Attention

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Our senses, indeed, by an effect almost mechanical, are passive to the impression of outside objects, whether agreeable or offensive; but the mind, possessed of a self-directing power, may turn its attention to whatever it thinks proper.

Plutarch, Life of Pericles

The word attention has had more varied usages than perhaps any other in psychology, all of which imply both intensive and selective aspects. Models of attention date back to Aristotle, who considered attention as a narrowing of the senses.[1] All science is based on the attention paid to models and philosophies of thinking that drive scientific enquiry. And it is on the basis of what appears to be proven scientifically, that clinicians apply such information in clinical practice.

The inner driving forces of attention are inherent in a genetic code that is committed to our survival. By paying specific attention to a life force work plan, what starts out as the union of a male sperm and a female ovum, goes into action to produce the structures of the embryo, fetus and infant at birth, with all its functional organs.

At the earliest and most incipient stages, attention appears to be programmed to operate through reflex responses to sensory stimuli as part of life sustaining and survival mechanisms. The infant, through olfaction, seeks out and centers in on a mother's breast, and displays visual, auditory, and tactile startle reflexes in response to visual and auditory, and touch feel, reception to bright lights, loud sounds and painful experiences. Very early on the infant becomes receptive to gravitational forces and develops righting orienting responses.

In considering the development of attention, I draw heavily on Piagetian models of human and intellectual development which appear to be universal and that can be applied to the scientific study of attention and its relevance in clinical practice.

Piaget[3] conceived of a developmental process that begins with sensorimotor operations, that develops intuitively to reach higher perceptual levels, and then on to more abstract cognitive levels through environmental and genetically induced accommodation and assimilation. Basic to these premises, Piaget incorporated a model of intellectual development that embraces sequential steps of ascending maturity, experience, social transmission and self-regulation. Figure 1 illustrates.

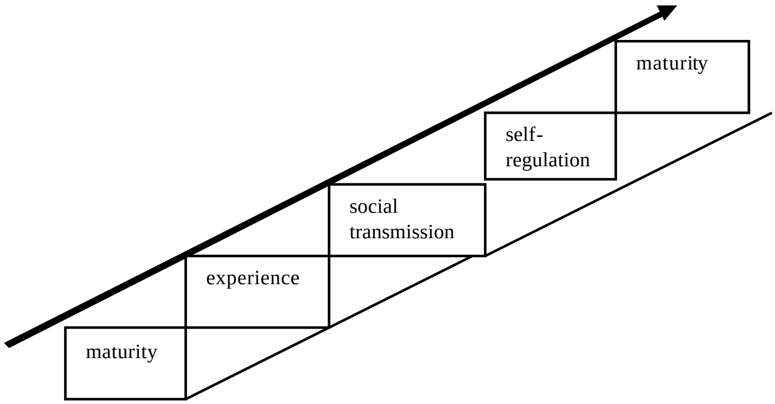

Figure 1. Piaget's model

It is the self-regulating and self-directing power of the mind that determines the attention process. This depends on levels of sensorimotor, perceptual and cognitive development, that are, in turn, dependent on levels of physical maturity, environmental experience, and social transmission–interaction with other human beings.

In a dynamic sense, attention relies on determining what to fixate, and focus upon, and to combine--fuse those mental and physical functions that lead to processing objects of attention. The holistic nature of attention can be explained in Gesellian terms of "attention through the whole action system, and the whole action system through attention."

Gesell et al.[4] associated the musculoskeletal system with sensorimotor system necessary to move into the area of regard to fixate attention. They associated the visceral (autonomic nervous) system with the automatic focus of attention, and lastly they associated the cortical (thinking) system with the combining and fusing of sensorimotor, perceptual and cognitive body and mind systems to make attention most relevant.

In trying to grasp concepts such as attention, we can further understanding, by applying Getman[5] concepts and concrete examples of reaching for, grasping, manipulating and releasing physical objects, as we carry out our tasks of daily living; and apply the functions of and *locomotion, location, labeling and language* that are implicit in the processes of learning and paying attention.

We can also benefit by considering a cybernetic servomechanism model conceived originally by Wiener,[6] that I have modified to create a model of learning development (figure 2).[7] This consists of linking functions of self-regulation, organization, input and output with a continuous feedback mechanism to regulate and improve efficiency levels, and a continuous feed forward mechanism to anticipate and plan future actions.

