A New Method for Localization Studies

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Summary
Many scientific studies investigate and technical applications use the acoustical localization in the field of vision. Therefore it is suitable to display the perceived auditory direction by a light point. In formerly known methods subjects use a hand-held light pointer or a pointer mounted on a revolvable axle in front of them. However, the subject's motor system or the optical parallax may influence the results of those techniques. The calibration of the system and data logging also turn out to be difficult. The proposed new method utilizes a laser pointer with a deflection unit instead, which is controlled by a computer. Subjects enter the perceived sound direction with a trackball. The laser spot moves according to the rotation of the ball smoothly on a defined track. A complicated mechanical calibration can be avoided by calibrating the deflection unit by a computer. The intuitive experimental operation and the high resolution of the system make this method particularly suitable for localization research in audiology, psychoacoustics, and virtual acoustics. The symmetric, bimodal outlay of the experimental task reduces interaction effects between different modalities. Localization results for variable and fixed initial laser position obtained by this method are presented and compared to results acquired by other methods.

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1. Introduction

Acoustical directional displays in real and virtual environments gain in importance by the introduction of multimedia in many fields of everyday life. Applications range from teleconferencing systems over computer games to user interfaces in control and surveillance systems. The multitude of new applications is accompanied by an increased demand of knowledge about auditory localization in the field of psychoacoustics and audiology or within the scope of a specific application. All methods for the investigation of auditory localization require the subject to specify the perceived auditory direction. Known methods compare two directions, i.e. detect the perceived difference between two directions, or directly point to the direction [1]. Besides the information about the mean apparent direction the directional scatter is of interest for the acuity of localization. To provide information on the uncertainty of localization the testing method must add less variance to the responses than the sensory task. The response bias introduced by the method should be small and a quantization of the results should be omitted. The method should be intuitively to handle and easy to learn for the subject. A computerized data collection is a prerequisite for a high data acquisition rate and a fast evaluation of the responses.

Several methods in ego- and exocentric space have been proposed so far. A simple exocentric method requires the subject to mark the perceived sound position in a coordinate system on a piece of paper [2]. Using this method distance information can also be assessed. A projectional pointer method in an exocentric coordinate system is the GELP-method or "Bochum Sphere", where subjects indicate the apparent direction on a sphere [3, 4]. This comfortable method covers the whole space and provides fast responses. However, Djelani et al. [5] point out that the GELP-technique requires some training and the projection leads to systematic errors in connection with a reduction in accuracy. If pointing in a non-body-centered system is not favoured, pointer methods in the egocentric coordinate system should be chosen. Hand-, head- and eye-pointing are extensively studied (hand [5, 6]), (head [5, 7, 8, 9, 10]), (eye [11, 12, 13, 14]). These natural and intuitive methods achieve a high accuracy in frontal direction despite the use of the motor system for indication of the auditory direction. At lateral positions, strong systematic errors occur due to limitations of the motor act and intersensory projections. The methods are thus limited mainly to the frontal sector. Further methods involve the naming of speaker numbers or the angle. The latter is referred to as "absolute judgement technique" and covers the whole space but requires extensive training [15, 16]. The precision of the visual system allows visual pointing to acoustic targets [17]. In order to minimize errors introduced by the mapping of auditive coordinates to visual or motorical coordinates acoustic pointers can be introduced [18]. Using these pointers, care must be taken that subjects use directional instead of timbral cues as a decision variable for the adjustment of the pointer. However, as the test-stimuli and pointer directions undergo the same coordinate transformation from acoustic (physical, external) to auditive (perceived) directions, a relative rather than absolute direction will be displayed in terms of a minimum audible angle [19]. An unimodal advantage is given if the pointer input-interface allows no direct relation to visual or motorical coordinates.

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rections, not significant at 1%). This is also reflected in the median absolute error of 0.2 deg. Further, the median upper (lower) quartile of the indicated directions is 0.5 deg (-0.6 deg) and thus about 4.6 (3.4) times, or 1.8 deg (1.2 deg), smaller than in auditory experiment 1 (exp. 2). When comparing this accuracy with the minimum observable auditory angle of about 1 deg [1, 19] it becomes evident that the visual pointing accuracy itself is adequate for pointing to auditory targets. The exact reproduction of visual positions with a movable pointer of variable initial position requires a mechanism of exact memorization of the perceived positions as the medians are not shifted significantly. Existing interference effects between the memorized and the pointer position are reduced by the statistically symmetrical, two-sided scattering of the initial laser positions. Thus, these interference effects rather result in an slight increase in variance than in a shift of the indicated position. The comparison of the perceived visual pointer position with the auditory coordinates, however, introduces some variance which is difficult to measure. This coordinate mapping from auditory coordinates to directions in other modalities is inherent to all pointer methods as they require the subject to compare both directions. The main benefit in this regard of the new method in contrast to many other formerly known methods is that it involves only two modalities, auditory and visual. As no motorical interactions occur and visual interactions are kept at a minimum, it can be assumed that the interference from other than auditory modalities is relatively low with the new method.

Although this method can be used only in the field of vision, the high accuracy of the method and the possibility of evaluating the variation in the responses give this method a wide range of applications. Besides applications in virtual acoustics and psychoacoustics, the intuitive and fast handling of the apparatus and method make this method particularly suitable for localization research in audiology [20]. In localization studies with hearing impaired subjects, the initial direction of the laser spot should not vary around the presented sound direction but should be straight ahead. Thus it can be assured that the variability in the adjusted direction is a measure for the accuracy in localization. As hearing impaired subjects gain more information from monaural level differences between the trials as normal hearing subjects, the level should be randomized in each trial. Besides that the mean level can be increased to 70 dB SPL.

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