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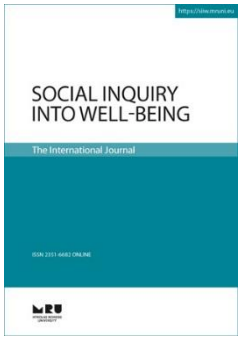

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Effective Communication as a Fundamental Aspect of Active Aging and Well-Being: Paying Attention to the Challenges Older Adults Face in Noisy Environments

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Abstract

Successful communication is vital to active aging and well-being, yet virtually all older adults find it challenging to communicate effectively in noisy environments. The resulting discomfort and frustration can prompt withdrawal or avoidance of social situations, which, in turn, can severely limit the range of activities available to older adults and lead to a less active and satisfying lifestyle, and, in some cases, depression. Using the International Classification of Functioning, Disability and Health's (ICF) multifactorial model (WHO, 2001), we review the wider aspects of functioning and disability as they relate to hearing difficulties and communication, placing a particular emphasis on the work we, an international and interdisciplinary group of researchers, have done in the context of the ERA-NET funded interdisciplinary HEARATTN project. The ICF model is particularly fitting because it allows us to consider how physiological changes in hearing and cognition affect listening in various situations, what the consequences of these changes are for communicative abilities and social participation, and how this in turn affects life-space mobility, self-reported well-being, and, ultimately, quality of life. We will discuss how environmental conditions (both physical and social) and personal factors can affect how well older adults can communicate in the situations characteristic of everyday life. In the concluding section we discuss some behaviours, techniques and strategies that can be adopted to maintain or improve effective communication under difficult listening conditions.

Keywords: Communication, ICF, older adults, hearing, speech comprehension, social participation, intervention

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Introduction

Difficulty hearing speech or following conversations is one of the most common complaints voiced by older adults (CHABA, 1988; Pichora-Fuller, 1997). This is particularly true when multiple talkers are speaking rapidly with less than perfect articulation about unfamiliar material, and when conversations are masked by environmental noises, other conversations, radio and TV programs, or distorted by reverberation (Pichora-Fuller & Singh, 2006; Schneider, Pichora-Fuller, & Daneman, 2010). It is less true when listening conditions are ideal, for instance when two talkers are speaking face-to-face in a quiet environment using language that is familiar, simple, and clearly articulated (Gagné, Rochette, & Charest, 2002).

Communication is a very general concept that can, depending on the underlying assumptions, include anything from passive listening for information (Wolters, Smeds, Schmidt, Christensen, & Norup, 2016) to the active interaction between communication partners (Lind, Okell, & Golab, 2009). While we know that the active exchange and interaction between partners represents a vital aspect of communication in real life, it can be difficult to study in the laboratory. As this article sets out to discuss mainly laboratory work, we define communication, in keeping with the laboratory tests we used, as the ability to receive information and either report it back verbatim (speech recognition tasks) or process it further for comprehension and later recall (comprehension and memory tasks).

Hearing loss can cause communication difficulties (Divenyi & Haupt, 1997; Era, Jokela, Qvarnberg, & Heikkinen, 1986; Helfer & Wilber, 1990; Humes & Christopherson, 1991; Humes & Roberts, 1990; Humes et al., 1994; Jerger & Chmiel, 1997; Jerger, Jerger, & Pirozzolo, 1991; van Rooij & Plomp, 1990, 1992). While age-related hearing loss has many consequences, the aspect most regularly assessed by clinicians is the elevation of high-frequency puretone detection thresholds. Detection threshold are assessed by measuring the minimum sound intensity required to hear a sound. Older listeners often require a much higher intensity level to detect a high-pitched sound than do younger listeners. Indeed, for frequencies of 2 kHz and higher, it is not uncommon for listeners over 60 years of age to need the sound level to be 30-40 dB higher compared to young listeners to detect the same tone (Pearson et al., 1995; Wilson & McArdle, 2013). Hearing loss is considered to be clinically relevant when the required additional intensity to detect a tone exceeds 20 dB compared to that needed by a normal-hearing young listener.

Besides changes to the sensitivity of high-frequency tones, and their consequences for speech perception, other aspects of hearing also show adverse age-related changes. Among them are sensitivity to the temporal properties of sounds and suprathreshold detection and recognition of complex sound features. These changes are also assumed to negatively affect speech perception, although the exact mechanism of the link is often not well understood (Frisina et al., 2001; Pichora-Fuller, Schneider, MacDonald, Pass, & Brown, 2007).

Despite all of these age-related auditory changes and their proposed link to speech perception, it is highly unlikely that hearing difficulties are the only cause for the communication difficulties seen in older adults. This point is illustrated by two findings; first even when matched with respect to frequency sensitivity (by means of shaped masking for instance), older adults often find it more difficult than their young counterparts to perceive and comprehend speech in noisy situations (Needleman & Crandell, 1995); second, two listeners with identical audiograms can have vastly different speech-in-noise performance (Gifford, Bacon, & Williams, 2007; Luterman, Welsh, & Melrose, 1966; Phillips, Gordon-Salant, Fitzgibbons, & Yeni-Komshian, 2000; Pichora-Fuller & Souza, 2003; Schneider & Pichora-Fuller, 2001). Hence, other factors must affect perception and comprehension of speech in noisy backgrounds. One of these factors is cognition, and a number of studies have now investigated how age-related changes in cognition affect speech perception and comprehension (Helfer & Staub, 2014; Humes, 2005, 2013; Lash & Wingfield, 2014; Schneider, 2011; Schneider et al., 2010; Wingfield & Tun, 2007). Cognition is important because in a conversation listeners not only have to detect, identify and perceive sounds but also extract the meaning of the utterances, integrate this information with their world knowledge and what has been said by the other participants in the conversation, store the information in memory for subsequent processing, and formulate responses when it is their turn to speak. These skills are often referred to as top-down processing strategies. In addition to the cognitive makeup of a listener, the listener's knowledge of the language (Garcia Lecumberri, Cooke, & Cutler, 2010), characteristics of the interlocutor (accent, manner of speaking, attitudes) and characteristics of the environment in which the communication takes place also determine communication outcome. Importantly, speech perception, comprehension and even interactive communication are often not ends in themselves but a basis for social participation, which in turn can be a determinant for well-being, and ultimately life satisfaction. In particular, when communication difficulties cause discomfort and frustration, they can prompt withdrawal or avoidance of social situations, and can severely limit the range of activities that are available to older adults (Laplante-Lévesque, Hickson, & Worrall, 2010; Smith & Kampfe, 1997). This can ultimately lead to a less active and satisfying lifestyle and possibly depression (Arlinger, 2003; Cacciatore et al., 1999; Gopinath et al., 2012; Mikkola, Portegijs, et al., 2015; Pronk et al., 2011).