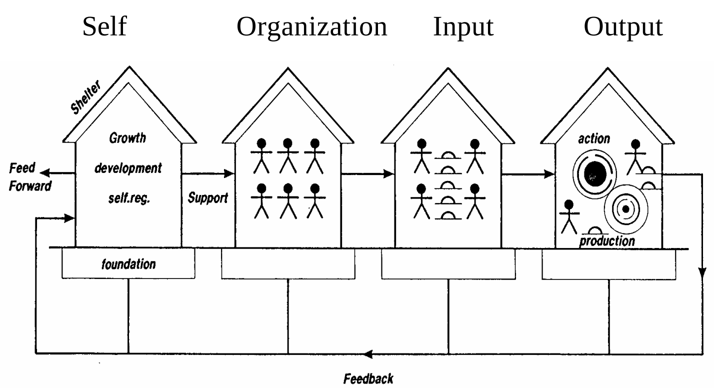

Figure 2. Model of learning development

What has been described thus far about the development of attention has been aimed at providing a practical, rather than theoretical basis for applying concepts of attention.

Attention has been used to refer to processes that involve alertness and vigilance within a stimulus field, and it has also been applied to the processes that determine which elements of a stimulus field will exert a dominating influence over behavior. Attention is a generic term for the various abilities to process incoming sensory and outgoing controlling information, selectively, so that some stimuli are processed more deeply than other competitive stimuli. In its simplest terms, attention refers to a selectivity of response. Attention relies on intention, intellect, psychological set, attitude, expectancy, need, and psychological and physical staying power to keep up appropriate, and sustained attention. It also requires the ability to be flexible and to move with facility from one object to another object of attention that results in meaningful processing in carrying out the chores of daily living.

Attention is controlled primarily by central executive top-down processes that are goal directed. In other words there is intention and deliberation that act to drive one's attention to fixate and focus on something specific. *Selective attention*, is goal directed and is based on an individual's decision to focus on something specific at the expense of one or more other objects that could be fixated and focused upon. Bottom-up sensory stimulation also acts to drive attention and occurs as an inbuilt vigilance process that reacts to unexpected and strong inputs (such as a brief flashes of light, or a loud sound, or a looming flying object, or even hearing one's name called out softly). Thus there appears to be a control network that decides between the importance of desired (top-down) and unexpected (bottom-up) sites for attention.

Attention to what, where, when and why something is, combine to determine meaning and subsequent action. In the case of top-down executive control, objectives of attention are determined by deliberation and decision making, that plan, and anticipate mental and physical actions in a feed forward manner that place our sensory receptors in the most ideal positions spatially and temporally to effect most appropriate actions. Such goal-directed attention decides on the destination, direction and the drive necessary to fulfill such goals. In such instances, our attention may be directed through one sensory modality rather than another, regardless of location,[8] or our attention may be directed to one particular location rather than another, regardless of sensory modality. Top-down attention has been labeled an endogenous process that is directed and moved voluntarily. Bottom-up attention has been labeled an exogenous process. Such attention is more reflex and stimulus driven, and occurs automatically to capture special environmental events and features.[9] Gibson[10] points to five modes of external (exogenous) attention: listening, touching, smelling, tasting, and looking. These orient the perceptual system and "are not to be confused with the capacities to hear, to feel touches, to experience smells and tastes, and to see, respectively. The latter are passive abilities." Endogenous and exogenous attention involve adjustments and exploratory movements of the eye-head system, the ear head system, the hand-body system, the nose-head system and the mouth-head system with a presupposed orientation of the head and body. These investigatory adjustment responses are made so as to enhance the input of information to clarify perception. Broadbent(1958)[11]regarded these responses, as kinds of overt or external attention, and not of an internal attention, which only acted as a filter to ignore impulses at centers of the nervous system. The basic orienting system does not have a specific mode of attention but acts more generally on levels of being awake, alert and postured. The postures and the orientation of the sensitive organs in the head depend on the posture of the head, and the postures of the extremities depend on the posture of the body; both are affected by how we react to, and counter gravitational forces.

