns.
In Meyer, the tendency to seek coherence, which is based on the notion that the brain is concerned with the forms of behaviors it assembles, is central to humans. This tendency is manifest in all aspects of behavior, from overt physical movements to the subtlest of intellectual insights. In the work of Dewey, one finds the very same tendency in humans to reorganize vague, discrepant, or chaotic experience. Dewey’s notion of reflective thinking is an intentional, intellectual act aimed at reconfiguring experience. The roots of reflective thinking lie in the transaction between the individual and the environment. That is, when there is a perceived discrepancy in a situation that involves the individual and the environment, there is a resultant attempt to resolve that discrepancy. Just as Meyer finds motivation arising out of incoherence, displeasure, so too does Dewey see all thinking, or inquiry, beginning with a perceived dissonance. The culmination of each process, albeit theoretical, is the resolution of that dissonance, the achievement of coherence. Dewey sees reflective thinking as the most reliable way to achieve coherence (1933).

Dewey’s idea of reflective thinking is chosen because reflective thinking is a cognitive process by which information and experience is organized. Reflective thinking is the process that best parallels and
facilitates the fulfillment of what Meyer sees as the biological tendency for the organism to seek coherence.

Dewey sees essentially the same process taking place. A state of incoherence or dissonance motivates the individual to think through an incoherent situation so that action will reliably resolve the incoherence. Where Meyer's theory is based in the neurophysiology of the individual, in that individual's subjective experience, Dewey emphasizes the dynamic interaction between individual and environment. His is a concern with the transaction between the individual and the environment.

A central concern in this chapter is to analyze this transaction as it occurs during the process of reflective thinking. In an effort at describing reflective thinking, Dewey discusses three common conceptions of thought—thought as the random coursing of ideas, thought as imaginative sequences, and thought as belief. He employs these conceptions because they hold much in common with reflection and at the same time contrast with it in significant ways.

What is Reflective Thinking?

According to Dewey people are always thinking in one way or another. All the time one is awake and at times when one is asleep, something is going on in one's heads. When asleep one may be dreaming; and when awake one has all manner of daydreams, idle chatter, and so on coursing through one's minds. This random coursing of ideas is
routinely referred to as thinking, or as stream of consciousness. It is automatic, unregulated, and difficult to stop. Waking life is spent thinking about something or other most of the time. Reflective thought is like this random coursing of things through the mind in that it consists of a succession of things thought of, but in reflective thought a chance sequence of things does not suffice.

In simplest form, reflective thought is a chain, with elements or links ordered consecutively so that one builds upon the next. The preceding links serve as supports for those that follow. Put another way, reflective thinking differs from stream of consciousness in that elements of reflective thought are bound together by some logic, some order.

One contrast that Dewey makes, then, between ordinary senses of thinking and reflective thinking stresses the requirement of some order or logic in reflectivity. Another contrasting sense of ordinary thinking for Dewey deals with things "in the head", things that are not sensed or directly perceived. Any act of imagination or mental invention would fall within this category of thinking. For example, children often imagine what it would be like to live on another planet. What is suggested here is that thought is composed of mental pictures of things not actually present, and that thinking is a series of these mental pictures. When the series of mental pictures hangs together in some meaningful way, it simulates reflective thought.

Beyond the mere enjoyment of engaging in flights of fancy, there is no real purpose to this raw use of the imagined. If, however, the train
of imagined events "aims at a conclusion", if it points to some end beyond or outside the images themselves, then the thought approaches reflectivity. Reflectivity is indicated further when the end or conclusion towards which the images points can be grounded in the world. The employment of the imagined or the invented to "think out" a problem or clear up obscurity is what marks reflective thinking from sheer fancy.

Thinking can also be viewed as being synonymous with believing. Saying "I think that the Indians won yesterday" is equivalent to saying "I believe that they won". When our ancestors thought that the world was flat, they believed such was the case. This kind of thinking often "grows up unconsciously" for Dewey (1933, p. 7) and becomes a part of our mental furniture. Because the idea behind the belief is generally current, customarily accepted, it is accepted. As such, these beliefs are closely allied with prejudices, as opposed to beliefs reached as a result of inquiry, observation, and evidence. The critical difference is that even when these beliefs of convention and prejudgment are correct, they are so by happenstance and not by personal mental activity. Belief has a very significant relationship to thought, but there is nothing in the ordinary use of the term to help one distinguish whether or not the particular belief is warranted or well founded except its apparent coherence. The seemingly coherent nature of a situation makes one tend to hold the beliefs as warranted.

With the idea of 'warrant', one is again brought to reflection as a special case of thinking. Thought, in the sense of the first two types mentioned by Dewey--the random coursing of ideas and successions of
imaginative incidents—can actually be harmful or counterproductive in distracting attention from the world. Yet at the same time these mental activities are enjoyable and additionally can be ingredients in art, such as literary works of fiction and non-representational painting. These artistic endeavors involve a kind of emotional commitment, but they need not have intellectual or practical commitment. They need not appeal to the world for support, verification. In the case of beliefs there is this commitment to the world; and, because of this worldly connection, beliefs do require at some time an appeal to the world for warrant.

As an illustration of this need for verification of belief, consider the belief that the world is flat (Dewey, 1933, p. 8). When one believes in the flat earth, the belief must at some point affect the person's actions in the world. This person must be wary not to travel too far from shore, for fear of falling off the world's edge, for example. As a contrast, Columbus' belief that the world was round allowed him to commit to a series of other beliefs about travel, and finally to acting on those beliefs, testing them in the world.

The earlier belief in the flat earth rested upon evidence of what people could easily see. This evidence was accepted without further inquiry; it was not checked by considering other evidence or searching for new evidence. The belief became one based on static custom. The earth-as-sphere belief stemmed from careful study of natural phenomena and from posing and reasoning through logical extensions of those phenomena. By purposefully widening the field of observation and by reasoning out alternative conceptions and their results, the spherical
earth belief became a warranted assertion and not merely a static belief.

The spherical earth example serves the function of distinguishing reflective thought from all three of Dewey's ordinary uses of the term 'thinking'. First, Columbus' belief that the earth is a sphere resulted from an orderly chain of ideas and was not a mere excursion into a stream of consciousness. Second, the chain pointed toward and was controlled by a purpose and goal, it tended toward a conclusion. Finally, the belief was held tentatively and was maintained only by the results of continued examination and inquiry.

Columbus, struck with the idea of the flat earth, doubted its veracity and began to inquire, to think. He continued to think until he was able to devise ways to test his belief and to produce evidence for his intellectual stance. Even if he were wrong, his belief was of a different order from that in vogue at the time. It was one based on inquiry and subject to verification in the world.

Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends constitutes reflective thought. Any one of the first three kinds of thought may elicit this type; but once begun, it includes a conscious and voluntary effort to establish belief upon a firm basis of evidence and rationality. (Dewey, 1933, p. 9)

The Function of Signifying in Reflective Thinking

Reflective thinking has been approached here via a circuitous route, begun by explaining three ordinary uses of 'thinking'. The first use
involved stream of consciousness, or thinking merely involving being conscious of something in any way whatsoever. Secondly, 'thinking' can be used to describe the wholly imagined or invented, the mental activities that center on things not directly felt, seen, heard, smelled, or tasted. The third type of thinking equates thought with belief, where the thinking rests on some type of orientation to the world. The three types of thinking used to compare and contrast with reflectivity are not sharply demarcated, however. They often blend with reflection and with one another. In employing borderline cases of reflection, cases that are neither wholly reflective nor precisely one of the other three types mentioned, Dewey attempts further to articulate the tenets central to reflective thought.

Consider the example of a person walking on a warm day (Dewey, 1933). The sky is clear on last observation, and the person walks on enjoying the day. Suddenly she perceives a drop in temperature, and the possibility that it might rain pops into her mind. Looking up she sees a dark cloud, and then quickens her steps. What in this situation can be referred to as thought? Noting the coolness and walking are activities not usually referred to as thought. However, the likelihood of rain is something that is suggested. This suggestion or possibility is the idea, the thought. "If it is believed in as a genuine possibility which may occur, it is the kind of thought which falls within the scope of knowledge and which requires reflective consideration" (Dewey, 1933, p. 10).

A similar situation occurs when one looks at a cloud and is reminded of a human face or a shape of an animal. Thinking, both in the case of
belief that the cloud indicates that it might rain and that the cloud brings to mind a face, involves first noting or perceiving a fact. Following this perception is the making of a connection between the thing perceived and that which it brings to mind, something else that is not observed but that is suggested by the thing seen. While it is true that in both cases one thing brings another to mind, the two cases of suggestion differ in an important way. One does not believe the face suggested by the cloud is really a face; one does not consider at all the probability of its being a fact. The threat of rain, however, presents itself as a real possibility. Said differently, one does not regard the cloud as meaning a face, but as merely suggesting it. One does, though, consider that the coolness may mean rain; not only is rain suggested, but also it is indicated by the clouds. Both the face and the rain are suggestions of something coherent, but they differ over whether they suggest and indicate a coherence that is real as opposed to apparent. "In the first case, on seeing an object, we just happen as we say, to think of something else; in the second, we consider the possibility and nature of the connection between the object seen and the object suggested." The perceived information is regarded in some way as the ground or basis of belief. That which is suggested is seen as possible based on "the nature of the connection between the object seen and the object suggested" (Dewey, 1933, p. 10).

This signifying or indicating function, whereby one thing is a sign of another, leading one to consider how far the existence of the one may warrant the belief in the other, is the central factor in all reflective or distinctively intellectual thinking. That is not to say that
reflection is identical with recognizing the mere fact that one thing indicates, means, another thing. Rather, reflection begins when one starts to inquire into the reliability or the worth of any particular indication. When one searches for the guarantee that the existing data really point to the idea that is suggested, one is engaging in reflective thought. One is trying to justify the belief that the drop in temperature and the dark cloud are indicative of rain.

Reflection then implies that one believes something not of its own accord, but rather due to its relation to something else, that something else acts as the grounds, evidence, or proof of our belief. At one time one actually feels the rain; at another time one concludes that it has rained from the appearance of the ground and the pavement or thinks that it is going to rain because of atmospheric conditions. One may also be unsure of what one sees or perceives. One then hunts for clues, accompanying facts that will serve as signs or indications of what one is to believe.

"Thinking, for the purposes of this inquiry, is accordingly defined as that operation in which present facts suggest other facts (or truths) in such a way as to induce belief in what is suggested on the ground of real relation in things themselves, a relation between what suggests and what is suggested (Dewey, 1933, p. 12).

A cloud suggests a face or an animal figure, it does not mean the face or animal, because there is no tie between what is seen and what is suggested (except perhaps, in the imagination). Ashes, on the other hand, not only suggest that there was a fire, but they indicate there has been a fire, because genuine ashes are produced only by combustion. The ashes are evidence for believing in something else, that there was a
fire. This objective connection, the link in actual things, makes one thing the ground for believing in something else. Beliefs then, do not simply rest on inference but on the "surest level of assurance" (Dewey, 1933, p. 1).

Doubt and Inquiry in Reflective Thinking

To this point reflective thinking has been set off from other types of thought. In so doing, what appear to be essential elements in reflectivity that may or may not be found in other senses of 'thinking' have been discovered. These include an orderly chain of mental events, an end toward which that chain proceeds, and the reliance upon grounds for holding beliefs. In line with these general characteristics, the need for continued inquiry into the nature of the perceived connections between an event and that which the event seems to signify was elaborated upon. Further consideration of reflective thinking, in distinction from other operations to which the name of thought is applied, is necessary, however.

Every cognitive activity, including reflective thinking, begins in a state of doubt, perplexity, or mental difficulty, and proceeds through an act of searching, inquiring, in an attempt to gather material that might resolve the doubt or perplexity. To explain these two aspects of reflectivity, let us return to the threat of rain illustration, in which a person is out walking on a sunny day and suddenly experiences a drop in temperature and the appearance of black clouds. The shock of the coolness, because it was unexpected, generated confusion and the
suspension of belief, at least momentarily. The abrupt change in
temperature created a problem. This problem, albeit slight and
commonplace in character, challenges and perplexes the mind so that it
makes belief uncertain; a genuine question occurs because of a sudden
change in the experience.

To bring recognition to the facts that will answer the question, the
person engages in activities such as turning the head and lifting the
eyes to scan the sky. The facts were perplexing as they first presented
themselves, in particular the drop in temperature; they suggested,
however, clouds blocking the sun. The act of looking was an attempt to
discover whether the suggestion of clouds was accurate. While it may
seem forced to use looking, an almost automatic reaction, as an act of
inquiry, if one is willing to generalize our conceptions of mental
operation to include the ordinary or what is thought of as trivial along
with higher mental functioning, then one can refer to the act of looking
as one illustration of inquiry. For the purpose of the act is to bring
facts to mind that enable the person to come to a conclusion on the
basis of evidence. Therefore the act of looking was deliberate and
performed with the intention of getting an external basis to confirm or
refute a belief. The act of looking exemplifies in an elementary way the
operation of "hunting, searching, inquiring, involved in any reflective
operation" (Dewey, 1933, p. 13).

There are many other illustrations where reflection is aimed at the
discovery of facts that will serve as the grounding or warranting of a
belief. Consider Dewey's (1933) example of one traveling in an
unfamiliar area and coming to a branching in the road. Having no sure
knowledge to fall back upon, she hesitates. Which road is right and how will the choice be made? The alternatives are blindly and arbitrarily to take a course, trusting luck for the outcome, or to find evidence for the conclusion that a given road is right. Any attempt to choose by thinking will involve inquiring into other facts, whether brought to mind by memory or by observation, or both. She must somehow search for evidence that will support her belief in one road or the other, allowing her to make an intelligent choice. She may search the horizon, looking for signs or hints. She may try to improve her vantage point by climbing a tree. Her reflection and behavior is nonetheless aimed at the discovery of facts that serve the justification of her suggestion.

