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# 1 What Is Attention?

## Learning Objectives

- Identify key figures in the history of attention research
- Compare and contrast basic functions ascribed to attention
- Describe classic experimental paradigms used to study attention
- Understand how attention research developed over time and its current directions

## 1.1 "Everyone Knows What Attention Is . . ."

In probably the most famous quote in the history of attention research, the preeminent psychologist William James (1890), shown in Figure 1.1, began his description of attention with the phrase "Everyone knows what attention is." This presumed familiarity has led to the ubiquity of the concept of attention in our vernacular but has also complicated research into the topic. The problem is that although everyone "knows" what attention is, there are a variety of mental processes that are subsumed under this term. A focus of this book will be to differentiate the neural mechanisms that make up the many different components of attention, as well as to explain why these varied processes are lumped together under the powerful umbrella term of "attention."

James' extended quote touches upon several of the most relatable aspects of attention and conveys some of the subjective "feel" of attention:

> Everyone knows what attention is. It is the taking possession by the mind, in 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, scatterbrained state which in French is called *distraction*, and *Zerstreutheit* in German. (William James (1890), *Principles of Psychology*)

The following sections of this chapter will introduce and provide background on the core processes highlighted in James' quote, including the unitary focus and selectivity of attention ("withdrawal from some things in order to deal effectively with others"), the phenomenological feeling of peak alertness ("a real opposite in the confused, dazed, scatterbrained state"), and the association with conscious awareness ("taking possession by the mind"). In the century since James' quote, many other processes associated with attention have become the focus of intense



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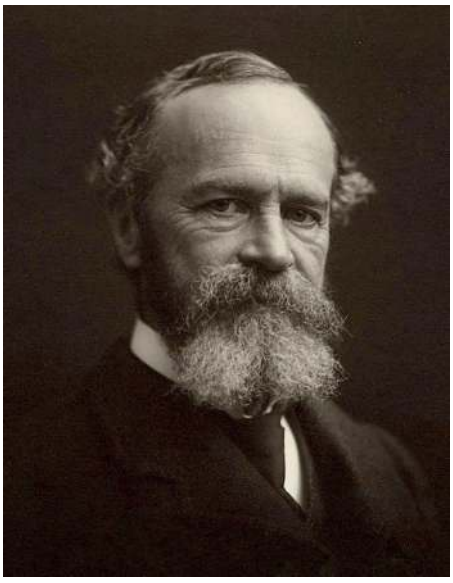

**Figure 1.1** William James. *Source:* Image from MS Am 1092 (1185), Houghton Library, Harvard University (public domain).

research efforts. As discussed later, these include the ability to sustain performance on a task for prolonged periods of time, the binding of multiple features together in object perception, and the increasingly common misperception that we can accomplish more by multitasking. Before moving on to discuss the role of attention in many aspects of our everyday lives (Chapter 2), this chapter will provide historical background into the research that set the stage for current cognitive neuroscience studies that are revealing the brain mechanisms of attention.

## 1.2 Prehistory of Attention Research: Philosophy and Psychology Precursors

Attention, as a phenomenon, was of interest to philosophers long before psychology became a scientific field of experimental research. As Williams James' quote suggests, it seems that everyone knows what attention is, even without empirical research into the topic. Attention has, however, been particularly hard to pin down when it comes to defining exactly what it is and understanding the brain mechanisms that support it. There are writings, from as early as the seventeenth century, showing that philosophers were grappling with just what attention is (Figure 1.2). In one of the earliest works to note the importance of attention, Nicolas Malebranche discussed how attention is critical because without such a mechanism, our perceptual apparatus would overwhelm our minds with a flood of information. Malebranche wrote: "It is therefore necessary to look for means to keep our perceptions from being confused and imperfect. And, because, as everyone knows, there is nothing that makes them clearer and more distinct than attentiveness, we must try to find the means to become more attentive than we are" (Malebranche, 1674, as translated in Nadler, 1992). Malebranche was also among the first to suggest that we don't have direct access to the external world itself, but rather just to our

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**Figure 1.2** Picture of writing with a quill pen. There has been interest in the topic of attention for centuries, with written records from philosophers dating back to the seventeenth century. *Source:* Getty Images; Creative #: 466268089; credit: aluxum.

mental representations of the world. His writings reveal that the importance of attention for focusing the mind was appreciated centuries ago, long before scientific experiments began to investigate the brain mechanisms underlying these critical processes.

