British children´s performance on the Listening in Spatialized Noise-Sentences Test (LISN-S).

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Abstract

Objective: To investigate whether British children’s performance is equivalent to North American norms on the LiSN-S.

Design: Prospective study comparing the performance of a single British group of children to North-American norms on the LiSN-S (North American version).

Study sample: The British group was composed of 46 typically developing children, aged 6 to 11 years 11 months, from a mainstream primary school in London.

Results: No significant difference was observed between the British´s group performance and the North-American norms for Low-cue, High-cue, Spatial Advantage and Total Advantage measure. The British group presented a significantly lower performance only for Talker Advantage measure (z-score - 0.35, 95% confidence interval -0.12 to -0.59). Age was significantly correlated with all unstandardised measures.

Conclusion: Our results indicate that, when assessing British children, it would be appropriate to add a corrective factor of 0.35 to the z-score value obtained for the Talker Advantage in order to compare it to the North-American norms. This strategy would enable the use of LiSN-S in the UK to assess auditory stream segregation based on spatial cues.

Introduction

One of the most typical complaints presented by children with listening difficulties is the challenge of understanding and focusing on a specific auditory stimulus in the presence of background noise (Jerger & Musiek, 2000; Vanniasegaram et al, 2004; Vermiglio, 2014; De Bonis, 2015). Previous research has hypothesized that, for some children, this difficulty might be caused by a deficit in spatial processing skills (Cameron & Dillon, 2008); more specifically, by reduced ability to use binaural cues to segregate and differentiate the acoustic information coming from sources separated in space. It is well established that when target speech and competing sounds are spatially separated, an improvement on speech intelligibility is expected, a phenomenon known as spatial release from masking (Litovsky, 2005; Best et al, 2012; Misurelli & Litovsky, 2015). In some children with listening difficulties, spatial release from masking is atypically small. This listening problem and related test deficit have been observed in about 20-30% of children with a past history of conductive hearing loss associated with otitis media (Tomlin & Rance, 2014; Graydon et al, 2017), highlighting the importance of assessing this specific skill in this population.

Several studies have investigated SRM, in adults and children (Litovsky, 2005; Marrone et al, 2008, Best et al, 2012; Papesh et al, 2017; Jakien et al, 2017). In adults, it has been shown that SRM may improve speech intelligibility up to 12 dB (Marrone et al, 2008) and the magnitude of this effect may also depend on non-spatial factors such as how similar masker and target are (the more similar the greater the SRM) (Misurelli and Litovsky, 2015), the type of masker (greater SRM for speech rather than non-speech maskers) (Misurelli and Litovsky, 2015) and the presence of hearing loss (Best et al, 2012). Some studies demonstrated that SRM in children and adults are overall similar (Litovsky 2005); others found differences for some specific stimuli, such as sentences, with adults presenting greater SRM than children (Vaillancourt et al, 2008) and older children having greater SRM than younger children (Cameron and Dillon, 2007).

Although several different tasks have been used to assess SRM, few clinical tasks are available. Hearing in Noise Test (HINT), for instance, assesses SRM through 3 different conditions that differ only in terms of spatial location between the masker and the target (sentences) (Nilsson et al, 1994). The test has been translated into several languages (Lolov et al, 2008; Bevilacqua et al, 2008; Vaillancourt et al, 2008; Wong, 2008) and the norms are available for adults and children. The LiSN-S is another clinical test that assesses not only SRM but also how effective the individual uses auditory cues related to the pitch of speakers´voice, to differentiate speech sounds presented simultaneously (Cameron & Dillon, 2007; Cameron & Dillon, 2009). It is well-known that the greater the similarity between target and masker, e.g. when they are same voice, the greater the masking (Misurelli & Litovsky, 2015). Because the LiSN-S involves the use of both tonal and spatial cues, separately and in combination, to segregate speech, it is considered as an auditory stream segregation test rather that only a SRM test.