The previous illustration provided by Dewey may be generalized. Thinking begins in situations that resemble this "forked-road" metaphor, in situations which are marked by ambiguity and which present a dilemma and propose alternatives (Dewey, 1933). As long as activity glides smoothly along, there is no need for reflection. Encountering a difficulty, an obstruction to one's way of reaching a belief, however, brings one to a pause. One then tries to navigate to find additional facts, gets a more commanding view of the situation, and decides how these facts relate to one another in order to find an optimal solution.

This type of thinking is regulated by its purpose. The demand for "the solution of a perplexity is the steadying and guiding factor in the entire process of reflection" (Dewey, 1933, p. 14). Where there is no problematic situation suggestions flow at random and one sees the first type of ordinary thinking described (stream of consciousness). If the flow of suggestions is dictated simply by their agreeableness or their
relation to some internal imaginative or fanciful purpose, one sees the 
second type (successions of imaginative episodes). However, the 
existence of an ambiguity to be resolved, a question to be answered, 
creates the end-in-view that provides structure for the inquiry 
process. Every suggestion then, is tested by its reference to the 
pertinence of the problem at hand, and this reliance on the match 
between the suggestion and the desired end actually controls the nature 
or type of inquiry that must be undertaken.

A traveler whose end is the most beautiful path will 
look for other signs and will test suggestions on 
another basis than if he wishes to discover the way 
to a given city. The nature of the problem fixes the 
end of thought, and the end controls the process of 
thinking (Dewey, 1933, p. 15).

The Process of Reflective Thinking

There is now enough information so that more specific analysis of 
the complete act of reflective thought is possible. Reflective thinking 
should be viewed as a process involving a pre-reflective situation and a 
post-reflective situation. In between these two situations or states 
are five different phases or aspects of reflective thought. The five 
phases represent only an outline of the aspects of reflective thought. 
There is no strict hierarchy to the five phases and the length of time 
spent in each phase varies, depending on the nature of the problem and 
the individual's knowledge and skill. There are however, particular 
characteristics of the phases of the reflective thinking process. The 
following is a concise description of the characteristics of the phases 
in the pre-reflective/post-reflective process.
Pre-reflective State: Before reflection begins there is a felt motive. An emotional quality invades a situation which is distinctively different from the quality that is experienced when a situation appears to be proceeding smoothly. The quality is marked by a sense that something is vague or wrong and is accompanied by a feeling of displeasure with the incoherence.

Suggestion: After experiencing incoherence, the difficulty, the tendency to act usually continues and suggestions arise as to what to do. Often many suggestions pop into one’s head without regard to their consequences. However, if a motive state is to grow into reflective thought then one needs to suspend the desire to act impulsively and to consider the responses to the given incoherence. The current action being taken needs to change and to take the form of an idea or a suggestion based on the elements that comprise the difficulty. To Dewey (and to Meyer), the pre-reflective state is pre-cognitive; cognition begins in the form of reflective thought when one recognizes that action needs to be suspended (Hoover, 1984). The inhibition of direct action is a hesitation that is necessary to reflective thinking. The suggestion phase of reflective thought, then, concerns what responses an individual makes to the pre-reflective phase.

To illustrate the suggestion phase, imagine someone hanging a picture on a living room wall. As she pounds the nail on which the picture will hang, she inadvertently hits her thumb with the hammer. The first suggestion is to hit the wall with her hand in anger. This impulse would in no way serve to resolve the incoherence (pain) that gave rise to the suggestion, however. Other suggestions would no doubt
arise, one of which, perhaps, being to soak the assaulted thumb in ice water. In the later phases of reflectivity one evaluates suggestions arising from the pre-reflective state.

**Intellectualization:** During this phase of reflective thought the situation becomes more defined. Instead of a felt difficulty, one more clearly articulates the problem through observation and analysis of the nature of the incoherence. There is a "process of intellectualizing what at first is merely an emotional quality of the whole situation" (Dewey, 1933, p. 109).

In accurately interpreting or defining the situation, the problem becomes conceptualized and determined. In other words, the indeterminate situation becomes a determinate situation because the problem is conceived in such a way that further reflection can occur. Through a process of observation and analysis of data, matching suggestions to the situation at hand, the nature of the problem unfolds.

The way in which the problem is conceived decides what specific suggestions are entertained and which are dismissed; what data are selected and which rejected; it is the criterion for relevancy and power of hypotheses and conceptual structures (Dewey, 1938, p.108).

The focus here is on the external situation and what it is about that situation that creates incoherence. Dewey's emphasis on the transaction between the person and the environment, between the inner psychological processes and the external logic of the experience at hand, is clear in the move from suggestion to intellectualization. As one proceeds through the stages, this back and forth movement and examination between the psychological and the logical will be more clearly explicated.
The Guiding Idea, or Hypothesis: Once the problem is brought into focus, an hypothesis regarding the action needed to resolve the original difficulty can then be generated. In this phase, possible relevant solutions are suggested. According to Dewey, the possible solutions are in the form of ideas. He defines ideas as "anticipated consequences (forecasts) of what will happen when certain operations are executed under and with respect to observed conditions" (Dewey, 1938, p. 109). Said differently, the suggestions or images which arise in the mind as possible solutions now have a point of reference, the observed conditions against which the probability of their adequacy might be assessed. A suggestion or image becomes an idea for a solution when it is "examined with reference to its functional fitness; its capacity as a means of resolving the given situation" (Dewey, 1938, p. 110). The idea, evolving from suggestion, then becomes the guiding factor to further the reflective process so that an optimal solution to the problem will be reached. What was viewed as possibility now can be viewed in terms of probability.

Reasoning: In the phase of reasoning, narrowly defined, one begins to develop the meaning-contents of ideas in relation to one another. In other words, each idea as a probable solution to the initial incoherence is examined in light of its particular consequences. In the previous phase suggestions become ideas when they are consciously brought to bear on the problem. In the reasoning phase the ideas are scrutinized for meaning which is most relevant to the difficulty at hand. For example, if one uses the first hypothesis, she may expect particular consequences, or she may see that additional information is needed. If
she takes a different hypothesis, she anticipates different consequences. On the basis of a survey of the relation of meanings between and among elements of this act of reflective thought she decides which hypothesis to test in action. Dewey notes that "through a series of intermediate meanings, a meaning is finally reached which is more clearly relevant to the problem in hand than the originally suggested idea" (Dewey, 1938, p. 112). The function of the reasoning phase then, may be seen as grounding the guiding idea or hypothesis and examining meanings so as to determine whether more observation and analysis is needed to optimally resolve the incoherence. The result is an effective hypothesis to be tested in the next phase.

**Testing:** In this phase some kind of test through overt action serves either to confirm or to reject the hypothesis. This may occur either by direct observation of existing conditions or by experimentation, where conditions are deliberately arranged to verify and test the problem and proposed solution.

If one of the hypotheses works out, the indeterminate situation becomes a determinate one in which specific action can be taken. If verification does not happen, then reflective thought must be redirected toward a different hypothesis. Dewey (1933) emphasizes that when the reflective thinking process has been used, failure to verify an hypothesis is not "mere failure." Failure, to the reflective thinker, is illustrative. The mistakes or errors made are indicators as to what further observations may be needed and what changes should be introduced in the working hypothesis. The outcome of this phase, then, is the
complete establishment of coherence--a problematic situation has become resolved and clarified.

**Post-Reflective Phase:** When the incoherence, the doubt, has been dispelled and an idea has acquired greater understanding and meaning for the individual, the post-reflective situation is experienced. During this state there is a sense of mastery, satisfaction, or enjoyment. A situation has been dealt with in such a way that it is now meaningful to the thinker. The sense of 'meaningful' is related to the fact that the conclusion of reflective thinking is warranted in some significant way. Reflective thinking involves predicting, forecasting, or anticipating possible future experience, based on empirical connections arising out of the testing phase. It is because of the notion of 'warrantability' that the conclusion of reflective thinking resolves the incoherence of the pre-reflective state. The information of the situation has been comprehended, understood, learned. This "means that various parts of the information acquired are grasped in relation to one another--a result that is attained only when acquisition is accompanied by constant reflection upon the meaning of what is studied" (Dewey, 1933, p. 137).

**Summary**

Dewey views reflective thinking beginning at the point at which routine action is disrupted. One then must pause and consider alternatives to the routine. These alternatives are examined with respect to the facts of the matter to define the problem more clearly. With the problem in better focus, hypotheses are generated and their
ramifications examined. The culmination of the reflective process is acting on one of the hypotheses, in an attempt at verification. Should the hypothesis tested be verified, the state of perplexity is resolved and coherence restablished. Action can proceed with new and deeper understanding of one's situation.

The process of coming to know centers on the transaction between the person and the environment for Dewey. In other words, his is a theory that constantly stresses the interplay between the "psychological" and the "logical". The interplay begins in reflectivity with the shift from suggestion to intellectualization. The immediate, spontaneous suggestions that pop into the head (the psychological) are compared in intellectualization against the objective elements (the logical) of the problematic situation.

As one proceeds through the stages, this back and forth shifting between the logical and the psychological continues. The guiding idea (hypothesis) is constructed out of the suggestion/intellectualization interplay. Reasoning (psychological and logical), in terms of projected outcomes or extensions of the hypothesis, involves an imaginative act in which ideas are scrutinized for meaning that is most relevant to the situation at hand. Finally, testing the hypothesis in the world (the external or logical) is a temporary culmination of the psychological/logical transaction. If the hypothesis is supported, one's conclusion—in terms of the post-reflective state—can be held as warranted and inquiry proceeds in new and expanding directions. If not, inquiry proceeds by formulating and testing new hypotheses, seeking warrant and predictability.
Reflective thinking, for Dewey, is an intentional act of creating meaning, grasping the previously unrecognized relationships between and among elements of problematic situations. One is consciously trying to make sense out of a confusing, vague experience. In reflective thinking there is a reconstructed logic for coming to know, for establishing coherence. The structure and stages of that process, along with that upon which one focuses in reflectivity (the problematic situation), are reasonably well described in Dewey. What is not so clearly rendered is the content or information with which one thinks. Here Polanyi makes a critical addition to the unfolding model of cognition and coming to know. His concept of tacit knowledge is essential to the understanding of the content of reflectivity, or of thinking in general.

Reflective thinking, then, is a process designed to resolve a problematic situation; it is an attempt at changing what is first perceived as disorganized and incoherent into something orderly and that is perceived as coherent. One begins with the feeling of vagueness and confusion and imagines that there must be a clear rendering somewhere. The process of reflection is designed to fill the gap between the experience of unease and the assumed state of resolution.

In the next chapter, Michael Polanyi is employed to address the content or information with which one thinks. For Polanyi, acquiring a skill of any type, sensory, kinesthetic, or cognitive, is essentially a task involving achieving coherence. To find the problem in the first place is an act of discovery, creativity. Once the problem is found, the task becomes the solving of the problem, and progress towards the
mastery of the problem bridges the gap between the initial state of incoherence and the state of resolution.

In the work of Michael Polanyi we gain insight into features of coming to know not apparent in Dewey or in Meyer. In particular, through his concept of 'tacit knowledge', we can begin to see how information is organized and reorganized, and how it is made available for use. The next chapter will explore Polanyi's notion of 'tacit knowledge' as it relates to establishing the perception of coherence.
CHAPTER IV
TACIT KNOWLEDGE

In Meyer one finds that the human organism seeks coherence. In this tendency to seek coherence, the brain appears to function in the organizing of behaviors it assembles, preferring coherent to incoherent assemblies. Dewey adds to this general human tendency a process, an intentional method by which the person reorganizes and reconstructs experience such that incoherent, problematic situations can be transformed into optimally coherent, resolved ones.

In Dewey, the situation upon which one reflects is well-described and relatively easy to understand. The focus of any act of reflective thinking is always the problematic situation, the barrier to action that creates the pre-reflective state (Dewey, 1933, 1938). In addition, the phases or steps of the process are well-specified and explained (Dewey, 1933, 1938). What is not so clearly defined is the content or information with which one thinks. Here Polanyi, through his notion of tacit knowledge, is particularly enlightening.

This chapter begins with a general discussion of Polanyi's theory of tacit knowledge, followed by the structure, content, and dynamics of tacit knowing. By providing this overview of Polanyi, the content of experience, and also what happens once a coherent act is formed, can be more fully understood. Knowledge that is held tacitly makes up the storehouse of resources that is applied to problematic situations.
(Broudy, 1979). The purpose of this chapter is to explain tacit knowledge and its related concepts in such a way that the general process of meaning-making so central to this study might be more adequately addressed. With this foundation laid, it will then be possible in Chapter V to explore the neurophysiological research relevant to the emerging model.

Polanyi's Theory of Tacit Knowledge

Dewey presents the goal of reflective thinking as the resolution of a problematic situation. The problem is experienced when behavior is interrupted by some perceived incoherence, some disruption of habit; and the problem is refined and made more explicit through intellectualization. The goal of coherent resolution is achieved by filling the space, through the various stages of reflective thought, between the recognition of incoherence and the ultimate resolution of that incoherence. For Polanyi, coming upon the actual problem is an act of creativity and discovery, in that it involves seeing something that at present is hidden. The knowledge that a problem exists is knowing things that are as yet unspecifiable, "a knowing of more than you can tell" (Polanyi, 1969, p. 131).