Another aspect of attention that was of interest to early philosophers was the link between sensation and consciousness. In the early 1700s, Gottfried Wilhelm Leibniz developed the concept of *apperception*, which held that there was a stage of processing at which current sensations were linked to previous experiences. According to this view, attention was a critical link that allowed sensory experiences to move into conscious awareness. Furthermore, this ability to link sensation to memory was thought to allow us to form a concept of "self" that experiences these things. Leibniz thus thought of attention and the linking of sensation to *consciousness* as central to who we are. The eighteenth-century philosopher Johann Friedrich Herbart explored the idea of *involuntary* influences on attention and consciousness. He suggested that unconscious processes linking dormant concepts in the mind to the information currently being attended could allow those additional concepts to break through to consciousness. Furthermore, in his theories on educational practices, Herbart emphasized the effectiveness of tailoring instruction to account for these processes for deepening the understanding of what was being taught (reviewed in Kenklies, 2012).

In the late nineteenth century, William James wrote his famous book that covered a variety of psychological processes and that included the quote presented at the start of this chapter. In addition to the important concepts highlighted in that quote, James also differentiated between multiple types of attention in his book. He distinguished between attention to stimuli currently impinging upon the sensory organs ("sensorial attention") versus attention to representations

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in the mind that were not physically present ("intellectual attention"). This latter type of attention has become an area of renewed interest, especially in recent studies of mind wandering. Indeed, James suggested that the ability to control this wandering had important implications, noting that "the faculty of voluntarily bringing back a wandering attention, over and over again, is the very root of judgment, character, and will" (James, 1890). In addition to this potential index of ones' character, James was more specific about the effects of attention, suggesting that it "makes us: a) perceive, b) conceive, c) distinguish, d) remember better than otherwise we could." (We will discuss each of these effects of attention in more detail in Chapter 5.) Later in the text, James added a fifth effect of attention – the shortening of reaction time – that related to the earlier work of Franciscus Donders and opened the possibility that attention could be investigated empirically. Following these early advances, however, the topic of attention was largely neglected in the following 50 years (see Box 1.1).

Franciscus Donders, a nineteenth-century doctor and professor of physiology, had an important and lasting impact on the study of cognitive processes. Much of his fame in the

### Box 1.1 Why attention disappeared in the early twentieth century

The quote from William James presented at the beginning of this chapter is one of the most famous quotes in all of psychology. With eloquence and depth, it describes the multifaceted functions of attention in a way that continues to resonate with people over a hundred years later. This could have been the spark that ignited interest in the cognitive abilities of the mind and spurred a flood of research into understanding the mechanisms of attention. Instead, almost no progress was made for decades. In much of the 60 years following the publication of James' *Principles of Psychology*, attention was ignored as a topic of scientific research. Why? In a word, "**behaviorism**." For the first half of the twentieth century, behaviorism dominated the field of psychology. Although not created to directly oppose William James' focus on describing the functions of the mind ("functionalism"), behaviorism as a school of thought didn't have room for the mental concepts James described. Behaviorism developed in part as a reaction to "structuralism," the school of thought that largely dominated psychological research in the late 1800s. Developed initially by Wilhem Wundt for use in the first experimental psychology lab, and expanded and championed by Edward Titchener, structuralism relied upon the method of *introspection*. As a method of research, introspection in the 1800s was quite different from how it is considered today. When we refer to introspection now, we typically mean that we're simply doing some self-reflection or thinking about our own thoughts. In psychology labs in the 1800s, however, introspection was defined in a much more restrictive sense. Introspective reports in those studies were acceptable only if they met certain strict criteria for describing the mental experience of a perception (e.g., its quality, intensity, duration, or clearness) without relying on simple verbal labels of the items' physical attributes (i.e., what Titchener referred to as the "stimulus error"). Furthermore, different labs had somewhat different criteria for what was acceptable as an introspective report, which made replication across labs difficult. Although structuralism intended to probe many of the mental functions that we continue to find important to this day