The LiSN-S has been mainly used to assess children with suspected auditory processing disorder (Cameron & Dillon, 2008; Cameron et al, 2015; Moore & Campbell, 2017) and it has been considered as a reliable and sensitive tool to diagnose spatial processing disorder (SPD), classified as a subtype of auditory processing disorder (Cameron & Dillon, 2008, Moore, 2018). It is also one of the few clinical auditory processing (AP) tests in which performance is not directly correlated to high-order cognitive functions, in that the spatial advantage measure, in particular, does not correlate with such functions (Tomlin et al, 2015; Moore, 2015). This is probably due to the design and method by means of which performance is analyzed. Different from most AP tests, the diagnosis is based on a relative measure ("advantage measure") that is calculated by comparing performance between two conditions that differ only in terms of presence or absence of an auditory cue, such as a different spatial location or different voice delivery of the target speech stimuli relative to the background competing discourse. Because the conditions otherwise have the same cognitive demands, the relative measures enable the control of high-order functions such as language and memory, annulling, consequently, any association between the resultant performance and these confounding factors (Cameron & Dillon, 2007).

Because LiSN-S was originally developed in Australia, its first version included Australian-accented speech stimuli (Cameron & Dillon, 2007). The authors, subsequently, developed a North-American-accent version, which is currently available for clinical use in the United States and Canada (Cameron et al, 2009). The reason for developing this last version was based on previous studies that demonstrated a significant influence of aspects such as semantic items and accent on non-native population´s performance in speech tests (Dawes & Bishop, 2007; Marriage et al, 2001). These studies investigated the performance of British children on a clinical battery of auditory processing tests (SCAN and SCAN-C) comprising North-American-accented speech stimuli. Both studies demonstrated that British children´s scores were significantly lower (worse) compared to North-American´s, with error analysis indicating a "word familiarity" and "accent" effect. Scores of the British group suggested that using the North-American (NA) norm would possibly lead to an inaccurate over-identification of auditory processing disorder.

Although SCAN and LiSN-S are both auditory processing tests involving speech, they assess different listening skills and this, to some extent, might interfere with the accent effect. Dawes & Bishop (2007), for example, observed that the difference between NA and UK performance was higher for filtered words and auditory figure-ground subtests, both tests involving “monaural low-redundancy degradation”. On the other hand, for the dichotic subtests Competing Words and Competing Sentences, no significant difference was observed. LiSN-S is also a binaural test involving competing speech, but a key output of the test is a difference score that assesses the ability to use spatial cues. It is possible that an accent or familiarity effect might not be observed for derived measures (i.e. difference scores), if familiarity with the accent has the same effect on the two base scores from which the difference scores are calculated.

The present study aimed to compare the performance of British children to NA normative data on the LiSN-S. This investigation is important since no previous study has investigated the performance of British-accent speakers on this specific test and no equivalent test is available in the UK. The current findings, therefore, will determine whether the NA norms may be valid for the UK population, enabling the clinical use of the test in this country. The reason for selecting the North-American-accent version for this study, instead of the Australian one, was based on the high popularity of NA TV programs and music. We assumed, therefore, that British children are more familiar with the NA than Australian accent, which might reduce the chance of observing a highly significant accent effect and poor performance of the British group, compared to the NA norms. The comparison between UK performance and NA normative data will be conducted not only for each advantage measure ("spatial advantage" and "talker advantage") but also for the "total advantage" measure and the two base conditions "low cue" and "high cue" that are amongst those used to calculate the advantage measures. We hypothesise that the degree of spatial advantage will not be affected by accent, because the two scores from which spatial advantage is derived should be equally affected by familiarity with the accent. Also, the binaural mechanism that creates the spatial advantage (better ear glimpsing; Brungart & Iyer, 2012; Glyde et al, 2013) relies primarily on acoustic head shadow effects that should be unaffected by familiarity with an accent. From a clinical perspective, we expect that these results will contribute to an improved diagnosis of listening difficulties and will support further rehabilitation.

Methods

This study was conducted at the University College London (UCL) Ear Institute and was approved by the UCL Research Ethics Committee under protocol number 6688/001. A written consent form with detailed information about the aim and the protocols of the study was also approved by this ethics committee. All parents provided written informed consent on behalf of their children prior to participation in the study.

Participants

A total of 46 typically developing children, aged 6 to 10 years, from a mainstream primary school in London, took part in this study. All children were monolingual speakers of British Standard English and were living in the same borough in London. According to the national index of multiple deprivation that varies from 1 (most deprived area in England) from 32.844 (least deprived area), the mean index of this specific area in London is 15.576, which represents an average score compared to the general population in England. The children, from both genders, were required to have no familial or personal history of diagnosed or suspected auditory difficulties (including any otological disease since birth such as middle-ear disease and listening difficulty such as understanding speech in the presence of background noise) and no developmental disorders, speech and language difficulties, psychological, or neurological disorders or injuries.