Our awareness of the unspecifiable, whether it be awareness of particular elements related to a problem, or to the illusive coherence of the problem itself, is precisely the "incipient knowledge" that drives one to gaining validation of that knowledge. It is this driving
force of incipient, or hidden, knowledge that gives a problem its power to guide inquiry. For Polanyi, what is normally referred to as knowledge is the same as the knowledge of a problem. He sees knowledge as a process or an activity and not as a static commodity.

   Indeed, as the scientist goes on inquiring into yet uncomprehended experiences, so do those who accept his discoveries as established knowledge keep applying this to ever changing situations, developing it each time a step further. Research is an intensely dynamic inquiring, while knowledge is a more quiet research. Both are ever on the move, according to similar principles, towards a deeper understanding of what is already known. (Polanyi, 1969, p. 132)

   Polanyi’s theory of knowing relates to both types of knowing--the dynamic and the quiet. He sees the problem of explaining knowing as lying in how one justifies what one claims to know, in spite of the fact that much of the contents of knowing is at times unspecifiable. By employing the concept of ‘tacit knowledge’, and its related notions of ‘subsidiary’ and ‘focal’ elements, Polanyi’s account of coming to know is explored.

   According to Polanyi (1967), people know more than they can tell. For example, while one knows a person’s face and recognizes it among a myriad of faces, one often cannot tell how recognition is achieved. Most of that knowledge is hard to put into words. The police have developed a method by which one can communicate this information. They have made up a collection of pictures showing different mouths, noses, and other facial features. From these a witness selects the particulars of a face, and the pieces can then be put together to form a fairly good likeness of the face. This suggests that one can communicate knowledge
of a face, provided she is given adequate means for expressing herself. However, the use of the police method does not change the fact that she did know more than she could tell at one point. Furthermore, one can recreate the face only by knowing how to match the features recalled with those in the collection, and often cannot tell how this is done.

People who play the game "Trivial Pursuit" often experience this same phenomenon and have probably been taken by surprise that they know the answer to a particular question. It is likely that they were totally unaware prior to the asking of the question that they possessed that element (answer) in their repertoire of experience. The answer just seemed to pop into their head.

Polanyi refers to these past experiences as a repository of learned elements which rise to consciousness in order to deal with a problematic situation (Hoover, 1984). In other words, past experience may be viewed as tacit knowledge. This knowledge is information that is tacit to, but dependent upon, focal awareness of an explicit problem. Tacit knowledge is information that one has gained or learned without being aware of that learning. In Polanyi's scheme, tacit knowledge is closely linked to the Gestaltist notion of perception, that one perceives the whole of something by integrating awareness of its particulars without being able to identify those particulars. Polanyi (1975) takes the Gestalt notion further, viewing perception as an act of tacit inference aiming at a correct interpretation of the traces made in the body by external objects. He suggests that the act of perception of the whole results from the integration of experience into a particular form. This
structuring of information into a particular shape or form is the creation of meaning (Polanyi, 1967).

Polanyi refers to meanings as coherences, suggesting that they are configurations of parts into wholes. "We accept certain meanings by deliberately merging our awareness of specific particulars into a focal awareness of a whole" (Polanyi, 1967, p. 57). When focusing on a whole there are the particulars making up the whole and the whole itself, even though one is not conscious of these characteristics of the experience. For example, the more one stares at someone's face the more aware she is of the specifics of that face—the color of the eyes, the hair, and so on. The same is true of the participating particulars; when one begins to look at the color of the eyes, the hair, and so on she begins to create or recognize a face.

According to Polanyi, meaning is made by establishing a coherent relationship between the parts and the whole. This establishment of a coherent relationship happens in two ways for Polanyi. In one case, a collection or set of particulars represents or stands for a given whole. The features of a face stand for and are a part of an existing whole—the face itself. Meaning is made when the preceiver is able to connect parts to whole. The problem is one of "recognizing" that the features of the face represent a singular person or face. Polanyi refers to this type of meaning as "representative" or "denotative" (1962, p. 58).

In the second type of meaning making, the "existential", meaning is hidden and can be discovered only after the comprehension of the particulars (Polanyi, 1962, p. 58). For example, in studying anatomy
one begins by examining parts of the body. The purpose in studying the parts is to arrive at an understanding of how the body works as a whole. Another example involving the body is the study of the various systems—digestive, endocrine, and so on—in terms of their relation to the body as a whole. In either case, meaning is made by seeing the functioning of the parts or the systems in the context of the whole body. Rather than parts denoting or representing the whole, parts have a functional relationship to the whole, and that relationship is context-bound.

In either type of meaning making—denotative or existential—there is an alternation of analysis and integration, of an emphasis on the parts and then on how those parts form the whole, that ultimately deepens understanding of both the parts and the whole. At the basis of this understanding is the recognition of order, or "certain standards of coherence" (Polanyi, 1962, p. 63).

Every kind of human knowing, ranging from perception to scientific observation, includes an appreciation both of order contrasted to randomness and of the degree of this order. (Polanyi, 1962, p. 38)

Perception, according to Polanyi (1969), is the most elementary form of human knowing. The pattern that the act of perception possesses is the structure of tacit knowing, and the process by which perceptual information becomes tacit is basically the same as that by which all other knowledge (e.g., motoric, scientific, technological, and artistic) is discovered and made available for future use. By examining the logic of perceptual integrations, insight may be gained into the logic of the discovery of other knowledge.
In sum, through Polanyi's concept of tacit knowledge it can be seen, as in Meyer and in Dewey, that humans are concerned with a comprehension of order, of organization. Meyer presents a theory that suggests a biological tendency to seek coherence, Dewey's notion of reflective thinking is a cognitive process directed at the achievement of coherence, and Polanyi suggests that all human acts of knowing involve an integration of information into a whole which results in the quality of the condition that possesses coherence.

As all of these theorists present the idea that knowledge comes from the integration of information, they also recognize that disorganization is a necessary component of coming to know. Meyer's theory presents the phenomenon of reactive inhibition, a neurophysiological process that dissolves the coherence of an act; Dewey discusses a felt emotional quality, such as confusion or doubt, that motivates one to think through and resolve a situation; and Polanyi hints at the motivational force behind knowing with his idea of tacit knowledge. The next section examines the structure of tacit knowledge. By adding the work of Polanyi to that of Meyer and of Dewey more insight is gained into the formation of wholistic mental properties which are central to the unfolding model of this study.

The Structure of Tacit Knowing

The basic structure of tacit knowing involves three components: the first term, or the subsidiaries; the second term, or focal target; and the third term, the knower or person. The subsidiaries are the parts of
the whole to which the person is attending; the focal target is the whole and is the result of the integration of the subsidiaries; and the person is the knower whose task it is to integrate subsidiaries into focal target (Polanyi, 1975, p. 38). Polanyi uses many terms interchangeably for convenience and clarity, the reader should feel free to substitute the words "parts" and "whole" for "subsidiary" and "focal", respectively. Tacit knowledge, according to Polanyi (1975), comes from the interaction of this triad and from the relation created by the knower between the first and the second terms.

To clarify what Polanyi sees as the structure of tacit knowing, imagine viewing a distant object through binoculars. When one looks through binoculars he sees one image, even though he is looking through two different lenses and eyeing two different images. One eye looks at an object through one lense and the other eye looks at an object through a different lense, each producing its own retinal image. But he focuses his attention on the combined image; he sees the two images only as they bear on the combined image. In Polanyi's terms, he is focally aware of the combined image by being subsidiarily aware of the two separate retinal images. In this example the retinal images resulting from neural traces are the first term or subsidiaries, the combined image is the second term, and the relationship between the two terms is created by the knower, the third term. This example also includes the three aspects of tacit knowledge that result from the relationships and interaction between and among the first, second, and third terms.
One aspect of tacit knowledge - the functional.

The relation between the first and second terms, subsidiaries and focal target, actually involves two types of knowing or awareness, an awareness of the subsidiaries and an awareness of the focal target. One knows the first term only by relying on awareness of it for attending to the second. One experiences, knows, the separate retinal images by relying on them to form the combined, focal image. They are the grounds for tacit knowledge. Polanyi refers to this as a functional or "from-to" relationship because the knower moves from one to the other, integrating the subsidiaries into a focal target. This is how one comes to know the subsidiaries without being able to identify them.

This functional, from-to relation of subsidiaries to the focal target also frames knowing or experiencing of the focal target. One knows the focal target by bringing subsidiary knowledge to bear upon it. The retinal image is integrated into a single focal image and that image is known as a result of the integration of the subsidiaries.

Using the binocular image example, then, it can be seen that the from-to relation of subsidiaries and focal target paves the way for knowledge of both terms. The knowledge of the focal is a result of the knower's integrating of the subsidiaries and the knowledge of the subsidiaries is determined by the role they play in integration into the focal target. The knowledge gained about both the subsidiaries and the focal target is a result of their functional relationship to one another. From-to knowing is thus knowledge that results from this functional relationship (Polanyi, 1975). Both the subsidiaries and the focal come to be known, though differently, as a result of this
functional or from-to relationship. Polanyi sees the functional relationship as the first aspect of tacit knowing.

A second aspect of tacit knowing - the phenomenal.

In coming to know the subsidiaries and the focal via their functional relationship, a change occurs in both terms. By attending from the first term to the second there is a transformation in the appearance of both. Polanyi refers to this as an integrated appearance or a coherent entity, meaning that now the focal target acquires different dimensions and characteristics such as size, shape, and color. The once disparate subsidiaries become integrated as the isolated parts merge into the appearance of the whole (Polanyi, 1969). Not only, then, does one come to know both the subsidiaries and the focal through their functional relationship, but their actual appearance changes as a result of the integration. Retinal images, once they are combined into a focal target, gain new meaning and make sense in ways different from one's experience of them prior to integration. Similarly, perception of the focal target, in this case the single image, deepens and changes, becoming three dimensional and set in a spatial context. This change in appearance alters and deepens knowledge of each, and Polanyi refers to this as the second aspect of tacit knowing - the phenomenal.

A third aspect of tacit knowing - the semantic.

So far the functional and phenomenal aspects of tacit knowing have been addressed; but there is also a third aspect of significance in the
relation of the two terms of tacit knowing which combines the functional and phenomenal aspects. Polanyi refers to this as the semantic aspect of tacit knowledge, and states

And finally, we may regard the appearance of a perceived object with constant properties as the joint meaning of the clues the integration of which produces that appearance. Such is the semantic function of tacit knowledge (1969, p. 145).

The semantic relation is established by integrating subsidiaries into a focus. The subsidiaries in tacit knowing, according to Polanyi, bear on a focal target and gain their meaning from that on which they bear. The meaning of the subsidiaries, then, is the focus. In other words, a coherence is established because the meaning of its parts have been revealed. The meaning of the parts, the separate retinal images in the binocular vision example, changes in character along with the phenomenal change discussed in the second aspect of tacit knowing. They no longer carry the same information as before integration; their meaning is the focal target on which they are brought to bear. It is this changed or enhanced meaning that Polanyi characterizes as the third aspect of tacit knowing--the semantic aspect.

The changed, enhanced meaning that flows from tacit knowing--its semantic aspect--comes about in at least two ways, according to Polanyi. He labels them "indication" and "symbolization" (Polanyi, 1975, p. 74). The critical difference between the two types of (semantic) meanings lies in the relationship of self to the process of creating the relation at the heart of tacit knowing. In the case of indication, subsidiaries are integrated into a focal target by projecting the subsidiaries away from the self and into the focal. The
resulting integration is achieved without the self being carried into the focal. For example, in the case of perceiving a single image through binoculars, the separate retinal images, along with all the other subsidiary clues, are integrated into the focal, but the "self is never carried away" into this integration (Polanyi, 1975, p. 74).

As a contrast to indication, symbolization 

requires that the self be carried over into the integration. The symbol, as focal target, is not given meaning simply by integrating subsidiaries directed away from the self to the focal. Rather, one must dwell in the symbol and surrender aspects of the self--experiences and memories, for example--over to the focal. In this way, the symbol represents a "visual embodiment" of these aspects of the self (Polanyi, 1975, p. 75). Where indications are seen by Polanyi as "self-centered", symbolizations are seen as "self-giving" (Polanyi, 1975, pp. 74-75).

To illustrate symbolization, imagine how one comes to know a piece of music. When one hears a piece of music, subsidiaries in the form of auditory stimulation and other bodily sensations are brought to bear on the focal--the music. Yet, for the music to have meaning, much more most likely occurs. The self also integrates additional subsidiaries in the form of feelings, emotions, memory traces, and perhaps unconscious elements of self into the focal target. The music serves as an embodiment of "diffuse aspects of the self." Quoting Polanyi,

This visible embodiment serves as a focal point for the integration of these diffuse aspects of the self into a felt unity, a tacit grasp of ourselves as a whole person, in spite of the manifold incompatibilities existing in our lives as lived. (1975, p. 75)
Rather than being a self-centered integration, as is the case with indication in the form of binocular vision, making meaning of music illustrates the self-giving nature of symbolization. Not only does the music-as-symbol become integrated, but so too does the self become a part of, or become "carried away by" or "given to" the music (Polanyi, 1975, p. 75).

The semantic aspect of tacit knowing, then, comes about in different ways with different effects and demands on the self. While the self is the creator of meaning regardless of the process of integration, symbolization incorporates the self into the integration to a much greater extent than does indication.

To summarize, the characteristic feature of the subsidiary awareness is a function of their bearing on the focus of attention. The focal target into which the subsidiaries are fused brings out the joint meaning of the subsidiaries, or the semantic significance of the relation. This integration results in a new phenomenon, or sensory quality, that was not present in the appearance of the individual subsidiaries. Both the binocular vision example of indication and the music example of symbolization, then, serve as illustrations of the structure of tacit knowing, with its characteristic functional, semantic, and phenomenal aspects.