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**Box 1.1 (cont.)**

(e.g., perception, thinking, emotions), the subjective nature of what constituted a "correct" introspective account frustrated other researchers interested in psychology. John Watson, B. F. Skinner, and other psychologists of the time felt that the reliance on subjective reports in structuralism was a fatal flaw. Instead, they suggested that one must focus exclusively on overt, objective, easily identifiable, and unambiguous behavior if one wanted to make progress in understanding psychology. Thus, behaviorism was born in the early twentieth century and enjoyed success, as experimental results were easily replicated across labs. This ease of replication, along with its quantitative results and its rapid progress in advancing the understanding of learning processes, helped behaviorism to dominate psychology research. For the next 50 years, research into the human mind was largely restricted to what behaviorists believed were tractable issues, which did not include ill-defined mental processes such as attention. As developed by Watson and Skinner, behaviorism was largely "anti-mentalistic." According to this viewpoint, mental phenomena like attention and consciousness were not worthy of scientific study, because such concepts did not have distinct and easily observable behaviors that could be unambiguously measured in a quantitative manner. Fearing that investigation into such concepts would only lead back to the inconclusive and idiosyncratic results that structuralism produced, the behaviorists strongly argued that psychology need only concern itself with overt behavior. Thus, for much of the decades from 1900 to 1950, concepts such as attention, language, and consciousness were largely ignored in psychology research. Despite William James' cogent description of the complex, multifaceted mental experience of attention, it took a revolution (the "cognitive revolution" – see Section 1.3) to allow attention to become a focus of scientific study.

area of psychology comes from his work on vision and the eye. In the mid-1800s he described processes of vision (e.g., refraction, accommodation, convergence) and eye abnormalities (e.g., astigmatism, presbyopia) in ways that are still useful today. His most critical contribution to the study of attention, however, wasn't related to his groundbreaking work on the eye, nor was it achieved through theories or experiments on attention. What Donders did that had a huge impact on attention research, and all of cognitive psychology, was to introduce the concept of **mental chronometry** – studying the timing of mental events. Donders had the critical insight that, although mental events could not be directly observed, the effects of mental events on overt behavior could be observed, and in highly precise and replicable ways if measured correctly. Implicit in his approach was the critical assumption that mental events take *time*, in stark contrast to a prevalent idea at that time that thoughts proceed at infinite speed. Donders' methods were based on the ideas that the amount of time required for a specific mental process should be consistent whenever engaged and that this time could be precisely quantified. In 1868, Donders published a study in which he used reaction times to show a consistent difference in the time it took subjects to respond to simple-response tasks compared to choice-response tasks (Donder, 1868/1969). In one of these, subjects were to make a rapid manual response to the appearance of a spot of light. In the simple-response task, subjects made

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the same response (e.g., button press with one hand) regardless of the color of the light; in the choice-response task, subjects responded differently to a red light versus a white light (e.g., right hand response to red light, left hand to a white light). Donders proposed that he could thus isolate a particular mental process by comparing two conditions, in which the process of interest was present in one task but removed from the other. Critically, all other aspects of the stimuli and task were the same, thus only the added process of interest should be different. This design was later termed the **subtractive method**, because by subtracting subjects' response times between the two conditions (e.g., choice task minus simple task), the resulting difference would be the time needed to perform that specific mental operation (e.g., the process of deciding which hand to respond with). Through precise measurement of response times, he was thus able to quantify how long that choice process took (154 ms in that particular experiment). It should be noted that the aspect of Donders' approach referred to as "pure insertion," in which an additional mental event can be inserted into a task without affecting in any way the other processes involved, has been shown in subsequent work to be an oversimplifying assumption, because there are often interactions with other mental processes when any process is added. More advanced analytical methods, however, can account for these interactions, so that meaningful measures of the timing of mental events can be obtained. Donders' development of mental chronometry was a critical step in allowing scientists to study the mental processes that philosophers had theorized about for centuries but that psychologists had avoided because there hadn't been a reliable and quantifiable way to measure such processes. With mental chronometry and the strategy of isolating mental events through comparison of well-controlled conditions, the pieces were in place to begin the scientific study of attention. But before cognitive psychology could flourish as a field, the dominating school of thought in psychology in the late nineteenth and early twentieth centuries, behaviorism, had to be challenged.