In summary, communication is a concept with many dimensions. To fully understand it requires a resolutely interdisciplinary approach in conceptualisation and methodology. ERA-NET, an interdisciplinary funding initiative supporting research into aging, allowed us to form an interdisciplinary group of researchers who investigated

the contributions and inter-relatedness of many aspects of communication, and considered how these aspects as a whole affected the individual's health and well-being. This interdisciplinary research group needed an inclusive theoretical framework that would accommodate a variety of viewpoints. The World Health Organization's International Classification of Functioning, Disability and Health (ICF) (WHO, 2001) was such a framework. Because the ICF is multifactorial and combines biomedical, psychological and social aspects for a wider understanding of human functioning (Danermark et al., 2010), it allowed us to incorporate many of the interdisciplinary aspects we considered important for investigating and understanding communication in older adults. It postulates that an individual's level of functioning is not simply the consequence of an underlying health condition but instead should be thought of as a multifactorial concept that includes a person's body functions and structures, the activities they perform and the social situations they participate in. In addition, it recognizes that an individual's level of functioning is influenced by internal and external factors, which may affect functioning both positively and negatively (Granberg, Swanepoel, Englund, Möller, & Danermark, 2014). Others before us have used the general ICF framework in connection with hearing and communication (Anderson Gosselin & Gagné, 2011a; Danermark et al., 2010; Granberg, Dahlström, Möller, Kähäri, & Danermark, 2014; Granberg, Möller, Skagerstrand, Möller, & Danermark, 2014; Granberg, Swanepoel, Englund, Möller, & Danermark, 2014; Hickson & Scarinci, 2007; Saunders, Chisolm, & Abrams, 2005). We will be using it to provide a framework to discuss the work we have done mainly within the ERA-NET funded HEARATTN project, whose goal was to understand age-related changes in communication ability and the consequences such changes have on health, well-being, and life satisfaction. Following the discussion of age-related changes in communication and their consequences, we will give recommendations on how to improve communication and ameliorate some of the consequences of poor communication in order to facilitate older adults' participation in those activities that comprise an active and satisfactory lifestyle.

The ICF

The ICF is a classification and conceptual model that allows for a discussion of the level of functioning of a health condition, in this case hearing loss. The level of function or dysfunction is discussed separately for changes in body functions and structures and for the affected activities and participation. Within the model, "activities" are defined as a person's capacity to execute a task in a standard way with the influences of environment (buildings, other people, technology) minimised. "Participation", in contrast, is defined as a person's capacity to execute a task in a real-life situation; that is, within the context of a particular environment. The environment includes both interactions with individuals (i.e., as concern group participation and communication), and with society as a whole (i.e., as concerns the level of social functioning and isolation due to policies and attitudes).

Some researchers argue that for hearing loss the domains of activities and participation cannot be meaningfully separated within the ICF model (Gagné, Jennings, & Southall, 2014) because all actions related to hearing require some type of interaction with the environment (Granberg, 2015). For example they argue that Hickson and Scanrinci's (2007) classification of listening and speech perception as activities (actions performed in a standard way) is debateable because both activities are inherently linked to characteristics of the interlocutor and the environment in which listening takes place. We agree with this assertion and will therefore discuss activities and participation in a combined section.

Given how crucial context is for communication, it is important to investigate these contextual factors in more detail. In general, contextual factors can be subdivided into environmental factors and personal factors. Environmental factors include such diverse aspects as the characteristics of the listening situation (acoustic and optical (lighting) factors, design of buildings), the nature of technological support (amplification and cochlear implants), the extent of social support, and the attitudes of individuals and groups. Personal factors include everything that is particular to the listener but is independent of the health condition under discussion, in this case hearing loss. Examples are age, gender, race, socio-economic status, personality traits and emotional make-up, and the knowledge of coping strategies, for instance those relating to communication. Besides understanding how they affect functioning, contextual factors also form an important basis for interventions.

As mentioned earlier, the ICF is not only a conceptual model but also a classification system, which uses letters and numerical codes to operationalise its concepts, namely Body functions (b), Activities and Participation (d), and Environmental factors (e). In the following we will give the ICF code when each of these concepts is discussed in turn.

Body functions (b)

Hearing functions (b230). Clinically relevant high-frequency hearing loss has a prevalence of about 55% for 70-79 year olds and of almost 80% in over 80 year olds (Lin, Niparko, & Ferrucci, 2011) making it the third most prevalent chronic health condition facing older adults (Collins, 1997). An adverse effect of elevated high-frequency pure-tone detection thresholds on speech perception has been demonstrated by many studies (Divenyi & Haupt, 1997; Era et al., 1986; Helfer & Wilber, 1990; Humes & Christopherson, 1991; Humes & Roberts, 1990; Humes et al., 1994; Jerger & Chmiel, 1997; Jerger et al., 1991; van Rooij & Plomp, 1990, 1992). However, a decrement in sound detection thresholds is not the only auditory change that occurs with age. Other auditory functions such as temporal and spatial sensitivity (Bernstein et al., 2013; Pichora-Fuller et al., 2007; Schneider, 1997; Schneider, Daneman, Murphy, & Kwong-See, 2000; Schneider & Pichora-Fuller, 2000) and dynamic gain (Dorn, Piskorski, Keefe, Neely, & Gorga, 1998; Gates, Mills, Nam, D'Agostino, & Rubel, 2002; Lonsbury-Martin, Cutler, & Martin, 1991; Uchida et al., 2008) have also been found to change, although the extent to which they have a negative

impact on spoken-language comprehension is not fully understood. One aspect of temporal sensitivity that was investigated by members of the group is the age-related changes in the sensitivity with which a small gap can be detected in an otherwise continuous sound. This aspect of hearing is known as gap detection and it is potentially important for speech perception because small gaps or pauses in a continuous speech stream can indicate the presence of stop consonants. In a series of studies we have found that the effects of age (with older adults generally having higher thresholds than their younger counterparts) and stimulus complexity (gap detection thresholds increase with stimulus complexity) interact in such a way that the extent of age-related differences tended to increase linearly as the level of stimulus complexity increased (Heinrich, de la Rosa, & Schneider, 2014; Heinrich & Schneider, 2006; Pichora-Fuller, Schneider, Benson, Hamstra, & Storzer, 2006). Such a result suggests that it might be difficult to extrapolate from the extent of an age difference using simpler stimuli to the extent of age differences using more complex stimuli. If this result generalises to other types of stimuli, which there is some indication that it might (see Humes & Dubno (2010) for examples), then using simple stimuli to estimate the effect of auditory aging may not give an accurate picture for the more complex stimuli that are typically encountered in everyday life. These findings highlight the fact that many age-related auditory changes noticed by older adults in everyday life are not easily and adequately assessed by standard audiometric measures (Pichora-Fuller & Singh, 2006).