The Content of Tacit Knowing

Given the three aspects of tacit knowing discussed above—the functional, the phenomenal, and the semantic—one can deduce that tacit
knowledge is knowledge of the relationship created by the knower between subsidiaries and focal target. Put differently, parts and whole are joined by the knower into a comprehensive entity, and tacit knowing is the understanding of the meaningful relation that integrates parts into whole. One comprehends the comprehensive entity by relying on awareness of its particulars for attending to their joint meaning. In other words one knows something to the extent that the subsidiary clues called forth by the focal target have entered into an integrated meaning. It must be remembered that the relation of a subsidiary to a focus is formed by the act of a person who integrates one into the other. This relation lasts only as long as the person sustains the integration. The person can dissolve this relation if she shifts her attention from the object of focus to the subsidiaries or particulars that bear on the object of focus.

For example, if focus is placed on a spoken word as a sequence of sounds, the word loses the meaning to which one would normally attend. Or, when riding a bike or playing the piano, if one attends to the specific elements of these skills, performance of them can be paralyzed.

As a personal anecdote to illustrate the above point, one day when I was writing on the chalk board I started writing with my right hand. I am left handed and was therefore shocked by the fact that I was writing with my right hand. As soon as I began thinking about my right-handed performance I could no longer write with my right hand. I had started to attend to the particulars or the subsidiaries of writing as a physical skill and thereby dissolved the relation of the subsidiaries to the focal. I had paralyzed the performance of a skill by turning my
attention away from the meaning of my written words and concentrating instead on the motions that compose the skill of writing. This occurrence illustrates that focusing attention on the particulars of a comprehensive entity can weaken one's sense of its coherent existence; and moving in the opposite direction towards a fuller awareness of the whole tends to submerge the particulars into the whole.

One notices particulars, then, in two different ways. Either they are attended to 1) as isolated entities or 2) as integrated aspects of a comprehensive entity. When one focuses on a set of particulars as isolated entities, they are relatively meaningless compared with their significance when noticed subsidiarily within the comprehensive entity to which they contribute (Polanyi, 1969). In some instances it is possible to identify the particulars of a comprehensive entity, such as some symptoms of a clinically diagnosed diseased, but the identification of particulars is necessarily limited because they are experienced in relation to a whole and not as isolated elements.

As another example, certain prehistoric ceremonial grounds that were not recognized as such by people who walked on them for years were discovered from the air after the invention of the airplane. When the prehistoric site is seen from the air, the meaning of particulars is easily grasped. Such sites are then seen as comprehensive entities, while the particulars remain relatively meaningless at close quarters.

The illustrations of the different ways in which particulars are noticed highlight another feature of tacit knowing--the creative power of the knower. When one studies the topography of something, one starts by seeing the particulars in themselves, unaware of their relation to a
whole, and then proceeds to realize their spatial relation which represents their meaning. If one were to study neuroanatomy, one could easily identify the anatomical parts of the nervous system (the brain and the spinal cord); but their relation inside the body can be grasped only by a sustained effort of the imagination. Similar difficulties have to be overcome in achieving an understanding of a how complex machine works, or understanding all the aspects that are contributing to a significant problem of any type. Any complex spatial or functional relation is difficult to comprehend because first, there is always a "residue" of particulars left unspecified; and second, even when the particulars are identified, isolation changes their appearance to some extent (Polanyi, 1969).

There are, then, two complementary efforts aiming at the elucidation of a comprehensive entity (Polanyi, 1969, p. 125). "One proceeds from a recognition of a whole towards an identification of its particulars; the other, from the recognition of a group of presumed particulars towards the grasping of their relation in the whole" (Polanyi, 1969, p.125). These efforts are complementary in that they contribute to the same final achievement of establishing meaning, yet it is also true that each counteracts the other to some extent. When attending to the particulars the sense of the whole is temporarily weakened and when attending to the whole the particulars are lost, so to speak, because they are submerged within the whole. The advantage of these two processes is that the very act of dismembering a whole into its parts and the new integration of the parts adds more to the understanding of both the parts and the whole. So it seems that one alternates between an examination of the
parts and an integration of the parts into a whole. This analysis and integration leads to an ever deepening of understanding of a comprehensive entity.

One might employ the work of artists such as Georgia O'Keeffe to illustrate this back and forth movement to deeper meaning of both parts and whole. When she paints a tree she paints all the different aspects of the tree separately and only then does she paint an entire tree. She feels that after she has looked at and dwelled in the parts of the tree she can see and paint the whole tree better. Polanyi (1969, p. 125) uses the field of medicine as an illustration of this process of analysis and integration in order to comprehend a whole. A medical student begins to know a disease by learning a list of its symptoms, but only clinical practice can teach her to integrate the clues observed on a patient to form a correct diagnosis of the illness.

The mastering of a skill is also improved by alternate dismemberment and integration of particulars into a whole. Sportsmen, artists, or craftsmen profit from an analysis of each motion, followed by a skillful incorporation of the isolated motions into a complete performance, but this analysis of a skillful feat in terms of its constituent motions (its particulars) always remains incomplete. Just as when one views a prehistoric site at close quarters and the relation of these particulars to the whole is lost, the dynamic quality of a movement or a skill performed in its entirety is lost when one is analyzing or dismembering the skill or the movement into its particulars. "Only by turning our attention away from the particulars and towards their joint purpose, can we restore to the isolated motions the qualities required for achieving
their purpose" (Polanyi, 1969, p.74). But, because attention is focused on the movement as a whole, the particulars of this integration are unspecifiable. One must depend on the right "feel" of a skillful act and, according to Polanyi (1969), the actor alone can "catch the knack" of a skill; no teacher can do this for her.

To summarize, then, the content of tacit knowing is the meaningful relation established by the knower between parts and whole. One comes to know the whole through the integration of the parts, and the parts gain their meaning from their bearing on the whole. When focusing on the parts themselves, their integration into the whole, even the whole itself, is lost. Similarly, focusing on the whole submerges the parts. Yet, through the alternation between focus on parts (analysis) and focus on the integrated whole (synthesis), both parts and whole come to be known more fully and deeply. Meaningful relations, as the content of tacit knowing, are always acts of creativity and imagination on the part of the knower.

The Dynamics of Tacit Knowing

As stated in the preceding section, when trying to understand a comprehensive entity or situation or when trying to master a skill, one alternates between an analysis of the parts themselves and an integration of the parts into the whole. Polanyi (1969) suggests, in other words, that when attempting to know something, one is always doing something. Knowing and doing something always occur together, not in isolation.
For an example of a combination of skillful knowing and doing, one might return to visual perception. When looking through a pair of binoculars there is an interaction of all parts of the visual field in determining what is seen. But it is the active pupil and lens adjustment and the convergence of the eyes that fashion or shape the two retinal images into the one picture or image that is "seen". The combined image might actually be considered a mind/brain artifact. The perceived picture depends on the adjustment and convergence actions, as the messages received from the muscles adjusting the eyes are incorporated by one into the qualities of the perceived object. This perception is also co-determined by messages from other internal data, from the muscles which keep the body and head in its position, as well as by a wide range of memories. The internal data both guide the reflexes of the eye-muscles in shaping retinal images and control the evaluation in terms of perceptions of the sum total of relevant stimuli.

The capacity to see objects is a skill and is acquired by training, just as is the case with any skill. Further, one comes to know the object visually by the integration of all of these particular, internal actions. People seem to shape parts to the whole. The first time one looks through binoculars, one probably has to work fairly hard at adjusting to the two images such that one might use them to focus on the object viewed. Returning to Georgia O'Keeffe, there are not many who "see" the way she does. Yet somehow she has developed the skill of drawing the isolated parts of a subject in a manner that ultimately helps her to "see" and to draw the whole with much more feeling and
expression than would be the case without her artisite analysis of parts.

Here Polanyi's notion of knowing and doing as they relate to the structure of tacit knowing is quite evident. But something new has been introduced—the way bodily processes participate in perceptions, in the knowing and the doing. According to Polanyi (1967) the body is the ultimate instrument of all external knowledge, whether intellectual or practical. One is constantly relying on awareness of the body as it comes into contact with things outside for attending to these things. The body is the only thing in the world which is normally not experienced as an object; it is experienced always in terms of the world to which one is attending from the body. It is by making this intelligent use of the body that one feels it to be one's own and not a thing outside.

Returning to the idea of subsidiary and focal awareness may explain the previous notion by saying that one attends to external objects by being subsidiarily aware of things happening within the body. One is still dealing with particulars and the relation of them to a whole; but, when seeing an external object such as the single image through the binoculars, a major part of the set of particulars shaping the sight of the external object are internal actions and stimuli. In other words, one is attending from these internal processes to qualities of things outside (Polanyi, 1967). The particulars of this type of perception are being projected from inside the body into the space outside of it. One becomes aware of these internal actions only as she interacts with objects outside the body, and in this sense she is subsidiarily aware of
them. One comes to know one's body and its particulars, then, by being aware of it as one attends to things outside of it.

According to Polanyi, awareness of the body as it bears on the world is a paradigm case of subsidiary awareness. "We may say in fact, that to know something by relying on our awareness of it for attending to something else is to have the same kind of knowledge of it that we have of our body by living in it" (Polanyi, 1975, p.39). Further, it is the transposition of these bodily functions and feelings into the perception of things outside of or external to the body that seems to be the fundamental means by which one establishes meaning.

Looking at a subsidiary awareness of tools and probes as a condition in which they form a part of the body might help further explain this notion of employing the body as the primary meaning-making tool. The way one uses and comes to know a hammer or the way a blind person uses a cane is very similar to how one uses the body. One relies on the tool or the probe and does not handle or scrutinize these instruments as external objects. Instead "we pour ourselves into them" (Polanyi, 1969) and assimilate them as part of the self. When these tools are being used, one is identifying the self with them and is relying on them to attend to things outside of the self. One becomes aware of these instruments by excercising a from-to way of knowing.

For example, when a person uses a hammer, she feels the impact of the tool on her palm and fingers and uses this feeling to guide the hammer effectively. The feeling of the hammer, though, is a different awareness than the awareness that she has of the nail being driven into the wall. She is focally aware of the tool’s action on the object and
subsidiarily aware of the feeling of the hammer in her hand. The impact of a tool on the palm and fingers is unspecifiable in the same sense in which muscular acts such as the convergence of the eyes that fashion two retinal images into one single image are unspecifiable.

The effects of the tool are integrated in a way similar to that by which internal stimuli are integrated to form perceptions (Polanyi, 1969). In this sense effects of the tool on the hand function as internal stimuli, and the tool functions as an extension of the hand. The same is true of a probe, such as a blind person's cane. The cane is used to explore the environment and the impact made by the cane on the fingers is "felt" at the tip of the cane, where it hits external objects. The cane has become a metaphorical extension of the blind person's fingers, and therefore is used (as the body is) in order to create meaning of the environment. Because the cane is a "part" of the body, the feelings of it are functioning much the same as internal stimuli and are transposed or transformed into qualities that become the perception of things outside the body.

However, when one uses certain things for attending from them to other things, in the way in which one uses the body, these things change in appearance. Their appearance is modified by the things to which one is attending from them, "just as we feel our own body in terms of the things outside to which we are attending from our body" (Polanyi, 1967, p. 42). In this sense, when one makes a thing function subsidiarily, as the first term tacit knowing, one incorporates it into the body--or extends the body to include it--so that one comes to "dwell in" it (Polanyi, 1967). Interestingly, Polanyi (1967) discusses the notions of
indwelling and empathy and refers to the teachings of some of the German thinkers who postulated that indwelling, or empathy, is the proper means of knowing man and the humanities. He refers specifically to Dilthey, who taught that the mind of a person can be understood only by reliving its workings, and Lipps, who represented aesthetic appreciation as an entering into a work of art and thus dwelling in the mind of the creator. Polanyi felt that these are excellent examples of forms of tacit knowing, but added that indwelling is a more defined or precise act than is empathy and underlies all understanding and observations in science and art.

This conception of knowledge through indwelling allows one to examine how one learns something, how one comes to know. In order to learn something one must incorporate it into one's reality. By dwelling in something a person comes to understand that thing because he has identified himself with it. When one identifies oneself with something one has "interiorized" it and can then use it to attend from it to other things, just as one always uses the body. Therefore, interiorizing gives meaning and connection to external knowledge because one is not looking at the particulars in isolation, but instead one is aware of them in their bearing on the coherent entity which they constitute.

Polanyi clearly states that

...to attend from a thing to its meaning is to interiorize it, and that to look instead at the thing is to exteriorize or alienate it. We shall then say that we endow a thing with meaning by interiorizing it and destroy its meaning by alienating it. (1969, p. 146)
Here Polanyi brings home the idea that it is not by looking at things, but by dwelling in them, that one understands their joint meaning.

It is easy to illustrate how close scrutiny of the particulars of a coherent entity changes the meaning of that entity and how the conception of that entity is destroyed. If one repeats a word several times, attending carefully to the motions of tongue and lips and to the sound made, soon the word will sound hollow, alien, and eventually it will lose its meaning. Similarly, if a pianist concentrates his attention on his fingers rather on the playing itself, he can paralyze his movement. As a final example, if one tries to look at the particulars of someone's face rather than at the face as a whole, the face no longer appears as a coherent entity, but rather as a conglomeration of features or parts. One loses sight of the pattern of the face (physiognomy, Polanyi says) when focusing on only one aspect of it.

It is important to note, though, that one can recapture the meaning or the wholeness of something if once again one interiorizes the particulars. The word spoken again in its proper context, the pianist's fingers used again with his mind on the entire piece of music, and the features of the face viewed once more at a distance all come to life and recover their meaning and coherence.

