

AUDITORY
COGNITION
AND
HUMAN
PERFORMANCE

RESEARCH AND APPLICATIONS

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CARRYL L. BALDWIN



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Preface

How people acquire and process information has been a fundamental question in psychology since its inception. Cognitive science has devoted much effort to addressing the question, but typically in the domain of vision. Auditory processing has generally received less-extensive inquiry, whether in basic perceptual or cognitive psychology or in applied areas such as human factors. Moreover, even within the field of audition, higher-order auditory processes have received less study than such lower-level processes as loudness and pitch perception (Bregman, 1990; Plomp, 2002). Yet, since the 1990s there has been a growing base of empirical research on auditory cognition and its role in human performance at work and in everyday life. I describe this work in this book.

The notion that listening requires attention and that it can at times be a difficult undertaking is well known to the elementary schoolteacher. Less well appreciated is the effort that we adults must put forth to comprehend auditory information in our everyday lives. Auditory processing relies on mechanisms of the brain as well as the ear. Describing the mental effort involved in these interacting mechanisms is the primary purpose of this book.

I first became interested in this interaction when I was a graduate student studying age differences in mental workload for complex tasks, driving in particular. I had just completed an investigation in which, as I had expected, the classic dissociation between the performance of younger and older participants was observed in the most challenging dual-task conditions, while no performance differences were seen in the single-task or simpler dual-task conditions. Closer inspection of the results, however, revealed that this age difference could be attributed to a small minority of the participants. The overwhelming majority of older participants had not only performed just as well, but in fact many had performed slightly better than their younger counterparts. Conventional wisdom at the time strongly suggested that the performance decrements observed by the small group of older participants were indicative of cognitive impairments. Perhaps this interpretation was true. However, I could not rule out that something else might have contributed to their poor performance. As was also conventional at the time, and sadly remains the dominant protocol, I had not collected basic measures of visual or auditory acuity that would allow me to rule out the possibility that perhaps sensory decrements were contributing to or masquerading as cognitive decrements. Convinced that this possibility must be ruled out before any conclusions could be drawn, I embarked on a series of investigations that has led to my current position on the matter and forms one of the primary themes of this book.

Auditory processing is a remarkable process demanding mental effort and relies heavily on the interaction between sensory and cognitive mechanisms.

There are many people to whom I am grateful for contributing to the development of this book, either directly or indirectly. Gratitude goes to my husband and colleague, Raja Parasuraman, for both encouraging me to write the book in the first place and for his support throughout the entire process. I am also grateful to the

many graduate students who have worked in my lab who have discussed different aspects of the research described in this book and offered valuable comments. Preparation of this book was also made possible by grants that I have received for my research from the National Aerospace and Space Administration, the National Institutes of Health, the Office of Naval Research, and the National Highway Traffic Safety Administration, although the views expressed here are my own and not necessarily endorsed by these federal agencies. Finally, I dedicate this book to Paeton, to who she is now and all she will become. May she forever find solace and joy in the soundscape of life.

About the Author

Carryl L. Baldwin, PhD, is an associate professor at George Mason University, where she directs an auditory research group and the Mason Transportation Institute's Driving Simulation Laboratory. She received her graduate training in human factors at the University of South Dakota in Vermillion, where she began to conduct research leading to her current interests in applied auditory cognition, mental workload assessment, and transportation. She received her undergraduate training from the University of Nebraska–Lincoln, where she developed a strong interest in auditory processing. She has taught classes at Western Iowa Technical Community College in Sioux City, where she was also chair of the Social and Behavioral Sciences Department. She was tenured at Old Dominion University in Norfolk, Virginia, before moving to join the faculty in George Mason's ARCH Lab and Human Factors and Applied Cognition Program. She currently resides in Falls Church, Virginia. She spends her nonworking hours playing music—particularly mandolin and guitar—gathering with friends and family, taking long walks outside, and traveling.