Attentional functions (b140). Cognition has emerged as an important concept in the context of speech perception and comprehension in the last fifty years (e.g., Rabbitt, 1968; Rönnberg et al., 2013; Schneider, 2011; van Rooij & Plomp, 1990, 1992; Wingfield, Tun, & McCoy, 2005), partly to account for finding that listeners with similar hearing impairments can vary widely in their level of functioning (Anderson, Parbery-Clark, Yi, & Kraus, 2011; Gordon-Salant & Fitzgibbons, 1993; Vermiglio, Soli, Freed, & Fisher, 2012). Cognition is a multi-faceted concept and in the following section we will limit the discussion of age-related cognitive changes to those aspects that are most likely to affect spoken-language comprehension. One of these aspects is attention. Attentional skills are required to segregate the target voice from a background, to detect and process the information that is important while filtering out distractors, and to switch between different conversational partners, among other things. Understanding how attention is affected by age may help us understand its effects on spoken-language comprehension. Attention itself can take many forms (Petersen & Posner, 2012). Those with a direct or indirect link to communication are the following. First, attention enables listeners to enter a state of alertness in response to signals that salient events are about to take place, and sustain such an alert state long enough to perceive relevant signals (Oken, Salinsky, & Elsas, 2006; Posner & Petersen, 1990). It furthermore enables listeners to orient their attention to specific regions of space or features of items in the environment, to better perceive stimuli that carry important information. It also enables listeners to build up expectations regarding the location of a speech source, which can then improve their perception of the contents of that speech. When speech or visual information turns out not to originate from the expected location, reorienting of attention to the actual source or location of the information of importance is required (Corbetta & Shulman, 2002). Intriguingly, while older adults respond more slowly in general to environmental stimuli, they may not have fundamental difficulties in orienting their spatial attention (Singh, Pichora-Fuller, & Schneider, 2008), though they may have some problems in reorienting attention to stimuli that appear in unexpected locations.

Besides spatial aspects of orientation and reorientation, the division and integration of information from other sensory modalities or concurrent tasks in addition to hearing and speech perception is also sometimes required, and this multitasking requires dividing attention. One aspect of simultaneously dealing with multiple sources of information is to decide, which information is relevant and which information should be ignored as irrelevant distraction (Ben-David & Schneider, 2009, 2010; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Bush, Luu, & Posner, 2000; Monsell, 1996). It has long been suggested that one consequence of aging is a reduced ability to divide attention (Craik & Byrd, 1982) and inhibit irrelevant information (Hasher, Lustig, & Zacks, 2007; Hasher & Zacks, 1988).

One reason why older adults have difficulties at least with some aspects of attention might lie in the fact that attention is shared by all processes - perceptual, physical and cognitive - and is limited in size (Kahneman, 1973). Age-related sensory declines may result in a redistribution of attention to support sensory processing, thereby short-changing the attention devoted to higher-order, more central cognitive processes supporting comprehension and memory (Avivi-Reich, Jakubczyk, Daneman, & Schneider, 2015; Ben-David, Tse, & Schneider, 2012; Heinrich & Schneider, 2011). In addition it has been suggested that the overall amount of attentional resources available is reduced in older compared to younger adults (Craik & Byrd, 1982). As a consequence of these two age-related changes the range of listening strategies available to an older listener might be more restricted or at least different to that available to a young listener. We will discuss this point in greater detail in the Activities and Participation section.

One way to think about the redistribution and potential restriction of attentional resources in terms of contextual factors is to invoke the concept of “listening effort”, where listening effort refers to “the amount of processing resources (perceptual, attentional, cognitive, etc...) allocated to a specific auditory task, when the task demands are high (adverse listening conditions) and when the listener strives to reach a high level of performance on the listening task” (Pichora-Fuller, Kramer, & Eckert, 2016). In listening, high task demand can occur when listening conditions are adverse, and when the listener strives to reach a high level of performance in the listening task. Contextual factors can substantially affect the amount of listening effort an individual has to expend in order to communicate. These factors comprise environmental factors such as background noise, competing speech, reverberation, etc., as well as a

person's cognitive make-up and language competency (McGarrigle et al., 2014).

Memory functions (b144). Attention is often required to encode into and retrieve from memory distinct episodes of information that the listener heard in the course of the conversation and that are important for a full understanding. The extent to which memory declines with age depends, among other things, on the extent to which it engages attention, and it is particularly pronounced for recall based on self-initiated retrieval strategies and least pronounced for recognition memory for which the retrieval cues are provided by the environment (Craik & McDowd, 1987; Grady & Craik, 2000).

Intellectual functions (b117). Another aspect of cognition discussed in the present paper is the role that general intelligence plays in speech perception, comprehension and communication. While a number of theories around the concept of intelligence exist (Binet, 1907; Cattell, 1971; Gardner, 1983; Spearman, 1927; Sternberg, 1988) we will concentrate on the distinction between fluid and crystallized intelligence, a distinction originally introduced by Cattell (1971). Cattell defined fluid intelligence as the ability to perceive relationships independent of previous practice or instruction. Crystalized intelligence on the other hand is acquired through knowledge and learning. Fluid intelligence declines as a function of age starting in the 5th decade of life (Salthouse, 2004). Working memory is closely related to fluid intelligence and a number of studies have reported that, in adulthood, working memory declines as a function of age (Morris & Logie, 2015). In contrast, measures of crystallized intelligence such as vocabulary knowledge have not been found to decline, and even improve with age (Ben-David, Erel, Goy, & Schneider, 2015). While some decline in fluid intelligence and its associated cognitive abilities as a function of age is normal, sometimes people show an abnormal decline. At least some abnormal cognitive decline can be subsumed under the term dementia. Dementia is linked to hearing impairment and some recent work appears to show that hearing impairment can substantially increase the risk of incident dementia (Lin et al., 2011). Not surprising, visual sensory impairments were also linked with dementia (Adlington, Laws, & Gale, 2009; Salamone et al., 2009), with a possible impact on selective attention performance (Tewari, Shakuf, & van Lieshout, 2014).

Mental functions of language (b167). The aspect of mental functions of language that is of most interest for the current discussion is language competency. We know that listeners, even when they are young and have normal hearing, find it much more difficult to comprehend speech that is not in their native language (their L1), especially in interaction with the environmental factor of background noise (for a review, see Garcia Lecumberri et al., 2010). Hence we might expect age-related sensory and cognitive declines to have a more profound effect when a person is listening in their second language (L2) as opposed to their native or first language (L1).