The recovery of these coherences is never quite the same, however. The original meaning is somewhat changed and perhaps improved upon. Often the meticulous analysis or dismembering of something, which can kill one's appreciation for it, can also supply material for a much deeper understanding of it. "In these cases, the detailing of
particulars, which by itself would destroy meaning, serves as a guide to their subsequent integration and thus establishes a more secure and more accurate meaning of them" (Polanyi, 1967, p. 19). In the act of tacit integration, or the comprehending of a whole, one is participating feelingly in that which one is trying to understand. When one becomes aware of things as one is of the body, one interiorizes these things and make oneself dwell in them. The extension of the self into something develops new faculties in one; in fact, one's whole education works this way (Polanyi, 1969). It is the empirical relation that links life in the body to one's knowledge that allows one to establish meaning. This tacit integration links the inner world with the outer world so that knowledge can function subsidiarily and be brought forth focally throughout life.

The example that most clearly illustrates the notion of tacit integration is inquiry or, as Polanyi (1975) puts it, the "propensity to be puzzled." Suppose one is puzzled by an intricate piece of machinery or by the layout of a building. What one is searching for is an understanding of the machine or the building--an insight into them, but not an explanation of them. Such insight is a form of tacit integration. When one integrates the particulars of the machine or the building and brings out their joint meaning, the puzzling aspect is transformed into a lucid image. The puzzlement is relieved by an insight which is itself a meaningful integration of the parts of the complex entity.

Another personal anecdote might illustrate this act of tacit integration further. When visiting a high school to which I had never
been before, I was trying to find a particular room. I was quite puzzled by the layout of the school. I was then told that the first floor was in the shape of an eight and the second floor was shaped like a six. My puzzlement was instantly resolved because I could very clearly image the entire layout of the school. Using the eight and six mental configuration, I was able to bring subsidiary information to bear on my focal problem—the layout of the school. With the eight and six metaphor, I was able to find my way; I knew the school in a more meaningful and deeper way.

Such insight, according to Polanyi (1969), is a mental fact, like other focal targets, comprising a large number of subsidiaries. But this type of insight differs from the other focal targets that have been discussed (the single image seen through binoculars or the discovery of the environment with a cane), in that this focal target does not lie away from its subsidiaries but coincides in one's imagination with its parts.

It is the aggregate of its parts mentally seen as they are (or as we believe them to be). It signifies that the imaginative probing of a puzzling aggregate has established in it an intelligible coherence or meaning. (Polanyi, 1975, p. 54)

It is the case, then, that one can gain a deepened understanding of a focal target independent of whether that target lies in the world or in imagination. Subsidiaries are still brought to bear and the resulting integration is meaningful to the extent that it results in a coherent resolution of the original puzzlement over the target.
Summary

This chapter discusses Polanyi's theory of tacit knowledge, in an effort at further illuminating the process of how meaning is made. The chapter begins with a general account of 'tacit knowledge' as the backdrop for why, in Polanyi's words, "we know more than we can tell." The chapter proceeds through the structure, content, and dynamics of tacit knowing, with particular emphasis on how tacit knowledge, and its related notions of subsidiaries and focal targets, complement the work of Meyer and of Dewey.

There are a number of similarities between and among the three theorists related to the need to resolve problematic situations, marked by incongruity or incoherence, in ways that are perceived to be coherent. Where Meyer provides the neurophysiological underpinnings of the striving for coherence, and Dewey the process of reflectivity that serves as an intentional coherence-seeking act, Polanyi supplies needed insight into the source and nature of information with which one thinks. Put differently, one needs some knowledge with which to recognize a problem and to begin the reflective process of idea generation and testing. Tacit knowledge is that informational backdrop upon which one depends for usable knowledge, knowledge with which to think.

Tacit knowledge also is central to understanding what happens to the knowledge gained once reflectivity is brought to a temporary close with the post-reflective state. It is at this point that the new knowledge gained through reflective thinking becomes a part of one's tacit
repertoire, adding further to the usable knowledge at one's disposal. Once coherence is achieved, in other words, the new meaning made is added to the storehouse of resources that might be called out by new focal targets or problematic situations (Broudy, 1979).

Polanyi, then, both supports Meyer and Dewey in reinforcing notions such as coherence and incoherence and in paralleling the problematic situation with his idea of the focal target, and complements them by providing additional insight into the contents of thought. While he does provide, through his Gestalt conceptions, a "bridge between the higher creative powers of man and the bodily processes which are prominent in the operations of perception" (1969, p. 7), there is no neurophysiological evidence in Polanyi, nor for that matter in Meyer or in Dewey, for any of the above. The task of the next chapter is to review ERP research in an effort at gaining empirical leads and support for the theoretical conceptions found in Meyer, in Dewey, and in Polanyi.
CHAPTER V

EVENT-RELATED POTENTIAL RESEARCH

This chapter will review particular experimental paradigms that have been used to study mind-brain interaction. Specifically the chapter will include a brief history of research that has influenced current event-related potential (ERPs) studies with a focus on one ERP component, the P300. As stated in Chapter I, there is an assumed neurophysiological change in the organism that accompanies the establishment of coherence. Current ERP research has yielded a brain response, the P300, that appears to be indicative of the establishment of coherence. The purpose of this chapter is to explore the question of mental operations via investigations focusing on the P300.

The chapter begins with an explanation of ERPs and their relationship to mind-brain interaction. Following the ERP explanation, a brief history of the precursors to ERP research is given to put current research in historical context. The earlier research can be viewed as a substrate of current ERP research, providing it with its conceptual and interpretive foundations. The chapter then presents an overview of relevant research methods, including the behavioral procedures that are used in conjunction with recordings of the P300. Finally, a sampling of ERP studies that focuses on the appearance of the P300 from birth through maturity is reviewed. This review accomplishes
at least three purposes: (1) it illustrates the research methods and behavioral procedures mentioned above, (2) it demonstrates the wide variation of characteristics defining the P300, and (3) it provides an overview of the results of P300 research.

The P300 as an Event-Related Potential

The P300 is a computer averaged cerebral potential recorded from the scalp by an electroencephalograph (EEG). The most general question of interest is whether the P300 is a consistent reflection of a particular cognitive process or mental event; and, if so, what the nature of that event is. Since the P300 is subsumed by a more general category of brain wave activity, that of event-related potentials (ERPs), it makes sense to explain ERPs prior to delving into the specifics of the existence and significance of P300s.

Event-related potential (Vaughn, 1969) refers to a class or family of brain waves that are phasic in nature (Torello, 1984). They are potentials that arise from neuronal activity which is time-locked to a particular event. The ERP is a subcomponent of the EEG, an electroencephalographic measure of brain activity recorded by the use of scalp electrodes, and is associated with specific sensory, motor, or cognitive events. The ERP is obtained by taking a series of EEG epochs and averaging them to filter out the "noise" and retain the "signal" (Churchland, 1986). Since ERPs are generally smaller than ongoing EEG activity, the background EEG activity must be removed. The resulting
recordings, actually averages of multiple ERP epochs, are then displayed graphically. "An assumption is made that the ERP of interest will have a stable temporal relationship with the stimulus of interest over a number of trials" (Torello, 1984, p. 22). An example of EEG and ERP data is illustrated by Figure 1. (Insert figure 1 here.)

The reason that ERPs form the general class of EEG activity are of interest here is their potential for being associated with other mental operations. The suggestion from many ERP researchers is that these specific waveforms can be correlated with specific types of cognitive and subcognitive processes that take place in mind-brain interaction (Churchland, 1986). Scientists have already found that the early ERP components represent signal transmission of basic peripheral sensory stimulation.

ERP recordings are divided into early components (waveform patterns occurring up to 40 msec after the onset of a stimulus) and later components (those occurring after the 40 msec mark). Components are labeled according to time of peak latency (e.g., 200 msec) and by whether they are positive in polarity (often represented as downgoing on a recording) or negative in polarity (often represented as upgoing). For example, the P300 is a positive, downgoing waveform occurring 300 msec after the stimulus presentation and the N100 is a negative, upgoing waveform occurring 100 msec after the stimulus presentation.

There is a difference in the early and the late components. The early components are said to be stimulus bound; they occur whether or not a subject is attending to a stimulus and they are sensitive to the physical properties of the stimulus (e.g., intensity). These early
Figure 1. The Relationship Between Ongoing EEG and ERP's (Torello, 1984, p. 21)
waveforms, therefore, are called exogenous (produced from without) components, in contrast to the later components, such as the P300, which are usually called endogenous (produced from within) components (Sutton et al., 1967).

The endogenous components of the ERP are waveforms that occur 100 msec or more after a stimulus has been experienced. These waveforms are independent of the physical properties of the stimulus and are supposedly invoked by some form of cognitive processing resulting from the demands of the task or stimuli presented. The endogenous, or later, ERP components are also affected by factors such as age and health. Because the late ERPs are primarily influenced by internal conditions, they are seen as endogenous as opposed to exogenous components (John, 1963).

One of the most extensively studied endogenous components is the P300 wave. This waveform consistently occurs in ERP paradigms that deal with information processing (Donchin, 1983). A large P300 is reliably produced in studies that use what is referred to as the "oddball paradigm", experiments designed such that signals occur unexpectedly and provide task-relevant information (Tueting, Sutton, and Zubin, 1971; McCarthy, 1978; Donchin, 1979; Kutas and Hillyard, 1984). The oddball paradigm consists of conditions in which subjects view a CRT screen or receive auditory stimuli through a headset. During the experiment the subject is sequentially presented stimuli from two categories, one in which the stimuli occur with high probability, approximately 80 percent of the time, and the other category in which stimuli occur rarely or only 20 percent of the time. The subject then is required to count the
number of stimuli from either the frequent or the rare presentation. The oddball paradigm has many versions and includes concrete stimuli, such as auditory tones, or abstract stimuli, such as male and female names (Kutas, McCarthy, and Donchin, 1977). The P300 is also evoked in other experiments designed to deal with information processing (Donchin, 1983). The P300 is seen in the omission of expected stimuli and also when more complex stimuli are presented, for example, semantically congruent and strange sentences such as "I spread my toast with socks" (Picton, 1974; Kutas and Hillyard, 1980).

In order to understand the interpretation of this waveform, a review of research that influenced recent ERP studies, and more specifically, studies using the P300 is necessary.

Precursors to ERP and P300 Research

The experiments of the past that seem to have had the most influence upon recent ERP research are reaction time studies. Current experimental paradigms used in ERP research are very similar to the reaction time paradigms developed by the Dutch physiologist Franciscus Cornelius Donders in the 1860s.

The first reaction time experiments, which actually set the stage for Donders’ work, were invented by the famous physiologist Hermann von Helmholtz (Hearst, 1979). He was concerned with the rate of neural impulses and succeeded in measuring the speed of conduction in a frog’s motor nerve. He was also interested in measuring the rate of nerve
conduction in human sensory nerves and obtained a rough estimation of this speed with rudimentary techniques.

In 1861, Hirsch, an astronomer from Switzerland, continued research on the human factor involved in reactions to data (Hearst, 1979). Astronomers were concerned with the errors that were being made in observing particular astronomical events, such as the time at which stars crossed the meridian. The Hipp chronoscope was used by Hirsch to measure what he referred to as "the physiological time of the eye, ear, and sense of touch" (Hearst, 1979, p. 9). He obtained measurements and values of simple reaction time in which the stimulus and the response were predetermined. For example, a simple reaction time protocol would be pressing a key (the predetermined response) when a light went on (the predetermined stimulus).

In the mid-1860s Donders went beyond simple reaction time experiments by attempting also to measure the physiological time of mental processes involving discrimination and choice (Hearst, 1979). Donders developed the subtractive method in order to measure these mental operations. Donders' protocol was based on his reasoning that if an additional complexity in the form of choice or discrimination is added to a simple reaction time task, one could subtract the simple reaction time from the total time taken for the entire task. This remainder, then, was indicative of the mental processing time involved in a choice or discrimination task. Donders did find that this reaction time was at least 100 msec longer than simple reaction time and concluded that this difference was the time required for mental
operations needed in a task involving choice and discrimination (Hearst, 1979).

An important note is that Donders viewed mental processing serially, as a consecutive sequence of temporally related events flowing linearly to a conclusion. Not all researchers used the same conceptual framework to interpret reaction time studies. Wundt found reaction time results interesting and sometimes important in themselves, but he did not find them helpful in gaining precise measures of time of processing involved in such phenomena as attention, perception, association, and choice (Hearst, 1979). The Wurzburgians, such as Kulpe, Watt, and Ach, attacked the ideas of simple and complex reaction time and came up with the idea of preparatory set. In other words, they claimed that there are a priori assumptions (e.g., subject's attitude, determinants of the task) that were influencing these mental processes. In the 1880's and 90's Cattell and Lange used reaction time paradigms to look at individual differences (Woodward and Scholsberg, 1955). Lange developed the notion of the sensorial attitude and the muscular attitude. He suggested that a person's response was determined by whether he directed his interest to the stimuli or whether he thought about how he was going to respond motorically (Woodward and Scholsberg, 1955). A good example of this would be to think of a runner in the starting blocks. Does she first think about the gun going off or about how she will push off the blocks? In today's research we might ask, "To what is she attending?"

In current P300 or ERP research the same processes are being observed, but the reaction time measurement occurs wholly within the central nervous system. And just as the researchers of the past
have labeled their results as specific aspects of mental processes, we too are currently labeling the P300 as a component of cognition. The problem is that the P300 has been indicated in everything from intelligence, attention, and dementia to being able to predict leadership capabilities (Restak, 1979).