## 1.3 The Cognitive Revolution (1950s)

Psychology research during the early decades of the twentieth century was dominated by "**behaviorism**" and its focus on investigating psychology and learning through highly controlled studies in nonhuman animals. As opposed to the sometimes-vague concepts and variable methods associated with Titchener's structuralism, dominant in the late nineteenth century, behaviorism provided clear aims and reliable and replicable experimental results. Behaviorism provided important insights into the learning process, from Ivan Pavlov's classical conditioning experiments in the late 1800s (e.g., a dog salivating at the sound of a bell, after it has learned that the bell is associated with delivery of food) to B. F. Skinner's (1938) work on operant (or instrumental) conditioning (i.e., using reinforcements or punishments to strengthen, reduce, or shape a response). Behaviorist approaches to the study of learning dominated the field of psychology in the first half of the twentieth century, and strong adherents of this approach such as John Watson and B. F. Skinner proposed an anti-mentalistic view of psychology. According to this view, it was unnecessary to consider unobservable mental events, because the behaviorist study of stimulus–response contingencies and schedules of reinforcement was all that was needed to understand human psychology and behavior.

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By the mid-1950s, however, doubts were beginning to arise about whether behaviorism was a sufficient means to understand human psychology. These doubts were fueled by a number of different events at that time. The "cognitive revolution" in psychology refers to the seismic shift in the focus of psychology research from the anti-mentalistic behaviorist tradition that dominated psychology research through most of the early twentieth century toward an interest in the internal mental states associated with thinking and the cognitive processes of attention, memory, language, and decision-making.

One highly significant event was World War II. As part of efforts to enhance the effectiveness and safety of troops, learning principles from behaviorist studies were applied to soldiers' training. However, the actions of soldiers and pilots during the war revealed that aspects of the training didn't always translate well to the battlefield. Well-trained soldiers would sometimes make mistakes in the field – or in the cockpit – that weren't easily explained by behaviorist theories. This resulted in a renewed interest in the other mental events, such as attention, which had long been theorized to play a crucial role in cognition but which had been largely ignored by behaviorists through the first few decades of the 1900s.

During the mid-1900s, researchers were also finding results that were at odds with core principles of behaviorism. For instance, in the cheekily titled article "Misbehavior of Organisms" (a play on Skinner's famous book from 1938 titled *The Behavior of Organisms*) the authors (Breland & Brelend, 1961) start off by saying, "There seems to be a continuing realization by psychologists that perhaps the white rat cannot reveal everything there is to know about behavior." They proceeded to report on multiple cases in which animals, of multiple species, were not behaving in the ways they had been trained, even though operant conditioning principles had been strictly followed. They describe numerous cases in which the training was initially effective in one specific context, but that over time, or in other circumstances, the animals began "misbehaving" and not performing the trained actions. The authors realized that these cases of misbehavior usually involved the animals reverting to natural instincts, and according to behaviorist principles, instincts, or any behavior that is not learned through conditioning, should not be able to trump the conditioned behavior. In one example, chickens were trained to "bat" a baseball that was set up on a tiny baseball field, complete with toy players and an outfield fence. Next to the field was an open cage, and the chicken was trained to go to one side of the cage and pull a string that was attached to a small bat, which would swing and hit a ball that was rolled out at one end of the field. If the batted ball rolled through to the other end and hit the fence, the chicken would receive a reward, which they picked up from a feed hopper at the other end of the cage. The chickens quickly learned to perform this behavior, pulling the string to swing the bat and then moving straight to the feed hopper to collect their reward. But when the environment was changed slightly and the outer cage was removed (the string to pull and the feed hopper remained), the chickens no longer performed as trained. Instead, the sight of the moving ball would excite them, and they would immediately chase it around, pecking at it. In trial after trial, they missed out on any chances for a reward, consistently chasing after and pecking at the ball. The change in environment had seemingly brought out something in the chickens that had never been conditioned by the experimenters but had a strong effect on the behavior, despite it never resulting in a food reward. Such findings revealed that even strict and highly controlled conditioning procedures were insufficient to fully

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understand behavior, especially outside of the laboratory. Together with the reports from World War II of soldiers not being able to perform operations in battle situations that they were highly trained to do, this suggested that something critical was missing from the behaviorist approach. Many argued that this missing piece was the investigation of the internal and "hidden" cognitive processes of the mind.