Activities and Participation (d)

Communication with – receiving spoken messages (d310). In the following, we will discuss how changes in various cognitive functions interact with hearing impairment to affect Activities and Participation for speech perception, comprehension and communication. We are aware that in audiological practice all speech tests are recognition tests and that none of the clinical tests assesses comprehension or aspects of interactive communication typically present in real-life situations. However, this is not true for experimentally used tests, which can be designed to assess comprehension and memory for heard information (Gordon, Daneman, & Schneider, 2009; Heinrich, Schneider, & Craik, 2008; Murphy, Daneman, & Schneider, 2006; Schneider et al., 2000). In the following discussion we will aim to highlight whether a particular speech tests assessed recognition, comprehension or memory.

Interaction of Hearing impairment with Attention and Memory. As mentioned before, the concept of attention can be linked to the concept of cognitive resources and resource allocation. In the following we will discuss age-related changes in this allocation. We have used a number of different paradigms to show these age-related changes. The first set of studies that show a redistribution of cognitive resources with age was conducted by Schneider and colleagues. These studies explored how older adults compensate for age-related impairment in hearing and vision in complex listening situations. They found that when the listening situation was adjusted so that word recognition was equivalent in younger and older adults1, age-related differences in the ability to comprehend and remember information in a number of different situations (e.g., listening to a lecture, or listening to multi-talker conversations) as well as in the temporal dynamics of the processing were minimized or even disappeared (Ben-David et al., 2011; Gordon et al., 2009; Murphy et al., 2006; Schneider et al., 2000). These results suggest that a major component of the limitations older adults encounter when listening in noisy environments are age-related perceptual impairments (see also Humes, Busey, Craig, & Kewley-Port, 2013), and when these impairments are compensated for, limitations are minimized. However, in everyday life opportunities for such compensation are rare as older adults typically do not have the opportunity to adjust the listening situation so that they can recognize words as easily as their younger counterparts. Instead of adjusting external environmental factors such as sound level or the noisiness and reverberation of a building, older adults have to compensate using internal factors such as cognitive abilities and engage top-down, knowledge-driven processes to compensate for difficulties in word recognition (Rönnberg et

[1] This is accomplished by adjusting the level of the background noise so that all individuals are equally likely to be able to correctly identify words in the absence of contextual support (see Schneider et al., 2000). Typically, this means that younger adults are tested in a higher level of noise than older adults.

al., 2013), which then limits the amount of attentional resources left for other aspects of language processing such as comprehension and memory (Tun, McCoy, & Wingfield, 2009; Wingfield et al., 2005).

Indeed, a second set of studies from our group illustrate the potential consequences of such an attention-based compensation strategy. They used memory performance as a measure of attentional engagement during word recognition (Heinrich & Schneider, 2011; Heinrich et al., 2008; Murphy, Craik, Li, & Schneider, 2000; Schneider, Avivi-Reich, Leung, & Heinrich, 2016) and showed that older listeners' memory was disproportionately more affected by unfavourable listening conditions (speech perception in noise) than that of younger listeners, even when the listening situation was adjusted individually so that all listeners were equally likely to recognize the individual words being spoken. They interpreted this result as showing that older listeners employed more attention-based top-down processes to accomplish the same level of perception of the words, which then depleted the pool of resources available for subsequent processing of the heard information. Hence, accounting for hearing impairment by equating for perceptual accuracy between age groups is no guarantee that perception will be achieved in similar ways in both age groups as older adults may distribute more attentional resources towards the perception of the words. This redistribution of attentional resources towards perception then led to a decline in memory performance, which was greater than what would have been expected from age-related changes in memory alone.

A third way to illustrate the potential use of a cognitive compensation strategy to counteract sensory impairment may be found in the result that older adults benefit more from context than do younger adults (Pichora-Fuller, Schneider, & Daneman, 1995). This may occur because older adults have learned that relying on semantic context is a beneficial strategy in challenging listening conditions even if it comes at the expense of depleting attentional resources for subsequent processing.

Finally, the redistribution of resources as a result of different listening strategies can also be measured using behavioural dual-task paradigms, an approach taken in our group by Gagné and colleagues (Anderson Gosselin & Gagné, 2011a, 2011b). In general, dual-task paradigms require individuals to divide their attention between two tasks. If we assume with Kahneman (1973) that cognitive resources are limited, a division of resources can then be used to assess the extent to which resources are used to process certain aspects of a task. For instance, when listening conditions are easy, the processing load of the listening task is low and spare capacity from the primary task can spill over to a secondary task chosen to assess the processing load of the listening task. Under easy listening conditions both tasks can be performed in combination without a problem. In contrast, under difficult listening conditions the processing load of the listening task is high and processing demands exceed capacity. In this case, little spare capacity is available to spill over to the secondary task, on which performance will then decrease when the tasks are performed together (Lavie, 1995). This decrease can therefore be seen as indicating high cognitive processing demands in the primary listening task. Besides the behavioural consequences of processing load, listening may also be perceived as more effortful. The dual task paradigm used by Anderson Gosselin and Gagné (2011a, 2011b) consisted of a speech recognition task (keyword recognition in sentences presented in a noisy background, sentences were presented either auditory-only or audiovisually) as the primary task and a tactile pattern recognition task (discriminating between two successive events that varied in duration, e.g., long-short) as the secondary task. They hypothesized that if the primary task either consumed more resources in the older group, or if the older group had fewer resources available, then the introduction of a secondary task should have a more pronounced adverse effect on that group. Moreover, the greater the decrement on the secondary task, the greater the assumed listening effort for the primary task. Conversely, if enough capacity was available either because the task was not overly resource-consuming or because enough resources were available, the introduction of a secondary task should not affect primary task performance. Their results showed that older adults possessed less spare capacity to perform the secondary task regardless of whether speech was presented in an auditory-alone or an audiovisual modality, and regardless of whether listening conditions were identical between both groups or whether noise levels were adjusted to produce equivalent performance in the two age groups (Anderson Gosselin & Gagné, 2011a, 2011b). Gagné and colleagues took these results to mean that older listeners employed more listening effort than young adults to perform the listening task in all conditions.