The following will be a presentation of selected P300 research, along with a summary of the data, concluding with suggestions as to what the P300 represents in this model of knowing and how that may be tested.

P300 Research Review

Because of the depth of P300 research this review will concentrate on the developmental aspects of this ERP component. These studies are chosen because they are examples of typical P300 paradigms and include a variety of subjects from infancy to adult. Although this review will include mention of the earlier and slow wave components of ERPs when discussing current research, the reader is referred to an extensive review of those components by Korman et al. (1978) or Torello (1984).

Before discussing the specific investigations, it is necessary to list procedures that were common to almost every experiment. If there were differences in experimental procedures that were specific to a certain study they will be noted; otherwise, these assumptions can be made:

1. eye movement was controlled by the use of UoE (upper eye, above eyebrow) and LoE (lower eye, infraorbital ridge) with reference to linked mastoids.
2. scalp sites were almost always Fz, Cz, Pz (Desmedt used in addition to those listed, C3, C4, F3 and F4).
3. the international 10-20 system was used to determine all electrode placements.
4. all EEGs recorded were amplified and computer-averaged.
5. waveforms were measured from baseline-to-peak or peak-to-peak (for example, N1 to P2). (Insert figure 2 here.)

From Infancy to Adulthood

Courchesne (1979) is one of the few people who has studied infants through adults. He is most interested in the late ERP components. He suggests that there are three different P300 waveforms that are indicative of cognitive processing: one that is maximal frontally (Fz area) and is elicited by novel, unrecognizable stimuli; one that is maximal parietally (Pz area) and is elicited by non-target, easily recognizable stimuli; and one that is maximal parietally but is elicited by target stimuli.

To test these assumptions Courchesne (1979) studied 24 subjects between the ages of 6 and 36 and 4-6 month old infants. The subjects viewed slides bearing the letter A (p = .76) or B (p = .12). Sometimes Bs were designated as targets and As were background; other times the reverse was true. The subjects were told to count the targets mentally. Interspersed (p = .12) were dim slides and novel slides. The dim slides consisted of letters C-Z with a lower luminance than the As or Bs. The novel slides were quasi-random, unrecognizable color
Figure 2. 10/20 Electrode Placement System

(Torello, 1984, p. 87)
patterns. The subjects were not told that they would see the dims or novels. The infants saw two faces; one 88% of the time, the other face 12% of the time.

Target stimuli (the infrequently presented stimuli) elicited P300s in all subjects. The P300 amplitude for targets was maximal over the parietal region for all subjects. The only age difference in the P300 waveform was that the latency decreased progressively from age 6 to age 36 (700 msec to 400 msec, respectively), with a corresponding decrease in reaction time (RT).

The novel and dim stimuli elicited different waveforms within different age groups. The infants' and children's ERPs to novels and dims were dominated by Nc and Pc waves (700 and 1,400 msec in infants with children's 300 and 400 msec earlier). In adults the targets elicited P300s that were maximal in the frontal area, but maximal in the parietal area for children 6-17 years of age. From this result Courchesne concludes that the emergence of a frontal P300 wave occurs at a later age in life. The dim slides, the easily recognized non-targets, did elicit parietal P300s in the older children and adults. The one aspect that did not change with age was the P300 waves to novel and dim targets. Those to targets were always higher in amplitude than to those to backgrounds.

When evaluating the amplitude changes with event repetition Courchesne found that in 6- to 8-year-olds, Nc and Pc amplitude decreased with repetition of novel and dim events. This finding suggests habituation. Children and adults showed no significant amplitude changes for target P300 waves across the first 16 events.
However, P300 amplitude to dim events decreased 40% across the first 16 dim events. It is interesting to note that Courchesne found complex P300 amplitude changes for novels in adults. At Fz, P300 amplitude decreased 42% across the first 16 novel events. At Cz, no significant changes emerged. At Pz, P300 amplitude increased 42% on novel events 5-8 as compared to events one through four.

The scalp distribution of P300 waves to novels, in adults changed with repeated presentations, becoming progressively more parietal with event repetition. Courchesne believes that this shift in distribution was the result of both decreased activity frontally and increased activity parietally. In contrast, P300 waves to targets and dims remained maximal at Cz and Pz.

In Courchesne's other studies using basically the same stimuli, he found similar results. In 1977 he studied young adults 18- to 28-years-old. The subjects viewed slides which represented task-relevant stimuli and non-target stimuli. The stimuli occurred as easily-recognized deviations from an on-going repetitive sequence. Courchesne (1977) was looking at scalp distribution and whether qualitative or quantitative aspects of the stimulus deviations, i.e. improbability or degree of physical contrast, were contributing to the elicitation of posteriorly distributed P300 waves.

In another study Courchesne found that P300 waves to novel or deviant non-target stimuli differ in their scalp distribution according to the stimulus content. Frontal P300 waves are elicited by non-target, unrecognizable stimuli. Posterior P300 waves are elicited by non-target, easily recognized stimuli. Posterior P300 waves are
elicited by any target stimuli and the P300 wave to target stimuli does not habituate.

In 1981, Courchesne studied 26 infants, 4- to 7-months-old. He did not find a long latency ERP wave of 300 msec or more. The infants saw sequences of slides consisting of random orderings of 88% of one woman's face and 12% of another woman's face. Both the frequent and discrepant events elicited Nc and Pc waves, (700 and 1,360- msec, respectively) in all infants. Unfortunately only 10 infants' responses were used for data. The other 13 infants either fell asleep or ripped the electrodes off during the testing. Nc amplitudes with a latency of 700 msec to the discrepant faces were higher than those to the frequent faces in every subject. The latencies of the Nc waves to the discrepant faces were longer than those to the frequent faces (752 msec vs 525 msec). In contrast, the amplitudes and latencies of Pc waves did not differ significantly.

Courchesne (1981) believes that the differential amplitude and latency responses of Nc waves implies that the infants were capable of remembering the frequently presented face from trial to trial and were capable of discriminating it from the discrepant, infrequently presented face. He suggests the infants looked longer at and preferred to see discrepant events.

According to Courchesne (1981) the Nc waves seem to be the earliest such waves to appear maturationally. They are nearly fully developed by 6 months of age and are prominent in middle childhood and wane by adolescence. In contrast, the Pc waves appear to mature more slowly,
being present in 6-month-olds, but not yet responding differentially to frequent and discrepant faces.

In a similar design with 3-month-olds, Hofmann et al. (1981) found the more infrequent of two striped patterns elicited a larger late positive waveform (300-600 msec) over the posterior region of the scalp. Kurtzberg et al. (1979) used a color discrimination task with 5-8-year-olds and also found a later positive component occurring at about 400 milliseconds. Hillyard and Kutas (1983) feel that these types of paradigms in which differential ERPs are recorded to familiar/unfamiliar or frequent/infrequent stimuli offer powerful approaches for analyzing perceptual and cognitive development in both normal and mentally deficient children.

More recently Strandberg et al. (1984) studied schizophrenic and normal children between the ages of nine and eleven. He used the Span Apprehension task, which involves the discrimination of a randomly placed target letter among distractors. This particular task has been used previously to discriminate between normal and schizophrenic individuals (Neale et al., 1969). The schizophrenic children produced small contingent negative variation waveforms (CNV--an expectancy waveform that is contingent upon two events) which were slow to develop and resolve as well as diminished amplitudes for N100, P300, and slow wave components (SW). Strandberg et al. (1984) suggest that this result indicates that these children are impaired in their ability to regulate processes involved in the mobilization and direction of attention and the discrimination of target stimuli. The schizophrenic children also did not show progressive increases in N100 and SW amplitudes in response
to increases in information processing demands as was seen in the normal children. Strandberg et al. indicate that the ERP components of the schizophrenic children were most aberrant at frontal sites, but that midline and lateral deficits were also seen at vertex (center) and posterior leads.

Shelburne (1973) also found differences in the late ERP components of 10-year-olds who performed poorly and those who performed accurately on a task involving a consonant-vowel-consonant sequence. The children were to press a button if the letter sequence, called a trigram, formed a word (i.e. "POT" versus "POV"). The children who did well on the task displayed a larger P500 to the third letter in the trigram. The children who performed poorly on the task did not show a larger P500 component. Shelburne (in press) has also found that learning-disabled children's P500 also fails to differentiate between the first and third letter of the trigram.

Interesting conditioning studies by Lelord et al. (1973, 1976) examined the evoked responses of 9- to 10-year-old children. In these studies a tone was the conditioned stimulus (CS) and a flash presented 700 msec later was the unconditioned cue (UCS). They reported a CS-evoked late negative wave elicited from an occipital site as the larger of two deflections occurring at 190 or 331 msec post-CS onset. The conditioning procedures seemed to enhance the amplitude of the negative waves at the occiput, relative to the habituation and extinction phase of the experiment. They also reported a slow wave peaking later than 400 msec post-CS that was most frequent during the conditioning phase of the experiment.
In one of the first studies done investigating late ERP components in children, Symmes and Eisengart (1971) found large negative waves (latency calibrated at (ca.) 520 msec) in 5- to 11-year-old children. The children were responding to colorful pictures of cartoon figures and familiar objects such as toothbrushes and keys versus defocused cartoons and blank slides. Significant amplitude differences in the waveform were found when focused cartoons and familiar objects were presented. They suggested that these waves reflect cognitive processes involved in the perception of meaningful visual stimuli (Symmes and Eisengart, 1971).

**ERP Research Involving the Elderly**

In order to get a complete developmental perspective of ERP components, research investigating these waveforms in the elderly must also be examined. The following research presented, even though it includes waveforms from young and old subjects, is some of the only available research done with the elderly.

Ford et al. (1982) suggest that one of the most pervasive manifestations of aging is the slowing of many responses. Ford et al. (1982, 1978) have used ERP latency information to study this phenomenon. They suggest that the P300 reflects the timing of stimulus evaluation and can be used as a relative indicator of how long it takes to evaluate a stimulus in different situations. In their experiments, designs are used that involve P300 and RT.

In one experiment Ford et al. (1982) presented auditory stimuli to 12 young subjects (mean \( X \) age = 22) and to 12 old subjects (\( X \) age =
78). The subjects listened to tones of 500 Hz (p = .10), 1000 Hz (p = .80), and 2000 Hz (p = .10). This design produced three classes of stimuli: frequent, infrequent target (requiring a key press), and infrequent non-target. The subjects were instructed to press an RT key whenever one of the infrequent high tones (i.e. 2000 Hz) was heard.

Both the target and non-target infrequent tones produced ERPs with a prominent P300 component. The latency of the P300 for both the target and non-target stimuli was markedly prolonged for the aged subjects. The scalp distribution of P300 also differed significantly between the young and the old. For the young subjects, P300 was maximal at Pz and smallest at the frontal site of the scalp (Fz). The old subjects had a similar but less pronounced distribution for the target stimuli and almost equal amplitude P300 at Fz, Cz, and Pz for the non-target stimuli. The old subjects had larger P300 amplitudes than the young at the frontal scalp site but smaller P300 amplitudes than the young at the parietal location.

The slow wave (SW) which is best observed after the occurrence of the P300 revealed significant amplitude and distribution differences when the young and the old subjects were compared. The young subjects elicited a negative SW at the frontal site and positive at the parietal site. The SW in the elderly was maximal over the parietal area but was positive at scalp sites Fz, Cz, and Pz. Scheibel et al. suggest that the absence of negative going waveforms seen in the older subjects may be due to structural alterations of the brain (i.e. loss of dendritic branches) which result in a decrease in the development of slow electronegative activity (Ford, 1982).
The P300 and reaction time (RT) correlations were similar for both young and old; however, the mean RT preceded P300 in the young, but not in the old. This finding indicates a need for further research when investigating the value of the relative P300 and RT timing for inferring the strategy used by a subject and the interaction of the P300-RT with age.

Ford et al. (1982) had similar results when they used a variation of Sternberg's memory set paradigm. The subjects were presented with digits in sets of either 1, 2, 3, or 4 numbers and were then flashed a probe digit. They had to press a key with either the right or left hand depending on whether or not the probe was a digit in the previous set. Again Ford et al. (1982) found that the P300 latency was longer and the RT was slower for the elderly. The P300 latency, however, increased as set size increased for both the young and the old.

ERP Research Involving the Elderly - the Omission Paradigm

Michalewski et al. (1982) found a difference in P300 amplitude rather than P300 latency when they tested young persons (X age = 22) and older individuals (X age = 66.8) using an omitted potential paradigm with auditory stimuli. Auditory clicks were presented binaurally through headsets at 60 dB above the subject's threshold. A test block consisted of 60 click stimuli presented at a rate of 1 per second. Within a block, three to nine stimuli were quasi-randomly omitted. Omitted clicks could not occur in succession, nor could they be given at the beginning or end of a block. The 10 blocks that were presented were separated by short intervals. The subjects were instructed to count the
missing clicks within a block and to tell the experimenter the number during the interval between the blocks.

The P300 amplitudes for both age groups showed similarities in scalp distribution, being maximal at the parietal region (Pz); but older individuals had smaller P300 amplitudes over parietal and central areas than the younger subjects. Michalewski et al. (1982) state that it is important to note that P300 potentials that result from omitted stimuli generally have longer latencies and smaller amplitudes than event-related P300s that are evoked in paradigms in which stimuli are presented (Ruchkin and Sutton, 1979). Ruchkin and Sutton (1979) suggest that it may take longer to decide stimulus absence than stimulus presence and this increased decision time contributes to the longer latencies observed for P300s in the omitted stimuli paradigm.