Top-down brain functions include abstract and creative thinking, fluency of thought and language, affective responses, the capacity for emotional attachments, social judgments, volition and drive, and selective attention. The organization of the centers of the sense organs via simple motor programs appears to be located in the midbrain. It is not a map of the body surface or of the visual field or the muscles per se – it is a map of orienting movements. Frontal lobe functions appear to play an attentional role, and especially in elaborating future actions and what we decide to do next. It is these types of connections that are necessary for selective attention, that focus both on sensation and movement.[12]

We are capable of selecting stimuli before they appear, and possess the flexibility to lift figures from infinitely complex grounds, and signals from noise. The limbic system has been implicated in all intentional actions, including perception and most forms of learning. To decide, one must know where one wishes to go and the time and distance it will take from what starting point,… and with what consequences. According to Freeman,[13(p.34)] this "assembled activity is unified, whole and purposive." Perception in this context is viewed as an active process designed to maintain attention and expectation. There is common accord among neuroscientists who focus on localizing brain areas related to brain function that implicates the limbic system as being the center of intentions that are transmitted by corollary discharge to all the sensory cortices in the process of preafference. Such focus does not reside in the thalamus or frontal lobe because the hippocampus has the neural machinery for directing intentional action through space-time. "Preafference provides the multimodal perceptual processes of expectation and attention. Without this preconfiguration, there would be neither search nor perception. Without sensory recursion, there would be no intentional action. Without emotion, there would be no remembering."[13(p.109)]

Selective attention is driven by perceived needs and leads to selective arousal and selective suppression, that goes beyond thalamic control mechanisms, and according to Pettigrew[14] involves the entire hemispheres of the brain, globally, and acting transversely in both directions. However, it seems even more feasible that both cephelocaudal/caudocephalo projections and association anteroposterior/postero-anterior connections are no less implicated in perception, attention and action processes.

Freeman[13(p.133)] summarizes what we might call selective attention as part of awareness, consciousness and causality. The primary sensory cortices are all components of a larger network, that incorporate the limbic system. Each of these components is liable to destabilization at any time, because of the interaction of populations by axonal feedback connections. Perception, can, and often does, follow the impact of sensory bombardment, but that which is perceived, has already been prepared for in two ways. The first is through past experiences, that have caused synaptic modifications that bias in favor of preferred spatiotemporal and behavioral patterns. The second is through the interaction and reciprocal relations with all the other sensory cortices, that biases in favor of the senses that provide the most meaning to any given situation, and to the exclusion of those senses that are considered not relevant, or provide conflicting inputs.

Attention is seen as an inner spotlight that illuminates the many different aspects of our experience. Attention constantly shifts between the different functions of our minds, bringing first one, and then another into the light. Postle[15] believes that although we may think that we are giving or paying attention, usually, we have little or no direct control over where our attention is focused. And yet we can deliberately shift our focus of attention if we choose to. The eyes play a significant part in where we direct our attention. When our eyes are open and active, the rest of the senses tend to become subservient and our attention tends to focus outwards. If we close our eyes, our attention tends to turn inwards.

At any given time, only a small portion of information available in the environment can be selected and identified for conscious processing. Optimally, this selection should be based on the information necessary for control of current and planned behavior and is most often described as selective attention.[1]

The reticular system (RS) has been shown to be involved with our degrees of alertness and intensity of attention[16,17,18] The RS is a column of nerve cells that extends through the lower brain and the brain stem that connect through afferent and efferent pathways to the cortex, and by afferent and efferent pathways to the rest of the body to influence motor functions.

Global functional brain imaging techniques (PET and fMRI) have confirmed that the brain networks involved in moving the focus of attention are different from the brain networks involved in processing an object of attention.[19,20] The regions exercising control of attention movement are in parietal and prefrontal sites, while attended sites are in primary and secondary cortices in the various senses (and also in motor cortex for response). Detailed timing analyses in humans, using EEG and fMRI methods, support the existence of attention-controlled feedback,[21] as well as the general model of control arising from superior parietal sites in the fast dorsal steam to gate slower object representations in the ventral stream.[22]

The lack of attention capture has been carefully investigated as has the phenomenon of inattentional blindness, in which apparently important and unexpected events just do not draw our attention.[23,24] The two sorts of attention, termed exogenous for bottom-up and endogenous for top-down, have been found to possess quite different times for onset and decay: exogenous attention is rapid, and reaches its maximum effect about 100-200 msecs after cue onset in humans, and then falls away as rapidly. On the other hand endogenous attention is slower, rising gradually to a maximum only at about 300-400 msecs after cueing occurs.