Interaction of Hearing impairment with Intellectual functions. Changes in listening strategy expressed as a change in resource allocation is only one way in which the cognitive involvement in listening changes with age. Another change might affect the type of cognitive skills engaged when listening becomes difficult. We know that in all individuals, comprehending what is being said requires the smooth and rapid functioning of a number of perceptual and cognitive processes and that those individuals in which these processes are more proficient tend to comprehend and remember more of the heard information than those with less proficient perceptual and cognitive abilities (Avivi-Reich, Daneman, & Schneider, 2014; Avivi-Reich et al., 2015; Schneider, 2011; Schneider, Avivi-Reich, & Daneman, 2016). Individual and age-related differences in processing proficiency are probably of relatively little importance when listening is effortless. Indeed, when listening is easy all listeners can be shown to engage the same range of cognitive processes (Schneider, 2011). However, when listening becomes difficult, older listeners depend more on the linguistic and cognitive abilities associated with so-called crystalized intelligence than do younger adults, who tend to depend more on the integrative processes involved in the interpretation and manipulation of the information they have heard. This pattern of results is demonstrated by a set of studies, which showed that, under difficult listening conditions, the ability of younger adults to answer questions about heard material was more highly correlated with their reading comprehension scores than with their knowledge of vocabulary. Older adults, on the other hand, showed the

reverse pattern such that for them, the number of questions answered correctly in difficult listening situations was highly correlated with their vocabulary knowledge but not with their reading comprehension scores (Avivi-Reich et al., 2014; Avivi-Reich et al., 2015; Schneider, Avivi-Reich, & Daneman, 2016). Interestingly, this increased dependence of older adults on crystalized intelligence (e.g., vocabulary knowledge) in noisy situations may be strategic in nature: we know that vocabulary knowledge is preserved with age in contrast to online auditory processing, and so using their more extensive knowledge of the language to correct for the increased number of errors in word recognition might be the most effective strategy. Hence, in difficult listening situations, older adults may have learned that focusing their attention and resources on word recognition may lead to better comprehension and recall of information conveyed through spoken language.

Interaction of Hearing impairment with Mental functions of language. So far we have only considered young and old listeners who operate in their native language. In our globalised world it is increasingly likely that people are required to communicate in a language that they acquired later in life. The resulting patterns of r speech perception can look quite similar for older adults with hearing impairment and young adults with limited language proficiency (L2) and difficulties in stream segregation have been implicated in both cases (e.g., Bradlow & Pisoni, 1999). Nevertheless, Ben David and colleagues (Ben-David, Avivi-Reich, & Schneider, in press; Ben-David et al., 2012) suggest that the similar outcomes are caused by different underlying factors. They base their suggestion on the finding that when young and old native (L1) and young non-native (L2) adults listen to words presented in background noise or babble, increasing the delay between the onset of the background and the word (background onset precedes word onset) leads to improved intelligibility in all conditions for younger adults independent of whether they are listening in their first or second language. For older listeners this was only true for the easier noise background but not for the more challenging multi-talker babble. Moreover, linguistic experience in L2 (measured as age of immersion in L2) did not appear to modulate the benefit of babble onset delay for young listeners. These results suggest that the way in which age-related losses in basic auditory abilities affect older L1 listeners and cause higher thresholds and the need for more favourable signal-to-noise ratios (SNR) is fundamentally different from the restrictions caused by insufficient or incomplete lexical development and knowledge in younger non-native L2 listeners. Moreover, it is unlikely that the need for a higher SNR in L2 listeners was caused by a reduced ability to inhibit the intruding background noise given that life-long active use of more than a single language was positively associated with inhibition efficiency (Green, 1998; Kroll & Bialystok, 2013; Pelham & Abrams, 2014; Poarch & van Hell, 2012). More likely, these difficulties can be related, in part, to impaired lexical access such as a smaller vocabulary size (Bialystok, Craik, & Luk, 2012; Portocarrero, Burright, & Donovick, 2007) and greater interference in lexical decisions (Michael & Gollan, 2005), as well as reduced phonemic discrimination (Garcia Lecumberri et al., 2010). Understanding pathways of influence is a prerequisite to design effective interventions and rehabilitations

Mobility (d4) - Walking (d450). Physical functioning is another aspect of body functions (besides cognition) that shows an intimate relationship with hearing impairment. Indeed, poor hearing has been associated with, for example, poorer postural balance (Agrawal, Carey, Della Santina, Schubert, & Minor, 2009; Viljanen, Kaprio, Pyykkö, Sorri, Pajala, et al., 2009), poorer lower limb performance (Chen et al., 2015; Mikkola, Polku, Portegijs, Rantakokko, Rantanen, et al., 2015), slower walking speed (L. Li, Simonsick, Ferrucci, & Lin, 2013; Viljanen, Kaprio, Pyykkö, Sorri, Koskenvuo, et al., 2009) and perceived walking difficulties (Chen, Genther, Betz, & Lin, 2014; Mikkola, Polku, Portegijs, Rantakokko, Rantanen, et al., 2015; Viljanen, Kaprio, Pyykkö, Sorri, Koskenvuo, et al., 2009). Impaired hearing also predicts the onset of new walking difficulties and falls (Lin & Ferrucci, 2012; Viljanen, Kaprio, Pyykkö, Sorri, Koskenvuo, et al., 2009; Viljanen, Kaprio, Pyykkö, Sorri, Pajala, et al., 2009).

Why this association between hearing and mobility exists is currently unclear, but one possibility is a shared underlying physiological basis given that both hearing and vestibular organs depend on the appropriate functioning of the stria vascularis, which via the endo-cochlear potential provides the “battery” for hearing, and which may also affect the functioning of the vestibular organ. Given that evidence from animal studies indicates that ageing leads to a degeneration of the stria vascularis in the inner ear (Schmiedt, 2010), it appears possible that this physiological change could lead to concomitant impairment in hearing and mobility (Agrawal et al., 2009; Anson & Jeka, 2016; Zuniga et al., 2012).

Interaction of Hearing impairment, Balance and Social participation. A joint impairment in hearing and balance can lead to a variety of participation restrictions possibly either because hearing impairment may deprive the listener of the auditory cues that are important for spatial orientation and that enable listeners, for example, to notice and avoid environmental hazards (Dargent-Molina, Hays, & Bréart, 1996) or because poor postural balance leads to an increased fear of falling (Viljanen et al., 2012, 2013). In either case, poorer hearing and poorer balance restrict mobility and participation in activities and community events.

Apart from the physiological link between hearing and balance, it is also possible that the association between the two Body functions and Activities & Participation is mediated by cognition. As the likelihood and cost of a fall, such as a broken hip, increase substantially with age, older adults may allocate a greater proportion of their attentional resources to maintaining their postural balance during common daily activities like walking (Lundin-Olsson, Nyberg, & Gustafson, 1997) than do younger adults. If attention is a limited resource (Kahneman, 1973) upon which all processes - including sensory and cognitive - draw, then older adults should suffer competition between speech comprehension and mobility when relying more heavily than young adults on attention to maintain postural balance while

simultaneously attempting to comprehend spoken language. This argument is supported by the finding that when older adults have to engage cognitive resources in order to maintain balance their ability to simultaneously perform other cognitive functions such as memorizing is compromised (K. Li, Lindenberger, Freund, & Baltes, 2001). Indeed, older adults generally find it quite difficult to carry on a conversation while walking, especially in environments in which the risk of a fall is high. Consequently this may lead to poorer communication, which in turn could lead to a curtailment of social activities.