The first stage of the group selection was conducted by the researcher with the help of the school staff composed of teachers, SENDCo (special educational needs and disabilities co-ordinator), learning mentor and administrators. The school team helped to identify and exclude children with a diagnosis of learning disability, speech and language, developmental and psychological disorders. They also provided information regarding the criterions "being monolingual". Children who were not excluded in this first stage of selection received the invitation to take part in the study and, accepting the invitation, also received the questionnaire to be completed. The second stage of selection took into consideration parents´ responses in the questionnaire, which included questions related to all those criteria. The participants were also required to pass an audiometric screen in a quiet room in their school using sound-attenuating headphones (pure-tone thresholds < 30 dB HL at 1 kHz, 2 kHz, and 4 kHz). This criterion is usually adopted in school hearing screenings in the UK (Fortinum et al, 2016) and also in previous research involving hearing screening in schools (Halliday et al, 2012). A phonological processing test (subtest Alliteration of the Phonological Assessment Battery/ PhAB, Frederickson et al, 1997) and a reading test (subtest Sight Word Reading Efficiency of the Test of Word Reading Efficiency [TOWRE; Torgesen et al, 1999]) were also conducted to obtain objective information regarding their language/reading skills. The characteristics of the group are described on the table 1.

(Table 1)

Materials and Procedures

LiSN-S is a binaural interaction speech test in which target sentences and background noise (competing continuous discourse / children´s stories) are presented simultaneously, in different conditions that vary in terms of the background noise´s location and voice (Cameron & Dillon, 2007). The differences in terms of location, provided under headphones (three-dimensional auditory environment), were developed by applying left- and right-ear head-related transfer functions (HRTFs) to single-channel speech recordings. The target sentences and competing continuous discourse might be composed of the same (SV) or different voice (DV) and be presented at the same (0° azimuth) or different location (± 90° azimuth), leading to four different listening conditions (SV0, SV90, DV0 and DV90). The location and voice of the target sentences are constant within each condition, but the level of presentation, which is initially 62 dB SPL, is adjusted adaptively, according to the listener´s performance. The Speech Reception Threshold (SRT), the minimum level in which the listener repeats 50% of the words in the target sentences, is then automatically calculated after 22 to 30 sentences, for each condition. The level of presentation of the competing continuous discourse is constant (55 dB SPL). Based on these SRTs, three advantage measures were calculated, according to the location and voice variables. The Spatial advantage variable is the difference between SRTs obtained at SV0 and SV90 and reflects how effectively the listener benefits from spatial cues. Talker advantage is the difference between SRTs obtained at SV0 and DV0 and it is related to the advantage gained through tonal cues. Total advantage variable is calculated through the difference between the low-cue SRT (SV0) and high-cue SRT (DV90) and reflects the combined benefit of talker cues and spatial cues (Figure 1).

(Figure 1)

LiSN-S was performed using a Gateway laptop computer, the LiSN-S software program (American version), Sennheiser HD 215 headphones and a USB-attachable *Phonak* soundcard. The test was carried out in a quiet room, in the school, during the regular school time. The data were collected in one single session of approximately 30 minutes for each child. The child was instructed to repeat the target sentences, more specifically, every word heard (since each word is scored individually) and ignore the background noise. Some practice trials were provided before the test to guarantee that the child comprehended the task. The presentation order of the four listening conditions was as suggested by Cameron and Dillon (2008): DV90, SV90, DV0 and SV0.

Statistical Analysis

The UK scores were compared to the NA norms by comparing the mean of the z-scores (computed by the software from the NA norms) to the expected value of zero, using the Student´s t-test (one sample). In addition, Pearson correlation was also performed to analyse the relationship between age and SRT (in dB) on each of the measures.