1 Hearing

The Neglected Sense

INTRODUCTION

Being able to hear and understand sounds—auditory processing—greatly enriches our lives and enables us to accomplish many tasks essential to survival. Although we engage in this process continuously throughout our lives, many may fail to appreciate that the seemingly automatic task of auditory processing often involves considerable mental effort to accomplish. Consider the following examples:

Lara is driving down the highway listening to a news program on the radio when she hears the name of her hometown. To better listen to and understand the subsequent story, she turns up the volume on the radio and quits eating popcorn from the sack on the seat next to her.

Johan is really hoping to get a chance to interview for a new position and feels he must show his knowledge of the topics discussed. The restaurant is crowded and noisy, and he struggles to hear so that he can follow the conversation. He concentrates, turns his visual attention to each speaker, and then realizes at the end of the lunch that he has barely touched his food.

In each of the scenarios, the effort required for auditory processing became more evident because it occurred in a situation when the person was engaged in other tasks (i.e., driving and trying to eat lunch). Simultaneous visual demands from the driving task were placed on Lara, and she chose to temporarily shed the task of eating as well as turn up the volume on the radio to allow her to focus more intently on the listening task. For Johan, visual speech cues aided his ability to understand the verbal cues. Auditory processing requires effort, even under the best of listening circumstances, although this effort may go unnoticed until the situation becomes more challenging. Challenges to auditory processing can stem from noisy or degraded listening situations, faint signals, or the concurrent demands of other tasks that must be performed simultaneously. Understanding these relationships is the focus of this book.

People use their auditory capabilities to communicate with each other, to locate sirens, oncoming traffic, and a host of other potentially dangerous objects in the environment. Auditory processing also enriches our lives in countless ways: Consider the pleasure of listening to one's favorite music, the relaxing sounds of a babbling brook, or the heartwarming sound of a child's debut in the grade school choir. Although

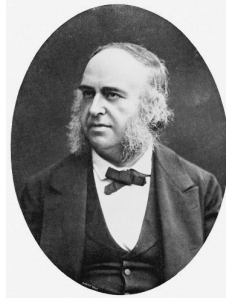


FIGURE 1.1 Paul Broca.

most of us seem to accomplish such tasks with little conscious effort, our ability to process the auditory world around us is nothing less than remarkable.

The human brain, in conjunction with the ear, has evolved in such a way that it enables humans to organize and interpret the complex array of sounds heard in everyday life. Remarkably, we are able to simultaneously segregate multiple sources of sounds into their individual units while combining individual components of each sound stream into meaningful wholes. During the Baroque era (1600–1750), composers such as Johann Sebastian Bach made use of some of these remarkable principles of auditory processing that were evidenced, if not fully understood, to suggest to the listener something other than what was actually presented. For example, Bach used this auditory streaming illusion in his Partita no. 3 for solo violin in E major to suggest two melody lines. This technique came to be known as *virtual polyphony* (Bregman, 1990).

In the 19th century, localized brain structures that had evolved to carry out specific language-processing tasks were identified by the seminal work of physicians such as Paul Broca (Figure 1.1) and Carl Wernicke (Kaitaro, 2001). This early work relating language functions to hemispheric specialization and modular organization of the brain was a significant contributing factor to the development of modern neuroscience (Banich, 2004; Corballis, 2000). However, despite the significance of early contributions in the area of auditory processing, and language processing in particular, the auditory sense has often been less appreciated than its cousin sense, vision.

THE BATTLE OF THE SENSES: VISION VERSUS AUDITION

In his engaging essays, *The Five Senses*, Gonzalez-Crussi (1989) reminded us that Aristotle first noted that sight and hearing were what distinguished humans from the animals because it was these two senses, he argued, that allowed the unique human ability of aesthetic appreciation—of art and music—a quality that animals and robots lack. Although Aristotle’s argument can be debated, most people seem to agree with the supremacy of vision and of the secondary role of audition.

If you could only retain one of your five senses, which one would you choose? Over the last several years, I have posed this question to hundreds of students in my sensation and perception classes, asking them to choose the sense (among sight, hearing, taste, smell, or touch) that they consider most valuable and cherished. Generally,