In Michalewski et al.'s 1982 study the comparable P300 latencies recorded from both young and old (approximately 407 and 412 msec., respectively) might indicate a similar decision time in determining click absence, whereas the reduced P300 amplitudes in the older subjects might suggest that they were less certain of stimulus omission than the younger group. Since the omitted paradigm can be considered a special case of a stimulus change condition, the interpretation that the older were less certain of stimulus omission suggests older people show less reactivity in response to stimulus change. Is this response difference in the elderly due to a change in the integrity of primary sensory pathways, or due to a change in cognitive functioning, or both?

Goodin et al. (1977) also studied the late ERP components which are sensitive to age-related neurological and psychological changes. They
tested 47 subjects (25 female and 22 males) ranging in age from six to seventy-six. The subjects were presented with 400 binaural tone bursts. Eighty-five percent of the tones had a frequency of 1000c/sec. and the rare tones had a frequency of 2000c/second. The stimulus sequence was random and no two rare tones appeared in succession. There was an "ignore condition" in which the subject was asked to ignore the tones and to read a magazine, and an "attend condition" in which the subject was instructed to keep a mental record (a response which requires no overt or observable action) of the rare tones.

The results of this study show that components of the auditory evoked potential change in a systematic manner with age. During childhood, the latency of N200 and P300 decrease rapidly with age (12.3 and 18.4 msec/year, respectively) to their minimum values in the mid-teens. This change is followed by a slower age-related increase in latency during adulthood (0.9 and 1.8 msec/year). Increasing latencies were associated with decreasing amplitude and vice versa.

**Summary of ERP Research - Infancy Through Adulthood**

Event-related potential research involving the young and the elderly seems to present the fact that P300 latency is a function of age. This appears to be one of the few valid conclusions that can be drawn about this particular event-related potential from the previously presented data.
P300 as a Postdecision Phenomenon

John Desmedt's (1981; Desmedt and Debecker, 1979, 1979a; and Desmedt and Robertson, 1977) ERP research speculates as to what the P300 reflects both psychologically and neurophysiologically. Desmedt and Debecker (1979, 1979a) argue that the P300, or as they refer to it, the P350, is a reflection of a postdecision closure activity. This late component is the end of a cognitive epoch functioning to clear the neurophysiological capabilities for further processing. Desmedt et al. (1977, 1979, 1979a) suggest that the P350 is different from the earlier ERP components such as the N100 and the N200, which they consider to be pre-decision potentials. They have shown that the P350 is discernible from CNVs and that the P350 has a diffuse bilateral distribution. They have also shown that the P350 is non-modality specific.

In some of their experiments subjects were presented with either auditory clicks or finger-shock stimuli (Desmedt and Debecker, 1979, 1979a). The subjects used a strict-criterion (Swets, et al. 1964), meaning that they should be sure that they perceived the stimuli. Equivocation (Ruchkin, 1979), the uncertainty of stimuli perception, was reduced by using an auditory click that was 90-95% threshold detection (rather than the normal 50%). Stimuli were presented randomly for 100 trials over a three minute period. The interstimulus interval (ISI) was also random, ranging from 1 to 15 seconds. Desmedt and Debecker did this to determine the effect of ISIs on slow potential shifts (SPSs), which often have to do with expectancy (Walter et al. 1964). In other words, the experimenters hoped to lessen the subject's expectancy of the stimuli by randomization of the time intervals between individual
stimulus presentation. During alternate runs of stimuli presentation subjects were told to attend to either the clicks or the shocks and to ignore the other stimuli.

In every subject large P350s were found when they attended to the stimuli and none were found when they ignored the stimuli. There was also a lack of any slow potential shift or pre-stimulus CNV waves either before or after the stimuli. This result occurred because of the complete randomization of sequences of target and non-target signals and of interstimulus intervals (Desmedt and Debecker, 1979, 1979a). They found the same results in 17 experiments of the same kind.

To substantiate the result that the P350 is discernible from other waveforms Desmedt and Debecker (1979a) repeated the exact experiment, but kept the ISI constant at 2.5 seconds. They found the same robust P350 but SPSs occurred before and after the P350.

Desmedt (1981, Desmedt et al., 1977, 1979, 1979a) also speculates about the neurophysiological basis of the P350 and earlier waveform components. "The P350 is not a hard-wired brain potential elicited at all times by some stimuli, (like the P200 to strong stimuli), but appears in conjunction with post-stimulus cognitive activity leading to a decision allocating an event to a task-relevant category" (Desmedt and Debecker, 1979, p. 677). Some waveforms' topography is restricted or varies with the sensory modality used. The P350, however, presents similar scalp topography and profile, no matter which sensory modalities or which types of processing rules are chosen for the relevant items of the task (Desmedt and Debecker, 1979). Desmedt and Debecker (1979) use the example that difficult discrimination between target and non-target
stimuli to different fingers of one hand activates contralateral brain processors indexed by P100 or N140 ERP components, but only the targets elicit a symmetrical P350. This suggests that the P350 cannot index any brain processor which identifies the sensory signals and compares them against memory to reach a decision, but is reflective of a post-decision event (Desmedt and Debecker, 1979). Thus, the pertinent element of a serial task for the P350 to appear is not the information value of any signal, or the processing itself, but the closure of cognitive activity having led to the decision (Desmedt and Debecker, 1979; Desmedt, 1981). If the P350 indexed pre-decision cognitive activity, the decision closure would occur after P350 onset and at about the P350 peak or later; this is not compatible with the finding that RT motor responses occur close to, and sometimes even slightly before the P350 peak (Desmedt et al., 1977, 1979, 1979a).

Since the P350 can occur in the absence of any pre-stimulus CNV, it therefore must reflect a distinct brain process that reacts differentially to experimental variables (Desmedt and Debecker, 1979; Donchin et al., 1975; and Chapman et al. 1979). Although task conditions influence the P350 and CNV amplitudes, they do not influence scalp distribution (Desmedt and Debecker, 1979). This suggests that the brain generators for CNV and P350 are largely coextensive, which is an argument for their relation to the diffuse projections of the mesencephalic reticular formation system (MRF) exerting neuromodulation of cortical circuits (Desmedt, 1981; Desmedt and Debecker, 1979). Desmedt and Debecker (1979) suggest that the P350 results from a phasic inhibition of the MRF at the closure of a cognitive processing epoch.
They indicate more specific subcortical nuclei, such as the thalamus reticularis, might control earlier ERP components. They also indicate the prefrontal granular cortex controls the reaction of these specific and non-specific subcortical nuclei.

Desmedt's studies indicate that the P300 is something more than an indication of surprise. Rather, the P300 seems to indicate that some cognitive decision has been made and that closure has been reached. In line with this idea is the evidence drawn from a study done by Kutas and Hillyard (1980).

Kutas and Hillyard presented subjects with sentences that were either completed in a congruent or an incongruent manner. Congruent sentences (such as "It was his first day of work.") ended with words that were semantically congruent with the rest of the sentence. Incongruent sentences (such as "He spread the warm bread with socks.") ended with words that did not fit the semantic context of the rest of the sentence.

Kutas and Hillyard's results show that incongruent endings produced not P300's, as the "surprise" interpretation would have one expect, but rather N400's. What was not reported by Kutas and Hillyard but is evident from their data is that a robust P300 followed the semantically congruent sentences, perhaps indicating again the brain's response to the occurrence of cognitive closure.

From the results of Desmedt et al. (1977, 1979, 1979a) and of Kutas and Hillyard (1980), among others, it would appear that the P300 holds the possibility of being the neurophysiological indicator of cognitive closure, or the resolution of an indeterminate situation into a
determined, coherent one. As stated in Chapter I, a number of interesting questions arise. Is the P300 the neurophysiological indicator of the resolution of a motive state (going from incoherence to coherence), rather than merely the reflection of surprise? Further, does this neurophysiological manifestation occur and continue to occur because coherent acts are more rewarding and readily learned? In other words, is this brain response indicative of the cognitive act and the feeling tone associated with the establishment of coherence and the making of meaning? At this point of meaning-making, is incoherence resolved, followed by the "aha", and a feeling of pleasure? Has information been reconstructed or reorganized coherently and do the stimuli have new meaning?

Summary

This chapter presents a brief history of the research that served as precursors to current ERP studies and focuses on the P300 component. The chapter then presents an overview of relevant research methods and behavioral procedures used in conjunction with the P300. Next, studies that analyze P300 across the lifespan are outlined, demonstrating the wide variation of characteristics associated with the P300. The chapter ends with studies that suggest that the P300 is more than what was previously believed, that in fact it may be a neurophysiological marker for the resolution of a motive state and the achievement of perceptual coherence.
If the P300 is a trace originating from the establishment of coherence, then one might expect normal individuals to exhibit consistently a P300 wave-form under conditions in which organizing acts are required. ERP research supports this contention (Hillyard and Kutas, 1980; Desmedt, 1981; Squire et al., 1980; Donchin, 1975; among others). However, it is important to note that most ERP research shows that the P300 is a function of several variables. For example, P300 latency is a function of age (Michalewski et al., 1982; Pfefferbaum et al., 1980; Ford, 1979, 1982; Squire et al., 1980; Courchesne, 1979; Goodin, 1977) and of the difficulty of the task, with the correctness of the response being epiphenomenal (Ford et al., 1982; Hillyard and Kutas, 1983). Ford et al. (1982) found that the elderly made more errors when responding to a memory set paradigm, but elderly subjects did display a P300 as long as they made the decision to respond.

P300 amplitude is also a function of expectancy, showing an inverse relationship between expectancy and amplitude (Hillyard and Kutas, 1983). Perhaps this is why there are amplitude differences in the P300 wave-forms of children and adults. Children often show a more diminished amplitude (Courchesne, 1979) than the elderly because they have less experience, hence, less of a repertoire of expectancies.

Research also indicates that P300 amplitude is a function of the degree to which the pre-cognitive conditions are normal. For example, Squire et al. (1980) found a diminished P300 amplitude in patients suffering from certain dementias caused by organic dysfunction (e.g., Alzhiemers, hydroencephaly, and brain tumor).
Meyer (Chapter II), Dewey (Chapter III), and Polanyi (Chapter IV) all deal at some length with the tendency in humans to seek coherence. The P300 literature reviewed here suggests that the P300 may mark the resolution of a motive state. In other words, the appearance of a P300 could be the empirical evidence for the creation of coherence from incoherence so central to Meyer, Dewey, and Polanyi.

The final chapter of this study is a synthesis of the three theorists--Meyer, Dewey, and Polanyi--and P300 research. The result is a model of how one comes to know, how one creates coherences. The theorists were chosen because of their many areas of commonality regarding the making of meaning, but the model employs their ideas selectively, as they illuminate the emergence of perceived coherences--Sperry's holistic mental properties. Included in this final chapter also are suggestions (1) for empirical study that would test relationships between and among components of the developing model and (2) for improving teaching and learning.
CHAPTER VI
SYNTHESIS AND SUGGESTIONS

This study develops a theory of how people come to know, how they acquire knowledge. The interaction of mind and brain is viewed as a dynamic process in which knowledge is emergent and changing. Knowledge is gained when past and present experience integrates with anticipations of consequences of future experience by establishing coherence.

When one experiences coherence, analogous to Sperry's holistic mental phenomena, aspects of the inner and outer world are being organized. There is an interaction going on between the self and the environment external to the self, referred to in this theory as the psychological and the logical. There is an integration of that which is being experienced presently with past experience, here posed as the focal situation and subsidiary or tacit knowledge, respectively, so that meaning can be made. What accrues from this meshing is some type of configuration that leads to cognition, whether it be a warranted assertion, a physical skill, or an artistic perception. The configuration also involves an emotional component which is the felt sense of clarity and well being when experiencing coherence. In this study optimal coherence, seen here as analogous to a warranted assertion, is achieved through reflective thought. The establishment of coherence also leads to a change in the organism, often behaviorally and
always neurophysiologically. The suggestion in this study is that the P300 is the neurophysiological evidence for the organismic change. What then is coherence and how is it established?

Let us once again return to Sperry (1970). He contends that subjective experience exerts a causal influence on brain activity. He sees subjective experience as an example of a large variety of holistic properties which affect neural processing. However, holistic configurational activity occurs whether or not neural events are involved in consciousness. This configurational activity is present and important in the control of cerebral activity at the perceptual and cognitive level. But neural processing involved in conscious experience is not only more complex, it is specifically configured functionally "to create particular sensations, percepts, and feelings, and to provide a rapid representation of external reality" (Sperry, 1970 p. 589). Functionally then, the mind and the brain are concerned with the organization and the relatedness of experience at all different levels of consciousness. Neural functions, perceptual functions, and higher level functions all evolve from a configurational process.

Consider Sperry's (1970) example of the perception of a melody played on the piano or the perception of a phantom limb (a body part that no longer exists but is perceived as still being there). In each of these cases, stimuli have functioned and been experienced as a unit by the mind and the brain. In the case of the melody, the notes that comprise the tune are merely "pressure waves", aspects of space and time. We experience these elements however as a unit, a melody. In the
case of the experience of a phantom limb, pain is often still experienced. When the limb is gone we still organize and interpret information in terms of units. In this case internal information is recalled as a configuration, here as a quality experienced as pain.

In either case some context, either internal or external, enables stimuli to be treated as a unit. According to Sperry (1970) external or internal information can carry an inherent excitatory hierarchy. This excitatory hierarchy, given the proper context, will function as a unit and be organized by the mind and the brain, thus the emergent holistic mental property. This holistic mental property may be experienced, using the previous examples, as a melody or as a quality such as pain.