Results

Comparison between UK group performance and the NA norms

Figure 2 shows the speech reception threshold for the low-cue and high cues conditions, and the three advantage measures, as a function of age. Each dot represents the performance of each participant (raw scores x age). The solid line represents the average performance as a function of age, based on the published NA data (Cameron et al, 2009). The dotted line fits the current data with the respective function (y) and $R^{2.}$

(Figure 2)

In general, the NA mean curves reasonably fit for all measures except the Talker Advantage measure, in which the British performance is clearly poorer than the expected performance (lower talker advantage score). A significant correlation was found between raw scores and age for all the variables (Low-cue: *r* = - 0. 31, p = 0.03; High-cue: *r* = - 0.44, p = 0.002; Spatial Advantage: *r* = 0.36, p = 0.012; Talker Advantage; *r* = 0.36, p = 0.012; Total Advantage: *r* = 0.30, p = 0.03). For the high-cue condition, which is the most realistic listening condition, the SRT on average decreased with age at the rate of 0.67 dB/year, which compares with the rate of 0.75 dB/year for the NA norms (Cameron et al., 2009).

In addition to reporting the raw scores, LiSN-S uses the raw scores to generate a z-score for each variable. The z-score represents the raw score relative to mean (NA normative data) and it is expressed in population SD units for children of the same age. For example, a z-score of -2.0 indicates that the performance was 2.0 NA population SDs below the US NA means for children of the same age.

The mean of the z-scores of each variable was compared to zero using the Student´s *t*-test. There was no significant difference between the UK mean z-scores and the NA norms (i.e. zero) for all the variables, except for Talker advantage in which the UK group performed significantly worse than NA norms [$t_{(44)} = -3.0$, p = 0.004]. No significant correlation was found between age and the z-score for any of the variables, which is consistent with the UK data varying with age in a manner similar to the NA normative data. Figure 3 shows the mean z-scores for each of the variables and it highlights the significantly lower mean z-score for Talker advantage, compared to the other variables.

(Figure 3)

The distribution and a fitted normal curve of the UK z-scores, is shown in Figure 4. Consistent with Figure 3 and a match to the NA norms, the fitted curves have their peak near zero, with the exception of Talker Advantage, for which the curve is shifted to negative z-scores because of a larger than expected number of children attaining scores around 1.5 SDs below the mean. The Shapiro-Wilk test indicates that the distributions did not significantly differ from normality in each one of the conditions.

Curiously, the figures also show that at least one child performed below z-score -2 for all the variables, except for Talker Advantage in which all performed above this usual cut-off score. This cut-off score is usually (but arbitrarily) considered as the level that delimits normal or outside normal limits.

(Figure 4)

Although not reported in the original publications on LiSN-S, the LiSN-S software (Cameron & Dillon, 2009) uses a "pattern measure" to determine whether the overall results are consistent with a diagnosis of spatial processing disorder. The pattern measure (in dB) is the average of spatial advantage and the difference between the DV90 and DV0 conditions. This latter difference is the corresponding "spatial advantage" in the context of the different voices competing messages. From this average measure (in dB), z scores are calculated. Using the z-score calculation based on the NA data (as implemented in the software), the UK pattern measure z-scores had a mean value of -0.12 and a standard deviation of 1.01. The mean was not significantly different from zero [$t_{(45)}$ = -0.86, p = 0.39], indicating that the pattern classification measure implemented in the NA version of the software is also appropriate for use in the UK.

Discussion

The main purpose of this study was to assess and compare the performance of

British typically developing children to NA norms. The results demonstrated that both British and NA children have similar performance for most of the measures, except for Talker Advantage, in which British children presented significantly lower scores. From a clinical perspective, the current results indicate that the NA norms might be adopted for UK children when assessing Low-cue, High-cue, Spatial Advantage and Total Advantage measures. For Talker Advantage measure, the average z-score for the UK group was - 0.35 relative to the NA norms. Therefore, when assessing Talker Advantage, it would be appropriate to add 0.35 to the value obtained in order to neutralize a likely “accent effect”. The significant difference between UK and NA norms only for Talker Advantage might suggest that the size of an “accent effect” can differ for different tests. Previous research has found, for example, an accent effect for filtered words and auditory figure-ground subtests, both tests involving “monaural low-redundancy degradation”, but not for the dichotic subtests Competing Words and Competing Sentences (Dawes & Bishop, 2007).