Recreation and Leisure (d920). So far, we have discussed social participation mainly in terms of speech perception, comprehension and communication. However, a wider definition that includes actual and perceived social involvement in more general terms might also be appropriate. These aspects of social participation can be assessed using a variety of measures including frequency of participation, time spent out of the home, perceived autonomy and loneliness. Within our group, Viljanen and colleagues have investigated the link between hearing impairment and this wider aspect of social participation and shown that hearing impairment can affect both the perceived and the actual extent of social participation. For instance, hearing-impaired older people participate less frequently in group activities and also perceive their participation and activities outside their home as more restricted relative to older adults with no hearing difficulties (Mikkola, Portegijs, et al., 2015). They also spend less time out of the home, are at higher risk for withdrawal from leisure activities (Mikkola, Polku, Portegijs, Rantakokko, Tsai, et al., 2015) and are just generally at higher risk for social inactivity (Crews & Campbell, 2004; Mikkola, Polku, Portegijs, Rantakokko, Tsai, et al., 2015; Mikkola, Portegijs, et al., 2015; Simonsick, Kasper, & Phillips, 1998; Viljanen, Törmäkangas, Vestergaard, & Andersen-Ranberg, 2014). In addition, studies have shown that poor hearing is associated with loneliness (Pronk, Deeg, & Kramer, 2013; Sung, Li, Blake, Betz, & Lin, 2015) and social isolation (Mick, Kawachi, & Lin, 2014; Mick & Pichora-Fuller, 2016). However, note that diverging results exist (Mick et al., 2014; Mick & Pichora-Fuller, 2016; Yamada, Nishiwaki, Michikawa, & Takebayashi, 2012), possibly caused by inconsistencies in hearing and social participation measures, and differences in study samples.

Besides measures of active participation, perceived autonomy and emotional well-being, and life-space mobility (Baker, Bodner, & Allman, 2003) are aspects of social participation that have gained considerable interest in recent years. Life-space mobility describes the balance between a person's individual resources and environmental challenges and provides a measure of the person's actual mobility and engagement with society. It is measured by investigating how far and how often a person moves outside their home, and whether or not the person needs assistance to travel in the area. Life-space mobility correlates for example with physical functioning (Portegijs, Rantakokko, Mikkola, Viljanen, & Rantanen, 2014), depressive symptoms (Polku, Mikkola, Portegijs, et al., 2015), autonomy (Portegijs et al., 2014) and quality of life (Rantakokko et al., 2015; Rantakokko, Portegijs, Viljanen, Iwarsson, & Rantanen, 2013), maybe even setting off its own downward spiral where hearing impairment-induced participation restriction leads to inactivity that further accelerates the overall disablement process. A recent study has shown that life-space mobility correlates with hearing insofar as older adults with self-reported hearing difficulties have poorer life-space mobility scores and an approximately two times higher risk for restricted life space at a two year follow-up compared to persons without hearing difficulties (Polku, Mikkola, Rantakokko, et al., 2015).

Environmental factors

Sound (e250). Environmental factors comprise such diverse topics as technology; the quality of the sound due to building specifications, background sound sources, and talker characteristics; the level of human support available to the listener; individual and societal attitudes; and the role of financial, social and health-care systems. As this paper aims to highlight the research conducted within our group, we will restrict the discussion to those aspects of the environment, which have been investigated as part of our collaboration, particularly sound (e250) and attitudes (e4).

Based on the discussion so far, we posit that cognition plays a vital role in speech perception, comprehension and communication in the wider sense, and that this role might change as hearing impairment worsens. This brings up related questions of how listening situations might require different cognitive abilities and how this might interact with age and hearing impairment. Posing these questions implies that functioning in the context of hearing loss involves different cognitive abilities depending on the domain in which it is to be accomplished (hearing, listening, participation). Within the framework of the ICF this equates to a complex interaction between domains of functioning (represented by the target stimuli), environmental factors (represented by the type of background noise or reverberation, the manner of target speech production and the language used) and individual cognitive abilities. While an intriguing suggestion, it is difficult to investigate because most studies use different combinations of speech and cognitive tests. The investigation of the question is further complicated by the fact that it is not clear how to measure the involved cognitive abilities most appropriately and in a way that makes measurements comparable across studies. A step towards solving these questions could be to use a theory-driven approach to cognitive test selection such that a range of cognitive tests represent one underlying theoretically-motivated cognitive construct. Then, while surface tests might change across studies, the underlying construct would remain unchanged and form the basis for comparisons across studies and listening conditions. We have recently started to follow such a strategy and are currently particularly interested to understand how the extent of hearing impairment affects cognitive involvement in speech perception and comprehension given particular environmental (background noise, amplification) and personal (age, cognitive makeup, educational attainment) factors. Preliminary results show that for older adults with mild-to-moderate hearing loss, below the clinical threshold

for hearing aid amplification, only listening to complex stimuli (sentences) in complex background (modulated noise) engages cognition in the form of executive attention (Heinrich, Henshaw, & Ferguson, 2015). For older adults with moderate hearing loss, treated with hearing aid amplification, the most complex stimuli (sentences) also engage executive attention. However, in addition, this group of listeners also shows an engagement of working memory across all tested listening conditions, as long as they at least require the perception of words (Heinrich, Henshaw, & Ferguson, 2016). These results speak to the large body of studies that have investigated the role of working memory for speech perception ever since Akeroyd (2008) suggested that "measures of working memory (especially reading span) were mostly effective [predictors of speech recognition in noise]", and concur with Füllgrabe and Rosen (2016) who suggest that the involvement of working memory for speech perception might be modulated by task difficulty, and might be strongest either due to hearing impairment, adverse environmental factors such as complex fore- and background stimuli, or unfavourable personal factors such as reduced proficiency of perceptual and cognitive abilities. One overarching model that has attempted to formalize these suggestions is the Ease-of-Language-Understanding (ELU) model (Rönnberg et al., 2013) that suggests larger involvement of working memory in speech perception when bottom-up and top-down information are mismatched. In aging, distorted bottom-up information, due to age-related sensory degradation, and increased top-down information, due to linguistic experience, may increase the competition. Indeed, when such a competition between top-down and bottom-up information was introduced in a word perception task using eye-tracking, working memory became engaged in the task even in normal-hearing young adults (Hadar, Skrzypek, Wingfield, & Ben-David, 2916).

