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attention

PHENOMENOLOGY, HISTORY, AND
SCIENTIFIC PERSPECTIVE

The word attention is widely used in our daily language as it serves as a topic of study and scientific debate in experimental psychology. It therefore seems appropriate to begin our review of the study of attention in psychology with two brief quotations from William James's book *The principles of psychology* (1890) (*see* JAMES, WILLIAM). These quotations underline the linkage between the two regimes

of usage, while also dating the scientific interest in the concept to the early days of experimental psychology.

> Every one knows what attention is. It is the taking possession by the mind, in a clear and vivid form of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter-brained state which in French is called DISTRACTION and ZERSTREUTHEIT in German.
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> (pp. 403–4)

When discussing the nature of the attended events William James was careful to observe that:

> The number of things we may attend to is altogether indefinite, depending on the power of the individual intellect, on the form of the apprehension, and on what things are. When apprehended conceptually as a connected system, their number may be large. But however numerous the things, they can only be known in a single pulse of consciousness for which they form one complex "object", so that properly speaking there is before the mind at no time a plurality of IDEAS, properly so called.
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> (p. 405)

Equal weights are given in James's thinking to external and internal objects of attention (see SELF-FOCUS AND SELF-ATTENTION). Objects can be external stimuli such as pictures and tunes or internal events such as specific trains of thought and attempts to retrieve information from memory. There is no unique, fixed, correspondence between stimuli, their properties, and attention objects. Experience, strategy, and individual capabilities may influence the connection between elementary stimulus units, thereby affecting the ways they combine to create a single complex attention object. In this observation William James anticipated by many years the contemporary distinctions between isolated items and chunks of information in working memory, grouping principles and integrality of dimensions in perception, and the development of organized memory and response schemas through practice and training. Each of these larger, many elements units, can constitute a single object of attention (see CHUNK-ING; WORKING MEMORY).

There are other effects of attention. In James's words, the immediate effects of attention "are to make us (a) perceive, (b) conceive, (c) distinguish, (d) remember better than otherwise we could" (p. 424). Six decades later, in his famous series of experiments on the "cocktail party phenomena," Cherry (1957) describes the perceived clarity and intensity, for a person standing in one corner of the room, of a conversation taking place at another remote corner, but is of high interest to him. This is the "work" of focused attention that seems to attenuate and override the physically much louder vocalizations of his own discussion partner and other surrounding parties. Embedded in the claim for such focalization, clarity, and increased processing efficiency is the idea of involved mental effort. This will in later models be argued to be an important determinant of the limits of attention.

Last but not least is the linkage between attention and consciousness. In the thinking of James and his contemporaries, the two concepts were closely linked. Attention determines the content of consciousness, and consciousness, through activation of interest and intent, is the main, though not the sole, guide of attention. Although attention may be "captured" involuntarily by salient features of the environment, in most instances it is directed by conscious intentions (see CONSCIOUSNESS).

The above quotations that describe so vividly one of the basic experiences of which every human is well aware seem also to encapsulate the main observations, topics for research, theoretical concerns, and debates which have motivated a century of scientific study of the concept. Setting out from the basic axiom that the human mind is limited and hence at any one moment only a limited set of the plurality of stimuli available or imposed on the organism can be attended to and processed, experimental psychologists rolled up their sleeves to study attention processes.

How does selective attention operate? What portion of the information can be attended to? Is the control of attention voluntary or involuntary? What is the relationship between attention and consciousness? What is the influence of attention on the focused, relevant information, and what happens to the unattended, irrelevant information? What happens when attention is divided between several concurrent goals; can we do two things at once? What is the nature of attention limitations and the sources of scarcity? What happens when a person is required to maintain attention and concentration for long durations? Is attention a single unified entity, or are there many types of attention (e.g. visual, auditory, motor)? This is a representative list of the main issues with which research has been concerned over the years.

Taken together, the study of attention has come to encompass all manifestations of behavior that involve the active influence of the human mind (which in contemporary terminology is often termed the human processing and response system) on the perception and transformation of stimuli from the outside world, and on the preparation and conduct of response. Aspects of the situation that without training are processed automatically, cannot be selectively ignored even with training, and cannot be shown to interfere with other concurrent processing activities, are termed preattentive and excluded from the study of attention. An example is the perception of the color of an object when the task is only to identify its shape. Preattentive processes have been argued to provide a preliminary organization to perception by a process of grouping and segmentation. The objects of perception are defined at that stage, and subsequent processes operate on these objects.

