Attention

Introduction

The study of attention has importance that is at once historical, theoretical, and applied. From a historical perspective, over a century ago William James, the founder of American psychology, devoted a full chapter to the topic in his classic textbook, Principles of Psychology (1890). Interest in attention as a field of psychological study waned during the behaviorist period in the first half of the century when attention was improperly dismissed as a mediating mental variable that could not be directly measured and was therefore outside the bounds of scientific inquiry. Nevertheless, even during this time a few classic studies such as Jersild’s (1927) and Craik’s (1947) work on attention switching were published. Then, following World War II interest in the topic blossomed, as is discussed in the next chapter, so it remains a fundamental element of psychological research to this day.

The theoretical importance of attention can be seen at two different levels. First, as one of the three main limits on human information processing (along with storage—memory and speed—response time), the study of attentional processing capacity is of fundamental interest in its own right: How many tasks can we do at once? How rapidly can we switch from task to task? How widely can we deploy attention across the visual field? Second, attentional properties underlie many other psychological phenomena: Attention is necessary to hold information in working memory and to efficiently move information to long-term memory, that is, to learn it. It is a vital component underlying decision making and is integrally related to perceptual processing.

The applied importance of attention is also manifest in several ways. For example, the aforementioned fields of memory, learning, and decision making all scale up to real-world problems such as eyewitness testimony, training, choice, and display design, so the attentional components underlying these naturally scale up as well. But attentional challenges and issues also are directly relevant outside of the laboratory: The dangers of distracted drivers, the attentional overload of making sense of massive data bases, the rapid attention switching required in the electronic workplace, the success or failure of unreliable alarms to capture attention, and the behavior of children with attention deficit disorder are all examples.
Varieties of Attention

The word *attention* encompasses a broad array of phenomena. Another founder of American psychology, Titchner (1908, p. 265), in introducing his chapter on attention noted, "The word 'attention' has been employed in the history of psychology to denote very different things" and then went on for a paragraph to list these different meanings. The present book considers several varieties of attention (see also Parasuraman and Davies 1984), which can be illustrated within the context of highway driving. The driver will first want to concentrate, or focus attention, on the driving task, in the face of many possible distractions—competing tasks and nonrelevant events. Thus, focused attention can apply to a task or a particular channel or source of environmental information. Rarely, however, does the driver carry out only one task, but he or she will often select between alternatives—for example, between lane keeping and checking the map. Here, selective attention can be defined either at a gross level, as selecting to devote attention to one task or another, or at a fine level, usually represented by visual scanning, as looking from one place to another. Intrinsic to the concept of selective attention is the notion of an attention switch, which describes the process of moving attention from one task, or channel, to another.

Now, sometimes the driver can succeed at actual multitasking, not by switching between tasks or channels but by actually processing them in parallel (i.e., simultaneously). Here we speak of the success of divided attention, which, like selection, can be described at two levels. At the task level, successful divided attention may include such things as successful lane keeping while understanding a news program or appreciating music on the radio. At the perceptual level, divided attention may involve the parallel processing of two aspects of a stimulus; a quick glance at the well-designed map, for example, can reveal the length of the highway, its direction, and destination, all understood within the single perceptual experience. Correspondingly, a quick glance out the windshield can reveal the color of an oncoming car, its speed, and its heading, all at the same time. It should be noted, of course, that parallel processing or successful divided attention does not necessarily imply that either of these are perfect—only that they are better (usually faster) than a purely serial allocation of selective attention would allow.

Finally, it is possible to speak of sustained attention as that variety of attention mobilized in continuous mental activity, whether that activity appears to be of high complexity (e.g., completing a three-hour final exam) or low (e.g., maintaining the night watch); in either case, there is a toll on human cognition due to trying to mobilize the high effort to perform a task for a long period of time.

In addition to these five varieties of attention—focused, selective, switched, divided, and sustained—it is possible to conceptualize attention metaphorically in two different ways: as a mental filter and mental fuel, both shown in Figure 1.1. The figure represents a conventional information processing
A Simple Model of Attention: The Filter and the Fuel

Figure 1.1 A simple model of attention. The influences on the filter of selective attention are shown, as are the influences of limited resources on the information-processing activities involved in divided attention and multitasking.

model of human performance and highlights the more perceptual aspects of attention as being the front-end filter, selecting certain stimuli or events to be processed and filtering others out as less relevant. If selection is aided by divided attention, then two or more channels may gain access to the filter at once. Then, as information-processing activities are carried out on the selected environmental information or on self-generated cognition, limits of the mental resources, or fuel, that supports such processing constrain the number of processes that can be carried out at once. This is true whether in the service of a single task (e.g., holding subsums while doing mental multiplication) or in the service of multitasking. Figure 1.1 presents a view of attention that is simplified but provides a heuristic foundation on which we build throughout the chapters of the book.

Relation to Other Applied Domains

As has been noted already, attention is closely tied to other domains of cognitive psychology, such as memory, learning, and decision making and perception. However, attention also links closely with four important applied domains, which are described briefly here and are revisited at times later in the book.