Attitudes (e4). Another environmental factor that we wish to discuss because it has links to both Activities and Participation as well as cognition is social attitudes and stereotypes shown by communication partners and society as a whole. Studies have provided ample evidence of the prevalence of ageism (negative stereotypes on older age), with older adults being stereotyped by both younger and older adults as incompetent across several mental abilities (Cuddy, Norton, & Fiske, 2005). A direct consequence of stereotyping is the fear of confirming the negative stereotype, the "stereotype threat", which in turn can negatively affect their performance on tasks related to the stereotyped trait (for a review, see Horton, Baker, Pearce, & Deakin, 2008). Prominent examples are results that show that African-American, but not Caucasian students, experienced performance deficits when a test was framed as assessing a trait stereotypically unfavourable to African-Americans (e.g., intelligence; Steele & Aronson, 1995) and that female but not male students experience performance deficits in tests where math abilities were made salient (Spencer, Steele, & Quinn, 1999). In the past decade, several studies have also demonstrated the negative impact of the stereotype threat for older adults (for a review, see Barber & Mather, 2013). For example, when negative stereotype words on aging were presented, older adults performed more poorly on subsequent memory tasks (Levy, 1996), whereas an implicit presentation of positive stereotypes on aging led to improved functioning (Levy, Pilver, Chung, & Slade, 2014).

The stereotype threat in aging can have severe consequences for speech perception in social situations. Once a negative stereotype regarding older adults' cognitive abilities is elicited, stereotype threat can lead to reduced performance on cognitive factors critical for speech perception, such as working memory. Indeed, stereotype threat does not have to be extreme. It can be generated even by engaging with a younger person in a foreign location, such as when the experiment is conducted at the university by a young research assistant (Sindi, Fiocco, Juster, Pruessner, & Lupien, 2013).

Stereotypes can lead to misattributions of factors that might cause activity limitations and participation restriction. A prominent example in the context of aging is provided by Eibach Mock & Cortney (2010) who manipulated the font clarity of the text, unbeknownst to the older participants. The resulting reduced visual fluency led older viewers to misattribute sensory changes as cognitive ones, and as a result of this misattribuation they became more susceptible to negative stereotypes of aging. Analogously, for the area of speech perception and communication one may expect that reduced clarity and fluency in speech perception, at least to a degree caused by age-related sensory changes, may lead older listeners to misattribute hearing difficulties to cognitive decline. This could trigger a stereotype threat, which leads to a reduction in cognitive capacity which, in turn, might reduce spoken-language comprehension.

For the population of older immigrants the stereotype threat is even greater because they effectively represent a double-minority social group due to their age and their cultures, an effect that might be even further exacerbated by the fact that they are separated from their family and culture (Amit & Litwin, 2010; Litwin, 1995). This can lead to isolation and alienation and increase their risk of developing mental health disorders. Indeed, research documents ethnic disparities in the prevalence of mental health disorders as well as the quality of services they receive (Nakash, Rosen, & Alegria, 2009).

Recommendations

So far, we have used the ICF to help illustrate some of the complex interactions between domains of auditory functioning and contextual factors. However, understanding the mechanisms is only one goal of research. Another is to provide listeners with interventions and rehabilitation strategies that will allow them to carry out hearing-related activities with greater ease, participate more fully and consequently lead a more fulfilling and satisfying life. In the field of clinical audiology, research into patient-centered rehabilitation strategies to improve listening in difficult conditions has a long tradition, and many of the recommendations discussed in this section come from this research (Erdman, Wark, & Montano, 1994; Gagné & Jennings, 2008; Gagné, McDuff, & Getty, 1999). However, more recently speech scientists have also started to systematically investigate intervention strategies, mostly in

the form of training regimens. Some of those will be highlighted in the following. The discussion of the improvement strategies will follow the ICF framework and distinguish between strategies that target physiological factors (Body functions), environmental factors and personal factors.

Body functions (b)

Appropriate sensory, and particularly visual functioning is important as a strategy to supplement missing auditory cues with visual information.

Besides the importance of adequate sensory functioning, the role of cognitive functioning has moved to the fore in recent years. This was sparked by the findings showing how important cognition can be for speech perception and understanding in certain situations. As a result, studies have started to investigate if and how aspects of cognition that are deemed relevant for speech perception can be improved and whether improved cognition functioning then transfers to better speech-in-noise perception (Henshaw & Ferguson, 2014; Wayne, Hamilton, Jones Huyck, & Johnsrude, 2016). So far, while training of cognitive skills appears possible, the benefits of such training for real-life listening are still elusive. Concerning physical functioning, we have shown that hearing-impaired individuals tend to show a mobility impairment, possibly because they lack environmental auditory information. As a consequence, moving may become even more uncertain for these adults, which may then lead to further avoidance of walking and other physical activities. Knowing the increased risk for mobility decline, persons with hearing impairment should consciously try to break the vicious circle by putting effort into maintaining sufficient level of physical activity. Exercise in older adults should include aerobic exercise, muscle strengthening exercises, and flexibility exercises. (See exercise recommendations for older adults here http://www.health.gov/paguidelines/guidelines/chapter5.aspx)

Personal factors

We know that the following personal factors affect listening and participation: demographic factors such as age, gender, race and socio-economic status, and the availability or use of communication strategies, among other things. While demographic factors are not amenable to rehabilitation, the other factors are. Education and training in communication strategies are classic fields of audiological rehabilitation, and a number of strategies have been developed over the years. Among them are speech-reading and techniques on how to eliminate background noise. Both are briefly discussed in turn.

Speech-reading emphasises the use of all information from the talker's face and particularly the lip movements. In order to be most effective, visual acuity in the listener needs to be good, the talker needs to be positioned in such a way that the person who has difficulty hearing can both hear as well as see the talker, and the talker's face needs to be adequately illuminated. The most effective way of placing communication partners to maximize the usefulness of visual cues is face-to-face at a small distance. While visual acuity can be corrected for, and the talker can be positioned in a certain way, adequate lighting can sometimes be difficult to achieve (e.g., a romantic candle light dinner or a poorly lit living room). If the lighting cannot be improved it may be best to move to an environment that is more suitable for communication or postpone the conversation to later. Depending on the initial level of auditory speech recognition, the provision of visual speech cues (to allow the listener to speech-read) can improve speech understanding by as much as 40 or 50% (Grant & Braida, 1991). Speech-reading training is not necessary to benefit from the availability of visual speech cues. Younger adults with normal hearing sensitivity show improvements on tasks of speech recognition in noise when they can view the talker's face as well as hear the distorted speech signal (Grant & Braida, 1991). Studies have shown that older adults benefit from using visual speech cues (although there is a debate concerning whether older adults are less proficient than younger adults at integrating auditory and visual speech information) (e.g., Sommers, Tye-Murray, & Spehar, 2005; Tye-Murray, Sommers, & Spehar, 2007). Some investigators have shown that providing visual speech cues in addition to the auditory speech signal is equivalent to improving the signal-to-noise ratio by more than 11 dB (Macleod, 1990; Sumby & Pollack, 1954).

