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Novel approaches towards more “real-life” listening experiments in complex acoustic scenes

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ABSTRACT

In real-life listening situations, we often listen to speech inside rooms with different room acoustics conditions and in the presence of masking noise. Most everyday listening situations consist not only of direct sound from multiple sound sources, but also numerous reflections reaching our ears caused by the physical environment. These listening situations are challenging for adults and especially for children. Acoustic environments in educational institutions (schools and kindergarten) are usually highly complex and noisy, hence it is demanding to identify relevant target speakers and to ignore irrelevant sounds.

Two approaches will be presented to examine more real-life aspects of complex listening situations in controlled listening experiments. The first approach is a speech-in-noise test, investigating effects of a moving masker including room acoustic effects in young and elderly listeners. The second approach is an auditory selective attention paradigm, which has been evaluated with adults, both in dichotic and binaural listening environments. Additionally, to meet the needs of children, the auditory selective attention paradigm was adapted and validated with children. This contribution highlights important (binaural) features in the transformation of experiments from simple instances of audio reproductions towards more life-like listening situations.

1. INTRODUCTION

In complex listening situations, communication and speech comprehension is a great challenge. Speech-based communication between speaker and listener requires a wide range of functions and processes across the entire spectrum of human information processing: Speech perception, for example in a noisy environment requires auditory scene analysis and connected cognitive information processing. However, research in this context is often conducted with well-controlled but unrealistic stimulus presentations, using simple instances of auditory reproduction of stimuli or simple technical implementations of virtual environments.

In order to include more ecologically valid complex listening situations, it is necessary to gradually incorporate features of realism by carefully observing the influence of each feature on a given experiment. These features may include advanced methods of auditory

reproduction of stimuli, room acoustics, number and type of sources, moving sources/listeners, various acoustic stimuli, etc. Each feature can have an impact on the experimental paradigm when improving realism, but each feature can also add artifacts and uncertainties caused by the methods, technologies and the implementation of the tools applied. Taking into account these various aspects a validation requires a consistent consideration of all possible factors.

This contribution provides an overview of two approaches for bridging the gap between standard laboratory conditions and real-life situations. To simulate a real-life conditions using acoustic virtual reality, the (binaural) reproduction of the spatial scene needs to be adequately plausible, if not authentic. [1] defines the perceptual identity in a comparison between a real scene and a virtual scene as “authentic”. A “plausible” reproduction, on the other hand, refers to a scenario in which the perceptual identity is not essential, which, according to [2] can be understood by “a simulation in agreement with the listener’s expectation towards a corresponding real event” (see also [7]).

2. DYNAMIC SPEECH-IN-NOISE TEST

In a complex acoustic scene a speech signal is usually spatially separated from the masking sounds, in this case the listeners can use the different directions of the sound sources to separate the speech perceptually from the masker and thus increase speech perception. This phenomenon is known as spatial release from masking (SRM).

In real situations we often listen to speech in the presence of masking sounds in rooms with different room acoustic parameters. Another degree of freedom is the type and nature of the sound sources: they can be stationary or moving (dynamic) generating many acoustic reflections that reach our ears at different times and with different intensity. Nevertheless, today’s audiological diagnostic systems or methods are mostly based on simple and static sound situations. A more realistic dynamic situation could reduce the SRM, especially if the reverberation increases. In our study on “Spatial release from masking under different reverberant conditions” [4], we studied the effect of moving or stationary maskers in different room acoustic conditions with young and elderly subjects.

Main findings were: A radially moving masker led to improved SRM in an anechoic environment for both age groups, while a circularly moving masker caused degraded SRM, especially for elderly subjects in the highly reverberant environment.

3. AUDITORY SELECTIVE ATTENTION PARADIGM IN VIRTUAL ACOUSTIC REALITY

Measurement paradigms for higher cognitive processing such as auditory selective attention may also serve as indices of binaural reproduction quality, especially concerning the quality of acoustic virtual reality situations such as a cocktail party.

We extended and applied a paradigm to examine intentional switching in auditory selective attention to a binaural version [6]. The same experiment was repeated with four different reproduction methods to obtain a spatial scene: real sources (i.e., loudspeakers) in an anechoic environment, individual binaural synthesis reproduced with headphones, non-individual binaural synthesis reproduced with headphones, and non-individual binaural synthesis reproduced with two loudspeakers using Crosstalk Cancellation Filters (CTC). Results revealed that it is crucially important to examine how spatial reproduction affects the results in experiments involving auditory selective attention, and therefore to determine whether different conclusions may be reached with different spatial reproduction methods or not. In this context, it may be pertinent to ask what qualitative difference, in terms of results, is likely between “real-life” situations simulated with high accuracy (including individual head-related transfer functions, etc.) and merely plausible rendering methods.

The binaural paradigm was also tested in simulated rooms with different reverberation times, because an anechoic reproduction fails to represent realistic listening experiences [9]. It was found that reverberation has a detrimental effect on reaction time when attention is required to be focused on one source at a constant spatial location. Intentionally switching attention to a sound source at a different spatial location appears to require so much more attention that additional reverberant energy does not have a further impact. There may be other variables, such as head and body movements [8] as well as additional distracting noise sources (e.g., cars, airplanes, barking dogs, construction noises, etc) that contribute to the complexity of an auditory scene, influencing the efficiency of cognitive processing. It is essential to consider both room acoustics and distracting sources when analyzing a natural acoustic scene or creating a dynamic reproduction of an acoustic scenario. Further extensions of the binaural paradigm are therefore necessary in order to examine auditory selective attention in realistic, complex environments.

Auditory selective attention is needed by human individuals of all age groups to succeed in noisy communication situations. Differences in the degree of success are expected during aging processes. As there is a trend towards an aging society, age-effects have become of greater interest [5]. Results show how older people have more difficulties to ignore distracting speakers than young adults when listening to a spatially binaural reproduction of a multi-talker environment.

With respect to children, we know that children spend a considerable time in educational buildings, like primary schools, with highly complex acoustic scenes including target speakers and many surrounding distracting sounds. Therefore, we studied auditory selective attention also with children. In our study, a suited paradigm for children was created in order to investigate their auditory selective attention and the impact of noise in comparison to adults [3]. The study revealed significant difference between the age groups indicating higher sensitivity to noise in cognitive processes of children in comparison to adults.

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