DEVELOPMENT OF A TELEPHONE HEARING TEST

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INTRODUCTION

Approximately one in seven adults in the UK (6m people) have a hearing impairment averaging 25 dB or more in the better ear across the test frequencies 0.5, 1, 2 and 4 kHz. This is a level of impairment at which hearing aids may start be give some benefit. At an average hearing impairment of 35 dB, prevalence is about 8% (3m) and hearing aids will give substantial benefit. Nonetheless, only 2m adults in the UK have actually obtained a hearing aid and only 1.4m use them. Hence, there is a substantial unmet need in terms of simple assistance for hearing impairment.

Proactive studies that set out to screen adults for hearing impairment and provide hearing aids to those who may benefit have shown to be effective (Smith et al., 2005). People identified in this way tend to accept hearing aids, to use them and derive benefit from them. This suggests that proactive screening programmes may be useful to address the unmet need.

An alternative approach is to offer a mechanism for self-screening, whereby people can test themselves to see if their hearing is impaired, and seek help accordingly. An innovative approach to self-screening has been pursued in the Netherlands using a telephone hearing test, based on recognition of speech in noise (Smits et al., 2004; Smits and Houtgast, 2005). The rationale for the test is that most hearing impairment affects the inner ear and is associated with a loss of ability to recognise speech against a background of noise: people need a more favourable speech-to-noise ratio (SNR) to obtain a criterion level of performance, typically 50% correct. This SNR loss is a face valid indicator of hearing impairment that can be tested simply over the telephone because it is more-or-less independent of the presentation level of the speech and noise. Therefore, it is not necessary to calibrate the output of the telephone to obtain meaningful results, because the SNR delivered during the test is determined by the test implementation and is independent of the test participant's telephone instrument volume setting. The test uses number triplets as the speech material and the participant responds by pressing the corresponding keys on the keypad.

The Dutch test uses speech materials in the Dutch language, which is unsuitable for use in the UK. Therefore, the aim of the present study was to develop a new English version of the speech-in-noise test over the telephone.

METHODS

The test development involved two stages. In the first stage, the number triplet test was developed and validated for direct presentation via earphones (i.e. not using a telephone) under computer control on a PC. The second stage utilised the same speech materials and implemented the test for telephone use using the facilities of a telephone service provider. The test is referred to here as the TRIPLET test.

The first step entailed recording the spoken digits. These were restricted to 0-9, with the exception of 7, which is a two-syllable word in English. The digit 0 was pronounced "oh" as is common when reading out telephone numbers. A female speaker with a neutral southern accent read out digit triplets in a large recording studio having minimal reverberation. The triplets were recoded onto digital audio tape at a sample rate of 44.1 kHz then transferred to digital waveform files (.wav). These files were then edited by equalising the overall levels of the triplets then cutting the individual digits to obtain two good examples of each digit in each triplet position. By retaining digits from each position, it was possible to preserve the natural intonation used when speaking the triplets. Following the process of cutting, new triplets were generated in random order by specially written software and compiled into lists of nine triplets. Each triplet was preceded by the lead-in phrase "The digits…". Each list contained every digit in each of the three positions. Lists with repeating digits within a triplet were rejected. A total of 20 lists were generated for evaluation, half composed of the first version of each digit and half composed of the second.

The triplets were mixed with noise at various SNR for evaluation. The noise was stationary and generated by filtering Gaussian noise so it had the same long-term average spectrum as the corpus of digits. Fourteen subjects listened to all 20 lists of triplets at four SNR to estimate the performance function relating percentage correct to SNR for each digit item. Logistic regression analysis enabled the SNR required for 50% correct recognition to be estimated for every item, as well as the slope of the performance function. Ideally the former would be equal and the slopes would be high. These data were used to select the better digit version and to calculate intensity adjustments that would be needed to make all digits equally recognisable.

Following this analysis, corresponding adjustments were made to the intensity levels of the digit recordings to equalise them and new sets of triplets were generated using only the better digit versions. These formed the material for the second stage of development: implementation of the telephone test.

