Hearing Research 349 (2017) 76–89

Contents lists available at ScienceDirect

Hearing Research

journal homepage: www.elsevier.com/locate/heares

Review Article

Effects of noise on speech recognition: Challenges for communication by service members

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ARTICLE INFO

Article history:
Received 10 August 2016
Received in revised form
5 October 2016
Accepted 11 October 2016
Available online 12 October 2016

Keywords:
Speech
Communication
Hearing-in-noise
Noise exposure
Hidden hearing loss
Military
Service member
Occupational noise

ABSTRACT

Speech communication often takes place in noisy environments; this is an urgent issue for military personnel who must communicate in high-noise environments. The effects of noise on speech recognition vary significantly according to the sources of noise, the number and types of talkers, and the listener's hearing ability. In this review, speech communication is first described as it relates to current standards of hearing assessment for military and civilian populations. The next section categorizes types of noise (also called maskers) according to their temporal characteristics (steady or fluctuating) and perceptive effects (energetic or informational masking). Next, speech recognition difficulties experienced by listeners with hearing loss and by older listeners are summarized, and questions on the possible causes of speech-in-noise difficulty are discussed, including recent suggestions of "hidden hearing loss". The final section describes tests used by military and civilian researchers, audiologists, and hearing technicians to assess performance of an individual in recognizing speech in background noise, as well as metrics that predict performance based on a listener and background noise profile. This article provides readers with an overview of the challenges associated with speech communication in noisy backgrounds, as well as its assessment and potential impact on functional performance, and provides guidance for important new research directions relevant not only to military personnel, but also to employees who work in high noise environments.

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http://dx.doi.org/10.1016/j.heares.2016.10.004

Abbreviations

AAA	American Academy of Audiology
AAO	American Academy of Otolaryngology
AAO-HNS	American Academy of Otolaryngology-Head and Neck Surgery
ABR	auditory brainstem response
AI	articulation index
BKB	Bamford-Kowal-Bench
CST	Connected Speech Test
DALY	disability adjusted life year
DoD	Department of Defense
DPOAE	distortion product otoacoustic emissions
ESII	extended SII
FMB	fluctuating masker benefit
HINT	Hearing in Noise Test
HPD	hearing protection device
MR	masking release
NIHL	noise-induced hearing loss
NIOSH	National Institute for Occupational Health
OSHA	Occupational Health and Safety Administration
PTA	pure tone average threshold
PTA-512	pure tone average threshold at 500, 1000, and 2000 Hz
PTA-5123	pure tone average threshold at 500, 1000, 2000, and 3000 Hz
PTA-1234	pure tone average threshold at 1000, 2000, 3000, and 4000 Hz
PTS	permanent threshold shift
QuickSIN	Quick Speech-In-Noise test
R-SPIN	Revised Spin test
RSIR	Revised Speech Intelligibility Rating
SDT	speech detection threshold
SII	speech intelligibility index
SIR	Speech Intelligibility Rating
SNR	signal to noise ratio
SPIN	Speech Perception in Noise
SPRINT	Speech Recognition in Noise Test
SRT	speech reception threshold, also termed the speech recognition threshold
STI	speech transmission index
TTS	temporary threshold shift
VA	Department of Veteran's Affairs
WHO	World Health Organization
WIN	Words in Noise test
WR	word recognition

1. Introduction

Noise-induced hearing loss (NIHL) and noise-induced tinnitus are the two most prevalent compensated disabilities for the Department of Defense (DoD) and the Department of Veteran's Affairs (VA) in the United States (Institute of Medicine, 2005; Yankaskas, 2013), in addition to their prevalence as significant public health issues for the civilian population (Nelson et al., 2005; Rabinowitz, 2012). Across regulatory agencies, there is a wealth of information on the importance of hearing conservation programs, with particular emphasis on engineering controls to reduce sound at its source, the implementation of administrative controls to reduce the duration of exposure for individuals, and personal protective equipment use when it is not feasible to reduce noise levels. In addition to these direct strategies for hearing loss prevention, hearing conservation programs are required to include education on the effects of noise on hearing, noise monitoring, and annual audiometric testing. Specific regulations related to each of these areas are codified for those employed by general industry (OSHA, 1983), mining (MSHA, 1999), railroads (FRA, 2007), and the Department of Defense (DoD Instruction 6055.12, 2010). Additional guidance on best practices is available from a variety of sources, such as the National Institute for Occupational Safety and Health (NIOSH, 1998), the Council for Accreditation in Occupational Hearing Conservation (Hutchison and Schultz, 2014), and the American Conference of Governmental Industrial Hygienists (ACGIH®) (Knowles, 2003).

All of the above regulatory guidance related to hearing conservation is directed specifically at hearing loss prevention, with little or no discussion of the challenges of communication in a noisy environment. However, communication in the presence of background sound is a major issue not only for workers in factories and employees in bars, clubs, restaurants, or other noisy venues, but also for military service members who face challenging high-noise conditions near or inside vehicles, in combat zones, and even during training exercises, including weapons training (McIlwain et al., 2008; Ohlin, 2009b). In the review by Grantham (2012), the importance of speech understanding for mission success is discussed in detail, including the impact of communication challenges when speech is delivered over radio headsets in noisy environments. In the workplace, the need to communicate with co-workers in noisy backgrounds can result in the removal of hearing protection devices (HPDs), compromising protection of the worker's hearing. For military service members in hazardous environments, the use of passive HPDs has the potential to interfere with detection, recognition, identification and localization of mission relevant sounds (Grantham, 2012). High profile active shooter situations highlight the potential for similar