Another influential event in the 1940s and 1950s was the invention of the computer, along with the rapid development and application of this technology (Figure 1.3). Computers could

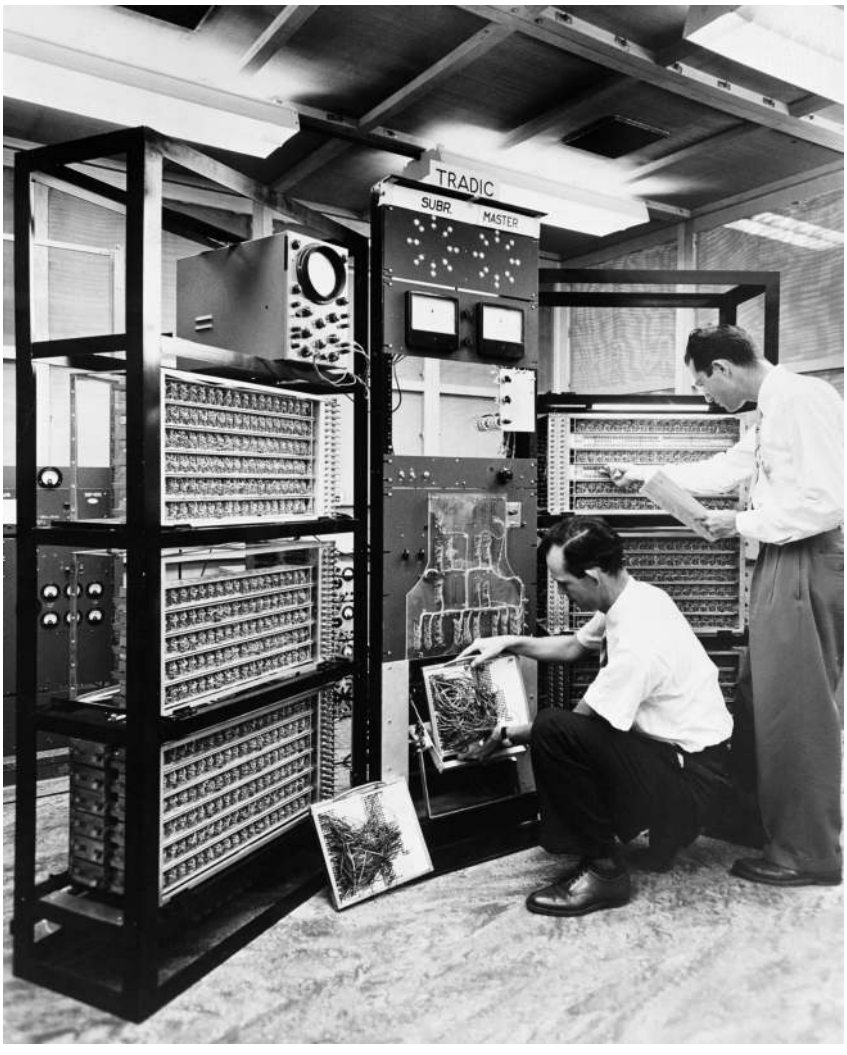


**Figure 1.3** Computer, circa 1954. The first transistorized computer in the USA, named TRADIC (for TRAnsistor DIgital Computer or TRansistorized Airborne DIgital Computer). It was built by Jean Howard Felker (at left). *Source:* Image retrieved from https://commons.wikimedia.org/wiki/File:TRADIC_computer.jpg (public domain).

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be used to perform complex tasks, conducting thousands of calculations with speed and accuracy. With further developments, higher-order information processing tasks (e.g., data processing, manufacturing control, vote tabulations) that used to be done by human workers were taken over by computers. With the realization that computers were performing some tasks as well as humans, it was natural to consider if the human mind might work like a computer. As opposed to the behaviorist viewpoint that an understanding of the human mind required only a complete understanding of stimulus inputs, schedules of feedback, and overt responses, computers needed specific instructions. These programming instructions, or code, had to be highly detailed, specific, and complete. The information processing that a computer performed was entirely dependent upon the code programmed into it. This led psychologists to question the behaviorists' exclusion of innate processes in the human brain and to wonder if it might be possible to discover the "code" that could explain how humans think. They realized that a new focus of research – into the internal mental events of cognitive processes – was needed.