The study of attention has had its ups and downs as a focal topic of investigation. It was central in the three decades between 1890 and 1920, when psychology was most interested in the study of consciousness and mental activity, and when INTROSPECTION was the main methodological tool. The interest declined and almost disappeared during the following three decades (1920–50), that were dominated by Behaviorism and Gestalt psychology. These schools of thought were more interested in the influence on perception and over behavior of external stimulus properties an sophisticated conditioning methods.

During the following three decades (1950–80), the pendulum had swung again, with cognition and attention having moved to the center of interest in experimental psychology. Our present knowledge and models are most based on the voluminous work conducted during these years. Since the beginning of the 1980s we have been witnessing the start of yet another shift of interest in attention studies. With the advance of computer technology an artificial intelligence, on the one hand, and physiological research on the other, there is growing interest in computational models of brain and behavior, that are mostly driven by the objective properties, probabilities, an time functions of stimulus and response. Attention processes, though not disposed of are superfluous for these models. Thus, th pendulum swings again (see ARTIFICIAL INTELLIGENCE).

THE STUDY OF ATTENTION

The interests, findings and models in th study of attention over the last three decade are best represented in the 13 volumes of *Attention and performance* published biannually since 1967. They present the papers and discussions from the meetings of the International Association for the Study of Attention and Performance, which was established in 1966 in The Netherlands. The following is brief summary of paradigms and major topic of study and debate.

EXPERIMENTAL PARADIGMS

Experimental paradigms in the study of attention may be categorized along several leading dimensions.

Time One dimension is time, distinguishing between studies concentrating on the short term, immediate effects of attention on performance, and studies interested in long duration tasks of sustained attention. The first an

the larger group is interested in the micro analysis of single or short-term processing cycles, such as the ability to focus attention on, and process information from, one of several distracting elements, or divide attention between two concurrently performed tasks. Sustained attention studies concentrate on the long-term time function of attention, lapses and cycles of attention, and the ability to maintain vigilance and alertness over long periods of time. Typical examples are radar observers and prolonged shifts of air traffic controllers. These studies are closely linked to the research on diurnal cycles of arousal and physiological activity, and examine the effects of such variables as sleep deprivation and background noise.

Type of task Experimental tasks can be generally classified into the filter paradigm and the selective set paradigm (Kahneman & Triesman, 1984). In the filter paradigm, the subject is exposed simultaneously to relevant and irrelevant stimuli. The relevant stimuli control a relatively complex process of response selection and execution. The property that differentiates the relevant from the irrelevant stimuli is different from the property that determines the response. An example is the shadowing of a string of words presented through one speaker while ignoring concurrent strings presented through another speaker. The main measure of performance is accuracy. In the selective set paradigm the subject is prepared for particular stimuli and is instructed to indicate by a speeded response the detection or recognition of those stimuli. Thus, the subject chooses which of several possible stimuli to anticipate or search for rather than which of several actual stimuli to analyze. An example may be a designation of a small set of letters, the existence of which should then be detected in brief exposures of arrays comprising both relevant and irrelevant letters.

Attention assignment The main distinction is between performance of tasks under *focused* or *divided* attention instructions. Tasks of focused or selective attention are used to study the resistance to distraction and to establish

the locus beyond which relevant stimuli are treated differentially. Divided attention tasks are used to assess the limits of performance and the extent to which different concurrent tasks can be performed or combined without loss (*see* DUAL-TASK PERFORMANCE).

Stimulus and response characteristics There are large variations in the selection of stimuli and responses and in the choice of variables along which they are manipulated. These are usually reflecting the specific domain of interest of the researcher. Tasks may vary in the modality of presentation, physical properties, semantic attributes, and type of responses. This variability is an important contributor to the identification of communalities and differences in functions of attention.

