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# A new hearing screening system for preschool children

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ABSTRACT

*Objectives:* This study aimed to investigate the practical application of Smart Hearing, a new hearing screening system for preschool children.
*Methods:* The screening system was applied to 6288 preschool children. The system auto-tested hearing thresholds at three frequencies: 1 kHz, 2 kHz, and 4 kHz; a 30 dB hearing level (HL) was the critical intensity for passing. Children with positive results were referred for audiological evaluation (pure tone audiometry, tympanometry and distortion product otoacoustic emissions assessment, etc.). To evaluate the test accuracy, 312 children (5%) were randomly selected to receive audiology assessment.
*Results:* In this study, 582 children (9.3%) tested positive in the screening, and the referral rate of the four age groups from 3 to 6 years old was 18.8%, 11.9%, 6.5% and 4.0%, respectively. A total of 463 children underwent audiological assessment, of which 12 cases (1.91‰; 95% CI: 0.83‰, 2.99‰) were diagnosed with permanent hearing loss, and 75 cases (1.19%; 95% CI: 0.92%, 1.46%) were diagnosed with temporary conductive hearing loss. No mixed hearing loss was found in this study. The specificity of the system was 92.6% and the sensitivity was only 37.5%.
*Conclusions:* This screening system is suitable for the universal hearing screening of preschool children above 4 years old, and further improvements of the system are needed to increase its sensitivity.


## 1. Introduction

Congenital hearing loss is detected approximately in 1.1–1.4 per 1000 births through universal newborn hearing screening programs in the United States [1,2]; however, the prevalence of hearing loss in children can reach 14.9% [3]. In addition to congenital hearing loss, hearing impairment can occur at any stage of growth and development in childhood, including late-onset, acquired, and progressive loss that cannot be identified through universal newborn hearing screening [4,5]. The preschool years, particularly between the ages of 3 and 6 years, are important for speech, language and cognitive development. Studies have shown that even slight or mild hearing loss can exert an adverse impact on children's behavior, development, education and overall well-being [6,7]. Early identification and management of hearing loss caused by various reasons is necessary for the sake of children's language, social interaction, learning ability, quality of life and long-term prospects [8].

Up to now, the hearing screening methods for preschool children have mainly included pure tone screening, tympanometry and otoacoustic emissions (OAE). However, with relatively few studies comparing these methods for different populations, there has been no clear consensus about a unified standard for screening. A systematic review comparing various screening protocols indicates that questionnaires and otoscopes should be used only as adjuncts to other methods of hearing screening [9]. Furthermore, tympanometry and OAEs require specialized devices and personnel, and are technically not tests of hearing thresholds. Tympanometry is used to evaluate middle-ear function, while OAE measures the function of the outer hair cells. Hence, some children having mild hearing loss or having an auditory synchrony problem may be missed by screening using OAE alone [10]. Pure tone

*Abbreviations:* CI, confidence interval; dBA, decibels A-weighted; HL, hearing level; OAE, otoacoustic emissions; PTA, pure tone audiometry.

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screening is highly recommended and currently thought to be the most suitable test for preschool hearing screening [9], but this technique also has its own problems. Its result relies on the testers' subjective judgment of children's reactions, and sometimes the children, especially those under 4 years of age, are unable to cooperate with the screening instructions, thereby interfering with the procedures and results.

All these problems suggest the need to seek a new kind of hearing screening system that is easier and more practical for use in preschool children. The Smart Hearing Screening system has been developed as a new type of behavioral hearing screening test based on the principle of traditional pure tone audiometry (PTA). The software conducts pure tone screening automatically and uploads real-time results to the network.

This study applied the new screening system to preschool children, aiming to evaluate the feasibility of its use with regard to its screening performance, sensitivity and specificity.

## 2. Materials and methods

### 2.1. The screening system

The screening system is a behavioral audiological test combining pure tone screening with multimedia and networked computers. The software, containing pure tone audio files and a set of cartoon animations for response to voice, can deliver pure tones (1 kHz, 2 kHz and 4 kHz) ranging in intensity from 20 dB HL to 60 dB HL, with adjustments at intervals of 5 dB HL. The software is installed on a Samsung GP-P6800 Smart Tablet, the platform of which is the Android 3.2 (Honeycomb) operating system with supporting Internet connection through a subscriber identity module (SIM) card. During the test, pure tones are presented via Bose QuietComfort 15 active noise-canceling headphones that effectively reduce low-frequency (100–1000 Hz) noise. The Internet is also indispensable in this system for uploading results. All the facilities have to conduct acoustic calibration before they are used. The complete screening procedure includes three parts: guidance, formal screening and uploading of results. Children passing the guidance would undergo the formal hearing test independently, and the results should be uploaded to the network immediately following a standard presentation by the device manufacturer before the next round of screening. Children with thresholds above 30 dB HL at any frequency of 1 kHz, 2 kHz and 4 kHz in either ear were deemed to have tested positive in the screening. Those who did not pass the guidance should also be classified as referral cases (see Appendix).