First, in the study of human error (Holmager 2007; Reason 1990; Sharit 2006) attentional errors, particularly attentional lapses, represent a major important source of cognitive deficit. Second, the lapses of attention are closely related to aspects of situation awareness (Durso et al. 2007; Endsley 1995, 2006;
Tenney and Pew 2007), a concept that has gained and has warranted great popularity within the past two decades. Situation awareness can be characterized as “an internalized mental model of the current state of the operator’s [dynamic] environment” (Endsley 2006, p. 528). In particular, it is conventional to break situation awareness into three levels or stages: (1) noticing events in the dynamic environment; (2) understanding the meaning of those events; and (3) predicting or projecting their implications for the future. Here, stage 1, noticing, clearly depends on effective deployment of the attention filter. Stages 2 and particularly 3 are resource intensive, if it is done well: An operator who fails to anticipate future events because of high concurrent task load will not succeed well in dealing with those future events.

Third, the study of mental workload has been another popular area of applied interest within the past twenty years, as designers endeavor to create systems in which the human mental resources required to operate these systems remain less than the available resources; that is, the fuel in Figure 1.1 is not depleted by mental operations so that there is always some residual in the tank to handle unexpected emergencies. Thus, the study of mental workload calls for ways to measure the fuel — both expended and remaining — and to reduce the demands imposed on it.

Fourth, with the increasing sophistication of computers and technology, often created with the goal of reducing mental workload, has come the issue of human–automation interaction (Sheridan 2002; Sheridan and Parasuraman 2006). Two aspects of attention in human–automation interaction are directly linked to situation awareness and workload as described already. First, a major impetus for introducing automation in the first place is the desire to reduce workload. At the individual human level, this may be to prevent human operator workload overload, as when an autopilot can offload the pilot allowing her to concentrate on many other task responsibilities. At a level of macroergonomics, automation and workload are related by manpower concerns: If the function of one member of a three-person crew is automated, an operation can then be conducted that has a 33% reduction in personnel costs. Second, it is now well established that high levels of automation that are designed to reduce workload also reduce operator awareness of the processes that are automated but over which the human may still have full responsibility. Such a reduction in situation awareness is often mediated directly by attention, as the human may cease paying much attention to the automated processes — a potentially catastrophic behavior if the automation fails or if other processes under control of the automation go wrong.

Scaling Up Basic to Applied Research

As noted already, attention is a psychological construct that binds basic and applied issues. In this regard, the reader will note the effort made here to treat both endpoints of this continuum as well as the full range of studies and issues in between. If both endpoints of this continuum are examined, at
one end is seen elegant and well-controlled theoretical work, conducted with no specific application in mind and, because of high control, often showing effect sizes that are no larger than a few milliseconds but highly significant in statistical terms. At the other end are seen analyses of many real-world accidents or incidents that are clearly related, in part, to attentional breakdowns (e.g., 10–50% of automobile accidents are related to distraction [Weise and Lee 2007]). But because of the lack of control over the collection of such data, it is impossible to preclude other contributing causes or to draw strong causal inferences.

The challenge in engineering psychology, the domain that represents the spirit of this book is to link the two endpoints. How do we extract the theory-based attentional phenomena and identify which ones scale up to account for real-world attentional failures and successes? How much variability do these well-controlled phenomena account for in the world outside the laboratory? Most critically, how well can the independent variables that modulate the strength of attentional effects in the laboratory be captured by design and training variables in the real world of human interaction with complex dynamic systems, where attention plays such a vital role?

An issue that grows in importance as one moves from more basic to more applied research is the distinction alluded to previously between statistical significance, typically defined in terms of the $p$-level of a statistical test, and practical significance, defined by the size of an effect in raw units (Wilkinson 1999)—for example, one second saved in the braking time in an automobile—by adopting a recommendation from attention research, like providing a head-up display or auditory display, or a 20% reduction in accident rate. Whereas basic research is typically most concerned with statistical significance, applied research must give equal concern to both types. After all, an intervention that only saves 1/100 of a second in braking response time in the automobile will be of little benefit, even if it may be significant at a $p < .05$ level. On the other hand, a manipulation that offers a potential one-second savings may be of tremendous importance to more applied researchers even if it has not quite reached the conventional $p < .05$ level effect of statistical reliability (Wickens 1998) but still is close to that level. In this regard, it is important to note that applied researchers cannot afford to ignore statistical significance—only that they must temper their concern for statistical significance with an appreciation of practical significance.

Importantly, there are two phases to the process of the scaling-up findings from the lab to application. First, it is important to show how laboratory phenomena in attention express themselves in real-world scenarios. Second, but equally important, is to devise attention-based solutions to enhance productivity and safety in these environments. The following chapters try to show how this is done by integrating across the basic-applied continuum.
foundations of a general model of how tasks interfere or compete with each other when people must divide attention between them: interference caused by their difficulty and their similarity. In addition, chapter 5 also highlights the critical role of effort in single task behavior, such as decision and choice, to the extent that humans tend to be effort-conserving in their choice of activities. Chapter 9 examines how multiple tasks are managed in a discrete fashion.

Chapter 10, “Individual Differences in Attention,” considers the role of ability differences, age differences, and training differences in attention with emphasis on the real-world implications of such differences to areas such as training, licensing, selection, and user support. Chapter 11, “Cognitive Neurosciences and Neuroergonomics,” focuses on brain mechanisms underlying attention but does so in a way that the practical applications of these mechanisms are clear.

Within each chapter, we try to maintain a balance between theory and applications, although occasionally we may veer more one way than another. Our hope is that the book will stimulate basic researchers to understand the importance of their work in the world beyond the laboratory and perhaps to goad them into tackling some of the complex problems that exist there—driving and cell phone usage has been a beautiful success story in this endeavor. Equally, we hope that those involved in applied human factors area of design and measurement can appreciate the importance of attention and the value of good science underlying attentional phenomena in exercising their careers.