Advancements in computer technology also led to the development of artificial intelligence (AI) research. In 1950, Alan Turing wrote an influential paper discussing the potential use of an "imitation game" to assess the possibility of intelligence in a machine (Turing, 1950). Later called the "Turing Test," the procedure involved asking questions of a machine and seeing if it answered in the same way as a human. Turing began his article with the question "Can machines think?" but then posed the more tractable question of whether a machine could respond in a way indistinguishable from a human. Importantly, the machine was not being tested on whether it would produce correct answers, which could be programmed into it, but rather if it perfectly mimicked human responses. For our purposes, it is interesting that Turing chose to proceed without defining "thinking" or "intelligence." Indeed, his article preceded the establishment of the research field of cognitive psychology, which would go on to investigate those very issues. Therefore, Turing cleverly avoided arguments over the way those complex terms could have been defined and instead stressed that if the machine could answer questions in a way indistinguishable from a human, then it would have attained that aspect of human thinking. Of course, the artificial machine had to be created by hand, with individual pieces of hardware for different functions and many lines of programming code to specify processing steps. The implication was that if we could program an intelligence, then human thinking could be separable into discrete pieces as well, raising the need for a science to investigate exactly what those pieces are. In 1955, Allan Newell, Herbert Simon, and John Clifford Shaw created an AI program that was able to prove mathematical theorems just as well as talented mathematicians (reviewed in Feigenbaum & Feldman, 1963). This provided strong new support for the idea that even complex human thought could be reduced to the manipulation of bits (many, many bits) of information according to a set of formal rules. With this as a sort of proof of concept that mental events could be represented in this way, the doors were opened to a new way of thinking about mental processes in the human brain, and experimental research in cognitive psychology began in earnest.

Another event in the 1950s that highlighted the limitations of behaviorism was a scathing review of B. F. Skinner's book *Verbal Behavior* (1957). Skinner had set out to explain how behaviorist theories of learning could explain human behavior, even something as complex as language (i.e. "verbal behavior"). Almost 2 years after the publication of the book, Noam Chomsky, a prominent linguist, wrote a lengthy review countering Skinner's arguments (Chomsky, 1959).

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One of Chomsky's core criticisms was that Skinner's account of how children acquired language was not feasible; it suffered from a "poverty of stimulus" – meaning that children weren't exposed to nearly enough linguistic information (stimuli) to explain their immense knowledge of language systems and syntax. The explanation, according to Chomsky, was that we must have an innate system in our brains that organizes the relatively sparse linguistic input we're exposed to and allows us to understand the complexities of language, despite the relatively impoverished input. Chomsky called this innate system "universal grammar." As described earlier, the strong influence of instincts in animals undermined behaviorist theories that held that behavior could be explained by conditioning principles alone. Here, Chomsky essentially made the point that something as important as language required a "language instinct" (e.g., Pinker, 1994), further exposing the flaw in the behaviorist approach. Chomsky's review hit a resonant chord with scientists who were interested in the processes of human thinking and were finding the theories and methods of behaviorism to be insufficient. These scientists thus began to focus on internal mental processes and to develop the fields of cognitive science, cognitive psychology, and cognitive neuroscience.

Before completely leaving the topic of behaviorism, it must be acknowledged that the learning principles discovered through these methods were clearly important findings that remain highly relevant to this day. Furthermore, many experimental procedures and designs developed by behaviorists are in use today, such as in important studies of addiction and the brain basis of some psychological disorders. But the strict exclusion of any research into internal mental events by early behaviorists has thankfully been put to rest. It should also be noted that although B. F. Skinner largely dismissed the importance of trying to study internal mental events, even he noted a few important aspects of attention. In his influential book *Science and Human Behavior* (Skinner, 1953), he commented on the role of attention in mediating between a stimulus and a response: "But attention is more than looking at something or looking at a class of things in succession . . . Attention is a controlling relation – the relation between a response and a discriminative stimulus" (p. 123). Since behaviorists were very much concerned with stimulus–response contingencies, it is quite the admission that something as vague as attention was given such a critical role. Skinner additionally noted that attention may be important because of the way in which it controls processing of a stimulus: "The control exerted by a discriminative stimulus is traditionally dealt with under the heading of attention. This concept reverses the direction of action by suggesting, not that a stimulus controls the behavior of an observer, but that the observer attends to the stimulus and thereby controls it" (p. 123). Finally, Skinner also commented that there are *involuntary* mechanisms that affect where our attention is focused: "Nevertheless, we sometimes recognize that the object 'catches or holds the attention' of the observer" (p. 122). The interplay of voluntary and involuntary mechanisms on attention will be covered in detail in Chapter 6 of the present book.

## 1.4 The Cocktail Party

As with most topics in the field of cognitive psychology, research into attention began in earnest in the 1950s. One of the first areas of research within the domain of attention centered on understanding "the cocktail party phenomenon." What Colin Cherry (1953), Neville Moray

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