SELECTIVE ATTENTION AND THE NATURE OF ATTENTION LIMITATION

Where is attention limited? One of the major topics for study and modeling was the locus of selective attention: the mechanisms, processes, and stages at which selection operates. Models have differed in their emphasis on early versus late selection. Early selection models maintain that the main problem facing the organism is the richness and complexity of information presented to the senses at any one time, which may confuse and overload high-level processing mechanisms. The mind is limited on the processing side. Using preattentive physical features such as spatial location, auditory pitch, and color, selective attention is likened to a filter which attenuates and excludes irrelevant information from further analysis of meaning, or storage in long-term memory. Most noted of the early selection models was the "filter model" proposed by Broadbent (1958). A wide variety of experiments, mostly employing the "filter paradigm," showed evidence in support of early selection. Thus, for example, subjects required to listen and repeat verbal information presented to one ear were unable to report the content or language of irrelevant messages presented simultaneously to the other ear, though they could identify the pitch and gender of the speaking voice. Similar findings were reported for other modalities.

Late selection models have contested the assertions of early filtering by designing experiments and tasks that demonstrated high-level analysis of all simultaneous information, both relevant and irrelevant. According to these approaches, the bottleneck and confusion are on the response selection side, resulting from the multitude of conflicting response tendencies that are instigated at any one time. Selective attention serves to magnify the relevant response tendency and inhibit competing responses. Supportive experiments primarily followed the "selective set" paradigm: they showed, for instance, that subjects can search effectively for relevant letters, or identify them in tachitoscopic presentations, in stimulus arrays containing both relevant and irrelevant letters. This is even if all stimuli are of the same modality and type, thus precluding the operation of perceptual filters.

Recent discussions have concluded that the human is modular, and the locus of selection is strategic and task dependent rather than fixed. It is adapted to the features of the situation and the nature of the required response. It can hence be early, late, or both.

How is capacity limited? What is the nature of attention limitations, and what are the sources of failures to process and attend? Models differ in their emphasis on structural versus capacity limitations. Structural models postulate that processing mechanisms and operations operate in an all-or-none fashion. Attention controls the scheduling and access of competing tasks to the limited mechanisms. Problems also arise when the inputs, throughputs, or outputs of competing tasks are hard to distinguish, so that the scheduler is confused.

Capacity, or resource approaches, emphasize the intensive costs of mental operations. The human processing system is conceptualized as an ensemble of limited capacity mechanisms – processing resources which can be allocated in various shares to the performance of tasks. A mechanism can serve several tasks simultaneously if their joint demands do not exceed its available capacity. This approach has been termed "energetic" because it is concerned with task demands, men-

tal effort, and notions of scarcity in energy and space of mental operations, as sources of attention failure. Scarcity of resources has a central position in capacity models, while the only scarce resource in structural models is time. By their nature capacity models are more interested in short- and long-term modulations of the physiological mechanisms of arousal. They also emphasize a detailed study of mental effort. These interests constitute a first step toward building a bridge, that has hitherto been missing, between the study of the microstructure of attention and models of performing long duration sustained attention tasks. In these tasks, arousal, motivation, and voluntary effort play a major role.

At present, there seems to be sufficient experimental evidence to support the effects of both structural and capacity factors on performance. However, there is still an ongoing debate as to which model accounts for larger portions of the phenomena and performance variability.

ATTENTION CONTROL

Attention mechanisms and attention control appear to play a major role in the performance of new and changing situations and in the acquisition of new skills. When the situation remains constant and experience is accumulated, consistent modes of processing and response emerge. Behavior becomes more automatic and attention demands are reduced. Contemporary research has shown that efficient control of attention in complex situations is a skill that can be trained and improved. Humans have limited knowledge on the efficiency of their efforts. They can be trained to develop better attention allocation policies, and strategies of coping with concurrent complex demands.

INDIVIDUAL DIFFERENCES

Consistent individual differences in basic attention capabilities have been reported by several researchers. The main dimensions of differences were in the ability to switch attention rapidly upon request, and in attention flexibility. These differences were used to construct tests of selective attention which have been found to predict success in flight

training, differentiate between high- and low-ability pilots, and predict accident proneness of bus drivers.

ATTENTION AND WORKLOAD

Attention theory and attention mechanisms are the building blocks for the study of mental workload, which is of major concern to engineering psychology. The complexity and high number of information sources in modern engineering systems impose high processing and decision demands on the human operators and push them to their limits. Interest in the study of attention is thus as strong in the applied domain as it is in basic research.

See also ATTENTION, INHIBITORY PROCESSES IN; AUDITORY PERCEPTION.

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