The telephone test utilises an adaptive algorithm, whereby the speech level is fixed and the noise level is varied to find the SNR required for 50% correct recognition of entire triplets (i.e. all digits correct and in correct order). This algorithm was specified in detail and implemented by a telephone service provider. The speech and noise were pre-mixed in compressed waveform files at all required SNR for all triplets used. The software simply selected appropriate files and replayed them according to the algorithm. The test participant responds by pressing number keys on the telephone keypad. The outcome of the test is a SNR value between approximately −11 and +5 dB in 2-dB steps, which is categorised into three levels: "within normal range", "below normal" and "well below normal". The test is invoked by calling the number 0845-600-5555. The caller hears a spoken explanation of the test then is asked to press keys to indicate age and sex. The test then runs, followed by a spoken indication of the result category, with advice on what to do next.

The telephone test was validated in five centres by 80 subjects with normal hearing to establish the range of normal hearing results. These results were used in combination with the published data from the Dutch test to set the boundaries of the outcome categories.

RESULTS

The first stage of development using earphone presentation demonstrated performance functions for lists as illustrated in Fig.1. SNR values for 50% correct for the digits averaged −11.6 dB; when the versions closer to the average were chosen, deviations from the average were within ±2 dB for 22 of the 27 digit/positions. The largest deviation was 5.5 dB. The earphone validation is described in detail by Hall (2006). For the implementation of the telephone test, these deviations were accounted for by adjusting the waveform files accordingly, so that all digits should be approximately equally recognisable. Overall performance-intensity functions obtained agree with corresponding Dutch test results, as do normative values for the telephone test. The mean SNR for 50% correct on the telephone test for normal hearing participants in the validation study was approximately −7 dB. This is 4-5 dB greater than for earphone presentation, which is due to degradations occurring in the telephone system.

To date the telephone test has been used by 220,000 people. Preliminary data suggests that participants are split equally between males and females, with approximately 60% aged over 50 years. Overall, approximately 90% are classified as "within normal range". The remainder are split almost equally between "below normal" and "well below normal".

Further studies are in progress to validate the test in a number of ways, utilising participants with normal and impaired hearing. These will assess the sensitivity and specificity of the test for identifying participants with impaired hearing. The actions taken by a sample of participants following taking the test will also be identified to assess whether the test advice leads to beneficial intervention.

CONCLUSIONS

The TRIPLET test format meets the requirements for a mass screening test of hearing, implemented via the telephone. Further refinement and validation are required to determine the sensitivity and specificity of the test to identify people requiring intervention regarding their hearing.

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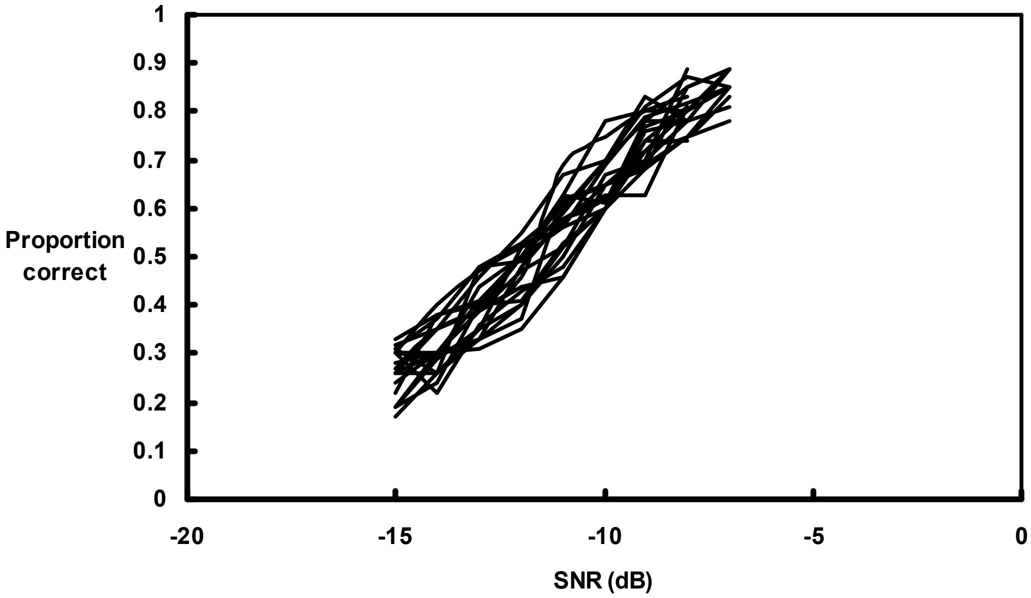

Fig 1. Performance functions for TRIPLET test lists via earphone. Each line represents one of 20 lists.