These holistic mental properties, according to Sperry (1970), are what lead to consciousness. What is suggested here is that there is then a human tendency to organize experience in such a way that a holistic mental property emerges. In this study it is suggested that these holistic mental properties result when information is organized and a sense of coherence is established. Further, the holistic mental properties that lead to enhanced consciousness are organized reflectively. What follows is a verbal rendering and a schematic representation of the elements and processes incorporated in this study that lead to the emergence of holistic mental properties.

The Model

Elements of the model should be thought of as interactive. It is through the purposeful and functional interaction of these elements that
holistic mental properties emerge. The emergence of these properties lead to enhanced consciousness and enriched understandings. A verbal rendering of the model follows, along with a schematic representation that is still in the initial stages of development.

In order to understand clearly what is being presented, one should try to keep in mind that mind and brain are always working in concert to organize information from the self and the empirical world into some form. The configuration of this form depends on the function and purpose it plays in response to the information being organized.

Initially, there is some transaction between the organism and the environment as one brings to bear past experiences on what is presently being experienced. In the model tacit knowledge is an example of past experience and is schematically represented as a circle within the sphere of experience. The focal situation is seen as the present.

If there is incongruity between past experience and present experience, in this case incongruity between tacit knowledge and the focal situation, there is a perceived incoherence. This perceived incoherence is what this study refers to as the motive state. As the reader recalls, the motivation to organize information occurs when this state is experienced. The pre-reflective state is an example of perceived incoherence and is a necessary condition for the resolution of a problematic situation.

In this model, reflective thinking is the process by which the problematic situation is resolved and enhanced perceptual coherence is established. In some situations there is no felt incoherence or sense of doubt. This could occur when there is an instantaneous match between
tacit knowledge and the focal situation and meaning is synchronous. In other situations, depending on function or on one’s purpose and intent, a more reflective process is needed to resolve the incoherence.

In any case, a number of important things happen when the motive state is resolved and perceptual coherence is established. Internal and external information has been organized in such a way that neurophysiological changes occur in the organism and some type of holistic mental property emerges. The suggestion is also that this property then becomes a part of one’s experience or part of one’s repertoire of tacit knowledge, for example. This information lays in wait and ready for use when the organism is again faced with a similar problematic situation. In this new problematic situation, there again is a discrepancy between past and present experience and a perceived incoherence is felt. The cycle to resolve the situation and establish perceptual coherence is then begun anew.

This model presents the simplest representation of the interaction between mind and brain consistent with the theory presented above. As studies are conducted to test the model and its constructs, it will probably become more detailed and elaborate. On the next page is a schematic representation of the model.
A Graphic Model

Stimuli

Perception of Incoherence → Motive State

Motive State

Perception of Coherence

Repertoire of Tacit Knowledge

Effort of Resolution through Reflective Thought

Outer World (Logical)

Inner World (Psychological)

situation Resolved

Figure 3
Examples

Suppose one is presented with a puzzle, such as one of the pictograms below:

Figure 4   Figure 5   Figure 6

How might one describe the task of solving the pictogram in Figure 4 in terms of the internal mental and neurophysiological processes at work at the initiation of the task, as the task proceeds, and at the conclusion of the task? To begin, incoherence is immediately experienced. The picture does not fit into an existing schema. There is a discrepancy between the external data or information, the focal target, and what one already knows, suggesting here that the solution is perhaps not a part of one's repertoire of tacit knowledge. The logic of the external situation does not "jump out", indicating in Sperry's terms that the holistic mental property that fits with this situation is lacking. In terms of the model, the puzzle presents a highly
motivating, problematic situation. The puzzle is motivating because of
the perception of discrepancy between past experience and the present,
focal experience. The model refers to the incoherence brought about by
this discrepancy as the pre-reflective state. Without incoherence,
there will be no motivation to reflect upon the problem so that a
solution and the perception of coherence might be established.

What, then, must be done to achieve this perception of coherence?
The first thing that one might try to do is to draw connections between
words and pictures. What are the possible meanings of the "R" and the
picture of the ice cube, and what are the possible connections that one
might draw between the letter "R" and the picture of the ice cube? The
greater the number of possible meanings and connections or
interpretations, the greater the ambiguity of the pictogram. This
ambiguity is precisely what Meyer was referring to when he spoke of a
low signal/noise ratio. To the extent that there are multiple
interpretations for the individual items and for their resultant
combinations in the pictogram, there will be more noise (wrong
interpretations of the items individually and in combination) in
relation to signal (the appropriate interpretation). In terms of the
model, this low signal/noise ratio means high incoherence. The initial
efforts to solve the puzzle focus on laying out the most likely
interpretations, thereby reducing noise in relation to signal.

As one begins to generate these multiple interpretations, the
process of reflective thinking has actually begun. These
interpretations serve as possibilities, as suggestions in Deweyan terms,
and represent the first phase of reflectivity. To illustrate a few
possible suggestions, the ice is in the shape of a cube, it also appears to be melting, and the letter "R" in some way apparently needs to be attached to the concept of the "melting cube". At one point a flash might appear regarding mathematical formulae involving a radius \( r \) being cubed, or raised to the third power. This mathematical flash, or suggestion, would then likely be explored almost immediately in terms of how that suggestion relates to the information in the focal situation. One's repertoire of tacit knowledge holds information relating a radius \( r \) and raising that \( r \) to different powers (cubed). The suggested formula possibility is then matched against the focal (the second phase of reflectivity--intellectualization) to determine its likelihood of success, and also to define better the problem itself.

In actuality, it would appear that the next two phases are collapsed into this process as well, in that the suggestion would likely be treated as a hypothesis (phase three) and then would be extended via reasoning (phase four) to its likely consequences, such as the need for other elements found in formulae containing \( r \) (\( \pi \), for example). At this point it would be clear that those other elements are not present, and the suggestion of a mathematical solution to the pictogram is discarded. The state of incoherence however remains, but all is not lost. One possible combination and interpretation is ruled out, and some noise removed from the picture. Also, through the process, the problem or focal target is more clearly defined. New suggestions can now be followed.
Throughout the process one continues to think of other uses of "R" and "ice" or cubes that might lead to other hypotheses *. What other elements and relationships does one hold in one's repertoire of tacit knowledge that might be used to bridge the gap between past experience and present experience with the focal target? The ice is in the shape of a cube and it appears to be melting. Are there combinations of "R" and cube, melting, cold water, and so on that might fit the rest of the focal? Each suggestion, when carried through intellectualization, fails to lessen the discrepancy between tacit and focal, therefore fails to establish coherence. If this puzzle is solvable, there must be some other connection.

Suppose the entire puzzle is based on letters and words, and not on the picture at all (another suggestion). Where might one be taken as a result of such an idea? After some trial combinations, one might simply combine "R" with the word "ice", yielding "Rice". Surely, this word

* I worked this example myself. Each new hypothesis generated failed the test of matching satisfactorily with available data. This became exceedingly frustrating and I decided to drop this example. I did look at the answer, however, and found that the first thing that occurred to me - "rice" - was in fact the answer. The decision to look at the answer was in response to my strong desire to resolve the incoherence, even though I was seemingly unable to solve the puzzle. Upon learning the answer, my incoherence was resolved and I moved on to other puzzles. I was a bit disappointed with what I thought was a relatively silly, overly simple resolution--I expected and wanted more.
makes sense, and it calls for nothing in the puzzle that is not there. In fact, there is nothing else in the puzzle at all. The hypothesis that the solution to the puzzle is "Rice" is then put to the test in a variety of ways. The verification of this solution can be accomplished through reasoning, the fourth phase of reflective thinking. Here one imagines the consequences of the solution and looks for information in the puzzle that is not contained in the solution. Once the hypothesis is regarded as the most probable solution, a final verification can be made. In this case the final test lies in checking the answers in the book that presented the puzzle. Indeed, "Rice" is correct.

With the final check on the accuracy of the solution, a number of important things happen. First, optimal coherence is reached, as signal is maximal and noise minimal. One and only one interpretive combination stands out from all the other possibilities that presented themselves following the pre-reflective state. With the resolution and the onset of the post-reflective state, not only is incoherence removed, but also the organism changes such that any time in the future that the same puzzle is viewed, it will be resolved immediately. There has emerged a new holistic mental property that can handle what was initially a highly ambiguous stimulus set.

The resolution of the puzzle and the emergence of this new property relates to a second important outcome of the process of resolving the incoherence of the puzzle. The solution may become a part of one's repertoire of tacit knowledge, available and waiting for use when a similar focal target is experienced in the future. The meaning of the pieces of the puzzle have become clear in terms of their relation to the
focal, and tacit knowledge in terms of that which has been used to solve
the puzzle as well as that which has been generated as a result of
interacting with the focal target has been refined and increased.

Finally, again due to the resolution of the previously problematic
situation one experiences a sense of clarity and a feeling of control
over the situation. At this moment one is not motivated to think
reflectively about the situation. But as a new puzzle is approached the
quest for coherence begins again.

Recommendations for Further Research

Given a model that integrates inner, mental and neurophysiological
processes with external, environmental stimuli and experience via some
type of transaction, how might one test the relationships between and
among the model components? What might an unfolding program of research
designed to test, refine, and elaborate on the model look like? What
follows is a suggestion of research that could provide empirical support
for the model.

If there is a change in the organism when the perception of
coherence is established, then there should be some neurophysiological
indicator of that change. Research reviewed in Chapter V suggests that
the P300 (a brain response seen in current event-related potential
studies) holds promise as that indicator. The P300 is a waveform which
consistently and repeatedly occurs under conditions in which organizing
acts are required.
The research ideas suggested would be designed to investigate whether the P300 or some other brain response is the neurophysiological marker of the resolution of a motive state--the achievement of the perception of coherence. The hypothesis is that during the subjective experience of perceptual coherence there is some organismic change. Therefore there might be a brain response, such as the P300, that is the neurophysiological indicator of the psychological quality experienced when perceptual coherence is established. Using this hypothesis, many questions can be posed and researched. For example, what stimuli can be presented to evoke motive states? How can the stimuli be organized and presented so that the perception of coherence or incoherence will result? Can the psychological quality of the perception of coherence be manipulated? And, does the neurophysiological response to the stimuli vary in amplitude and latency as a function of the perception of incoherence or coherence?

A research effort with these questions in mind has been developed and can be found in Appendix A. The significance of this study as it relates to educational practice follows. Since this study was done in a college of education, suggestions for practice are limited to that arena.

Suggestions for Educational Practice

While the temptation is great to suggest wide-ranging implications and changes, one must be reminded that although this model is grounded in neuroscience and in psychological and educational theory, the
connections between and among its components have not been empirically verified. Recommendations should be held tentatively and used as information with which to think.

If we use the model as a metaphor for schooling, then the following questions need to be posed about the nature of the educational environment.

**Curriculum**

1. Is the function of a learning task such that it will encourage the emergence of a holistic property?
2. Does the learning task pose a true problem for the student?
3. Is the learning task understandable in terms of students' past experience?
4. Does the learning task lend itself to reflective thought?
5. Does interaction with the learning task help students to better anticipate and control future experiences?

**Instruction**

1. Does the method of instruction tap tacit knowledge so that students will interact with the curriculum in ways that are enriching?
2. Does the method allow for or encourage student hypothesis generation through use of imagination?
3. Does the method allow for the perceived ambiguity necessary in a reflective thinking task?
4. Does the teacher then help direct the students' perceived ambiguity toward reflective thinking?
5. Does the teacher consider the multi-faceted nature of achieving coherence (the emotional, cognitive, and physical)?
Does the teacher recognize and consider the evidence for the emergence of reflectivity in both student and teacher?
Appendix A

A Study of the P300 as the Neurophysiological Indicator Associated with Perceived Coherence
This research effort will examine the influence of melodic sequences upon human event-related potentials (ERPs). The three major research questions to be examined are: (1) Is there a neurophysiological response related to the stimulus event (the melodic sequence that is tonally resolved) that is perceived as clear and experienced as pleasant? (2) Can the psychological value (the sense of clarity and feeling of pleasure that accompanies the establishment of coherence) of a tone that completes a melodic sequence be manipulated by the tones that precede it? And if so, (3) Is there a more robust neurophysiological response that is related to the stimulus event (the melodic sequence that was atonally resolved) that is experienced as unpleasant and unclear?

The hypothesis to be tested is that the P300 is the neurophysiological marker associated with enhanced perceptual coherence. The working hypothesis is that the most robust (in terms of amplitude) P300 waveform will occur when the melodic sequences are resolved in their most coherent manner (tonally).

Related to this notion of maximally coherent resolution is Meyer's idea that perceptual coherence can be thought of as a function of the ratio of signal to noise. As this ratio increases, the stimulus event is perceived to be more highly structured and therefore more coherent. In the study outlined here, the concept of tonality can be viewed in terms of a signal/noise ratio.

The concept of tonality involves the organizing of pitches around one particular tone—the tonic—with the other tones closely related to the tonic (Krumhansi, 1985). This suggests that a tonal context imposes a kind of hierarchy in the set of tones, with the tonic dominating the
hierarchy. The hierarchical ordering of tones affects the degree to which the elements are perceived as being related and creates preferences for the order in which the elements are heard (Krumhansl, 1985; Jones, 1982). This ordering around the tonic is parallel to a high signal/noise ratio—the hierarchy of tones is signal, and deviation from the hierarchy noise.

By using the model presented in this dissertation the outcome of this type of research could be interpreted as a subjective response to the organization of information. If the most robust P300 is found to be associated with the tonally resolved patterns, then there is evidence supporting the idea that the organism responds in a very particular way to perceived coherence, and that the P300 is the indicator of that perceived coherence. Further, since this neurophysiological indicator would appear to have followed the mental organizing act, the suggestion is the emergence of a holistic mental property. The finding would support the idea of mind and brain interaction.
LIST OF REFERENCES