Attention can be divided between two modalities, such as vision and audition, but the degree of coupling of the control over attention in different modalities is still controversial.[25]

A major aim of selective attention research is to identify the neural loci of attentional control processes, and to reveal the situations in which these processes are used to enhance selection.[19,,26,27] Experiments support the belief that cued global and local target stimuli are selected for more attention in the presence of distractors.[28] During the past decade, functional neuroimaging studies have revealed that widespread regions of a frontoparietal network are involved in selective attention.[29,19] Increased activation of sensory cortices that process attended stimulus features is also associated with selective attention.[30,31] Such activations may be driven by top-down signals from the frontoparietal network, which bias sensory cortical activity in favor of target versus distracter stimuli.[20,30,31] Prior data have indicated a role for frontal, parietal, and occipital cortices in orienting attention toward global and local aspects of hierarchical stimuli.[32,33]

Neuroimaging studies have implicated top-down control mechanisms that activate regions associated with cued attention and distractor incongruency. These show up in the frontal middle, inferior, and medial gyri, the prefrontal gyrus, the superior and inferior parietal lobes, the middle occipital gyrus, the thalamus, lateral global pallidus, the caudate head, cerebellum, nodule and pyramus Regions activated by distracter incongruency, but not by cued orienting of attention, show up in the middle and inferior frontal gyri, the anterior cingulated, the precuneus, the fusiform gyrus, the middle occipital gyrus and the thalamus.[28]

Experiments[34] have been conducted to assess the effect of selective attention on implicit learning,[35,36] that is learning that occurs without intention or conscious awareness. Both attention and learning are fundamental to human perceptual and information processing. Selective attention allows us to pick up behaviorally relevant information and ignore vast amounts of irrelevant information. Failure to attend to critical information reduces the efficiency of sensory, perceptual and cognitive processing. In extreme cases, inattention can make observers functionally deaf and blind. This point is well illustrated by recent research on inattentional blindness.[37] Equally indispensable in perceptual processing are learning mechanisms. For example , people process visual information more efficiently when visual experience provides schemata to organize complex scenes.[38]

Jiang (2001) [34] articulates these concepts well with supportive references in stating the following:

"Implicit learning may allow perceivers to acquire useful information about the structure of the visual world.[39,40] Although these two topics, attention and implicit learning, have largely been investigated separately, they interact in meaningful ways to facilitate visual processing. On the one hand, implicit learning

shapes selective attention. An important factor that determines what gets attended in a given situation is past experience. Gibson[10] *talks about the "education of attention" or, in other words, how attention is affected by perceptual learning. Recently, Chun and colleagues*[39, 40,41,42,43] *have demonstrated that implicit learning of visual context guides attention toward targets in a visual search task. On the other hand, attention also influences the extent of implicit learning. What is learned is partly determined by how much attention is allocated to it.*[44,45] *Thus, there is a bi-directional interaction between attention and implicit learning."*

A typical situation contains many different objectives and objects that compete for neural representation. This is because of the limited processing capacity of the sensorimotor, perceptual, and cognitive systems, The competition among multiple objectives and objects in the brain and cortex can be biased by both bottom-up sensory-driven mechanisms and top-down influences, such as selective attention. Functional brain imaging studies reveal that, both in the absence and in the presence of stimulation, biasing signals due to selective attention can modulate neural activity in the brain and cortex in several ways. Although the competition among stimuli for representation is ultimately resolved within the cortex, the source of top-down biasing signals derives from a network of areas in frontal and parietal cortex.[20]

Event-related fMRI methods help to distinguish between neural networks involved in top-down attentional control processes and those participating in the subsequent spatially selective attentional processing of target stimuli.

Clinical aspects of attention

From a clinical and teaching standpoint it is important to consider the functional elements of attention. In order to pay meaningful attention that leads to meaningful processing and action, there needs to be purpose and reasons that relate objectives to objects of attention. This involves learned skills and applications of attention. Equally important are the mechanisms of attention. Conscious attention uses energy to generate arousal levels of awakeness and alertness to objects or events that are considered pertinent. On one hand, the energy required to concentrate and pay attention is boosted significantly when there is purpose, interest, understanding, skill, and motivation. On the other hand the energy required to concentrate and pay attention is diminished significantly when there is no purpose, interest, understanding, skill, or motivation. However, there are also physical and psychological/emotional components of energy that relate to our levels of concentration. These have to do with individuals' physical and mental health status and their physical strength and stamina and motor controls that are required to stand up to attentional demands required to meet attentional goals. Ill health, fatigue and sleepiness may all affect the quality and quantity of attention adversely, as may levels of mental stress, worry, emotional disturbance and work overload. The motor skills necessary to take us appropriately to areas of regard, combined with the acuity of our sensory systems that affects the clarity of objects of attention are critical to our levels of concentration. No less critical is understanding what it is that needs to be attended to and focused upon.

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