Another option to improve speech communication is to modify the listening environment by eliminating the source of background noise. This can be achieved by turning off the television, the radio, the noisy air conditioner, or by moving to a different area where the deleterious effect of the distracting background noise can be eliminated or reduced (e.g., the quiet living room rather than the busy and noisy kitchen; quieter section of the restaurant).

Environmental factors (e)

In the same way that listeners can employ communication strategies to improve communication, communication partners can also learn to use communication strategies. Two of those strategies are clear speech and provision of contextual support (Tye-Murray, 1994). Under normal everyday conditions, with a familiar person, talkers tend to use suboptimal speaking patterns (Lindblom, 1996), where they employ the minimum amount of speaking effort required to be understood by the listener. This type of speech is known as hypo-speech or conversational speech, and it is characterized by a fast speaking rate, a minimum amount of pauses and articulation patterns that are not very precise. At the other end of the continuum there is hyper-speech or clear speech. Hyper-speech is characterized by a much slower rate (typically about twice as long as hypo-speech), by significantly more pauses to separate syllables, words and phrases, and by articulation patterns that are more precise (e.g., the tongue movements inside the mouth more closely approximate the ideal place of articulation in the vocal tract) (Picheny, Durlach, & Braida, 1986). Several investigators have shown that hyper-speech is significantly more intelligible than hypo-speech (Picheny, Durlach, & Braida, 1985). For instance Gagné and colleagues have shown that, on average,

hyper-speech is approximately 20% more intelligible than conversational speech (Gagné, Masterson, Munhall, Bilida, & Querengesser, 1994; Gagné, Querengesser, Folkeard, Munhall, & Masterson, 1995). For some individuals the use of clear speech may improve their speech intelligibility by more than 30% relative to their intelligibility for conversational speech. Interestingly, in most instances improved speech intelligibility can be achieved simply by asking the talker to: 'slow-down the speaking rate and articulate as precisely as possible each syllable, without unduly exaggerating'. Gagné and colleagues (Gagné et al., 1994; Gagné et al., 1995; Gagné et al., 2002) have shown that using clear speech will enhance the intelligibility of the auditory, visual and audiovisual speech.

Providing the communication partner with contextual cues has been shown to improve speech intelligibility. For example the talker may introduce the topic of conversation before stating the intended message (e.g.: 'Mom, I'm thinking about Sunday dinner. Should I get some wine?). Garstecki and O'Neill et al. (1980) and Pichora-Fuller and colleagues (1995) have shown that the provision of contextual cues in listening tasks can improve speech recognition scores of older adults with hearing loss by as much as 20 – 30 percent. Similarly, Gagné and colleagues (1991) have shown that the provision of contextual cues in a speech-reading task improved visual-speech recognition scores by approximately 20 percent.

Besides using communication strategies, a number of other environmental factors are also amenable to improve communication. They include amplification technology, characteristics of the listening environment, social support, and social attitudes, all of which are discussed in turn.

Hearing aids, intended for listeners with a clinically recognised hearing loss, and personal sound amplification products (PSAPs), intended for listeners with hearing sensitivity within the normal range, both provide amplification of sounds by changing the acoustic environment in the listener's ear canal. Some of their features, such as directional microphones and noise reduction algorithms, are designed specifically to improve speech communication in noise. In addition to hearing aids and PSAPs, hearing assistive technologies (HATs) are also available. HATs include any device designed to help persons with hearing loss detect and recognize sounds. Examples are devices with remote microphones such as a wired personal sound amplification systems (e.g., a pocket talker) and wireless sound amplification systems (e.g., a personal FM-amplification system). A special feature of some HATs, such as a personal FM-amplification system, is the fact that they must be used by the listener as well as the communication partner. Using a wireless HAT can improve the level of the speech compared to the background noise (signal-to-noise ratio) by more than 10 dB (Lewis, Crandell, Valente, & Horn, 2004). This level of signal improvement provides a significant benefit to a listener who has difficulty processing speech in the presence of a distracting background noise.

So far we have only talked about strategies to be taken on an individual level. However, there are also strategies that can be implemented by society as a whole in order to improve communication and ensure appropriate accessibility of public space. Over the last few decades there has been substantial improvement in accessibility to public spaces for those with mobility problems. In large part this is due to legislation requiring that public spaces be wheelchair accessible. At the present time there is little recognition of the communication problems that older adults experience in both public and private places, and very little in the way of legislation that would lead to improvements in hearing accessibility (see The Americans with Disabilities Act (ADA), https://www.ada.gov). To remedy this situation will require that architects, public planners, etc. be made aware of these communication problems, and work with acousticians and hearing professionals on devising ways of overcoming them so that public buildings are designed to reduce extraneous noise and reverberation and provide adequate lighting for optimal visibility of visual speech cues.

Finally, information and education for the general public concerning age stereotypes, sensory-cognitive misattributions and their adverse role in communication may help to change societal attitudes and lessen their negative impact. Acknowledging the large costs of a sensory unsupportive atmosphere to older adults' cognitive performance would be a first step to avoid misattributions. An alternative and preferred option would be to ensure sensory-friendly environments so that the ability of older adults to perceive the input would not only be improved but the stress related to the fear of being negatively stereotyped as wizened might also be lessened.

In addition, communication partners of all ages need to become aware that certain age-related stereotypes are inappropriate when it comes to communicating with older adults, and of strategies for improving communication with older adults. For instance, when many younger adults are finding it difficult to communicate with an older adult, their first attribution as to the source of the problem is cognitive decline on behalf of the older listener (Wallhagen, 2010). A better approach is to assume that there may be a hearing problem, and that the communication difficulty that they are experiencing may be overcome by a change in venue to a more hearing-friendly environment, a change in their behaviour (using clear speech, facing the older conversational partner), and allow more time for the older adult to respond. Similarly, older listeners need to be aware that they themselves may hold age stereotypes that prevent them from acknowledging their hearing impairment and seeking the available support.

Conclusion

Hearing and cognitive abilities decline with age. As a result of these impairments older adults have more difficulty understanding speech, especially when they have to process speech under poor listening conditions. Only by working together in interdisciplinary teams that include researchers and clinicians across a whole range of fields can we investigate all of the factors affecting speech perception, and develop effective strategies to improve communication, thereby increasing older adults' sense of well-being, life satisfaction and quality of life.

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