### 2.2. Subjects

This was a cross-sectional study with a sample of 6372 preschool children enrolled from 41 kindergartens spread throughout Yangpu District in Shanghai (a total of 106 kindergartens in this area). Among the total sample, 76 children refused to take part in the screening, and another eight children were diagnosed with learning disabilities such as growth retardation, autism and cerebral hypoplasia before by designated medical institutions. These 84 children were excluded from this study. Therefore, 6288 eligible (98.7%) preschool children, consisting of 3282 (52.2%) boys and 3006 (47.8%) girls with a mean age of 5.05 years at testing (range = 3.01–6.92, standard deviation = 0.71), participated in this study (Fig. 1). All of these participants were not diagnosed with mental abnormality before their inclusion in this project, and all had normal vision or normal corrected visual acuity. Written informed consent from children's parents was obtained prior to the screening. This study was approved by the Medical Ethics Committee of the Xinhua Hospital affiliated with Shanghai Jiaotong University School of Medicine (No. XHEC-C-2012-006).

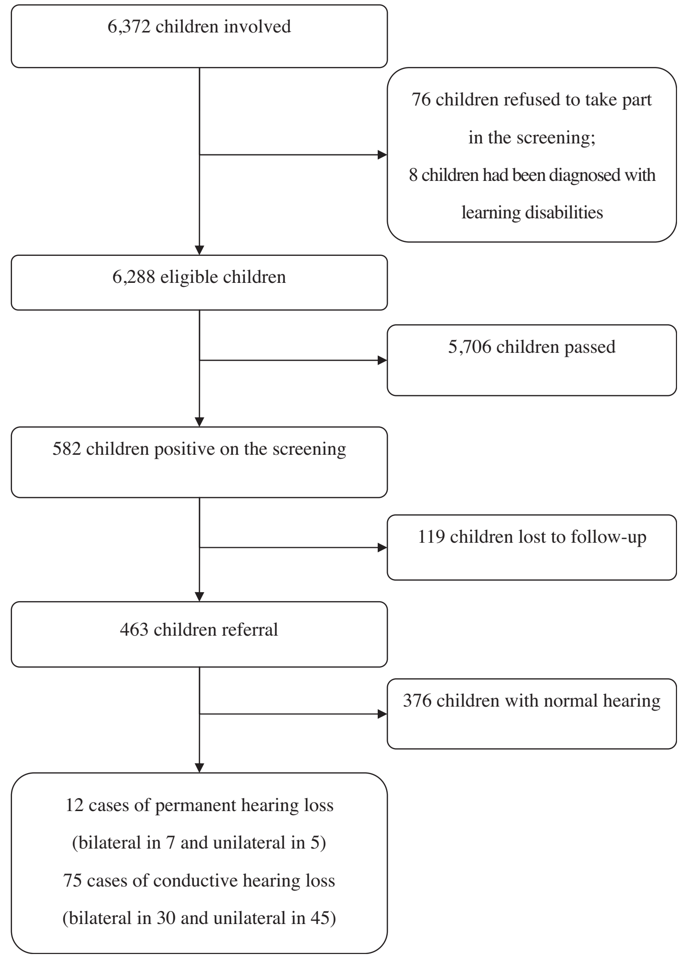


**Fig. 1.** Flow diagram of participants through the study.

### 2.3. Screening procedures

All the screening personnel, with normal hearing, had undertaken specific training in the screening procedures. Children were tested in relatively quiet rooms within each school, in which the ambient noise did not exceed 55 dBA (between 39.8 and 50.5 dBA) as measured by a TES 1357 sound level meter. The testers began the hearing screening following routine calibration of the device each day. A program of daily calibration was set in the Smart Hearing Screening system, which aims to detect system malfunctions and prevent audio outputs that produce significant bias. Through the self-test settings, testers had to ensure that pure tones of 30 dB HL could be clearly heard symmetrically on both sides by headphones in the test environment to prevent issues with device connection. Children who did not pass the test in the initial screening were immediately rescreened. Those who failed in the rescreening and in the guidance were referred for diagnostic assessment (Fig. 1).

In order to estimate the sensitivity and specificity of the new screening system, 312 children (5%) were randomly selected from the 6288 eligible children before the screening. Regardless of the screening results, all of these 312 children (mean age = 5.06, standard deviation = 0.72) received audiological assessment by pure tone audiometry (PTA) or play PTA supplemented by tympanometry and distortion product OAE.