Regarding the Spatial and Talker Advantage, our results suggested that an “accent effect” might impact negatively on the use of tonal, but not spatial cues. The finding related to the use of tonal cue is in line with previous studies that demonstrated a relationship between talker-identification abilities and language-familiarity (Perrachione et al, 2009; Zhang et al, 2016). The studies demonstrated that being familiar with the language that is spoken facilitates the talker´s identification due to integration between the linguistic and the talker processing system for speech and voice perception. Therefore, in the current research, the reduced familiarity of the British children with the NA accent might have affected their perception related to the talker´s voice differences, reducing the benefit of the vocal cue provided. On the other hand, the lack of an accent effect for the use of the spatial cue might be related to the fact that the perception of spatial location differences is not directly associated with stimuli characteristics associated with accent. This would consequently lead to the similar performance of both NA and British group regardless of the verbal accent.

Our results also indicated a significant but weak correlation between age and raw scores for all the LiSN-S variables. The presence of this age effect was also demonstrated for the Australian group (except for the Talker advantage measure) (Cameron & Dillon, 2007) as well as for the NA group (Cameron et al, 2009). Other studies involving different SRM tests found discrepant results regarding age effect. Schafer et al (Schafer et al, 2012), for instance, did not observe any age effect on SRM and suggested that this was probably due to the large performance variability observed in their study since they assessed very young children (between 3 and 6 years old). On the other hand, studies that included older children (≥ 6 years old), such as the current one, also found SRM differences across age groups (Vaillancourt et al, 2008; Myhrum et al, 2016), corroborating the present results. Vaillancourt et al (2008) applied the Canadian French version of the HINT test in children between 6-12 years old and observed an improvement on spatial advantage with age. Similar results were reported by Myhrum et al (2016) when applying the Norwegian version of the HINT test.

It is well-established, through studies involving normal behavioral development, that auditory perceptual skills develop at different rates and during a prolonged period, reaching a mature state at the age range between 6 or even 14, depending on the auditory skill (Sanes and Wooley, 2011). Regarding the stream segregation process, specifically, the development might continue until the age of 9-11 years (Sussman et al, 2007; Yuen and Yuan, 2014), and up to 15 years in the case of spatial stream segregation (Cameron et al 2011). Although the current research findings corroborate these previous studies, they also indicate that maturation is not the only factor related to LiSN-S performance, since only a weak-to-moderate correlation was observed for all the measures. According to previous studies, experience may be another important element that contributes to the acuity of auditory stream segregation (Sussman et al, 2007).

Tomlin and Rance (2014) and Graydon et al (2017) demonstrated, for example, that children who experienced middle ear disease, and consequently auditory deprivation during a critical developmental period, showed lower performance compared to controls, for the spatial advantage but not for the talker advantage measure. This is also in line with studies that demonstrated an association between middle ear disease and low performance on masking level difference – MLD (which like spatial release from masking relies on binaural cues, although the mechanism is different) (Hall et al, 1995; Moore, et a, 2003; Cameron and Dillon, 2008) and also no association between middle ear pitch discrimination, which is the auditory ability likely to be associated with the voice advantage. These results suggest that auditory experience can shape and affect the development of each auditory skill, reflected in different measures, in a different way.

The present study has some limitations. The sample size of the group was relatively small and the group was composed of children from a single school in London. Therefore, these results may not be directly extrapolated when assessing children from distant areas such as Northern England, Scotland or Wales or areas with markedly different socio-economic advantage.

Conclusion

The present study demonstrated no differences between the performance of British typically developing children in a London borough and the NA norms on the LiSN-S, with an exception for the Talker Advantage, in which the UK group presented lower performance. This result indicates that it would be appropriate to add 0.35 to the value obtained for the Talker Advantage when assessing British children.

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Table 1 - Group characteristics

Variables	
Gender - n (%)	
Female	14 (27,5%)
Male	32 (62,7%)
Age (mean ± SD)	8,53 ± 1,34
Language/reading skills (standardized score ± SD)	
PhAB	
Alliteration	94,2 ± 9,2
Reading	
Sight word reading efficiency	106,7 ± 17,2
Hearing	pure-tone thresholds < 30 dB HL at 1 kHz, 2 kHz, and 4 kHz

SD: standard deviation; PhAB: Phonological Assessment Battery; HL: hearing level

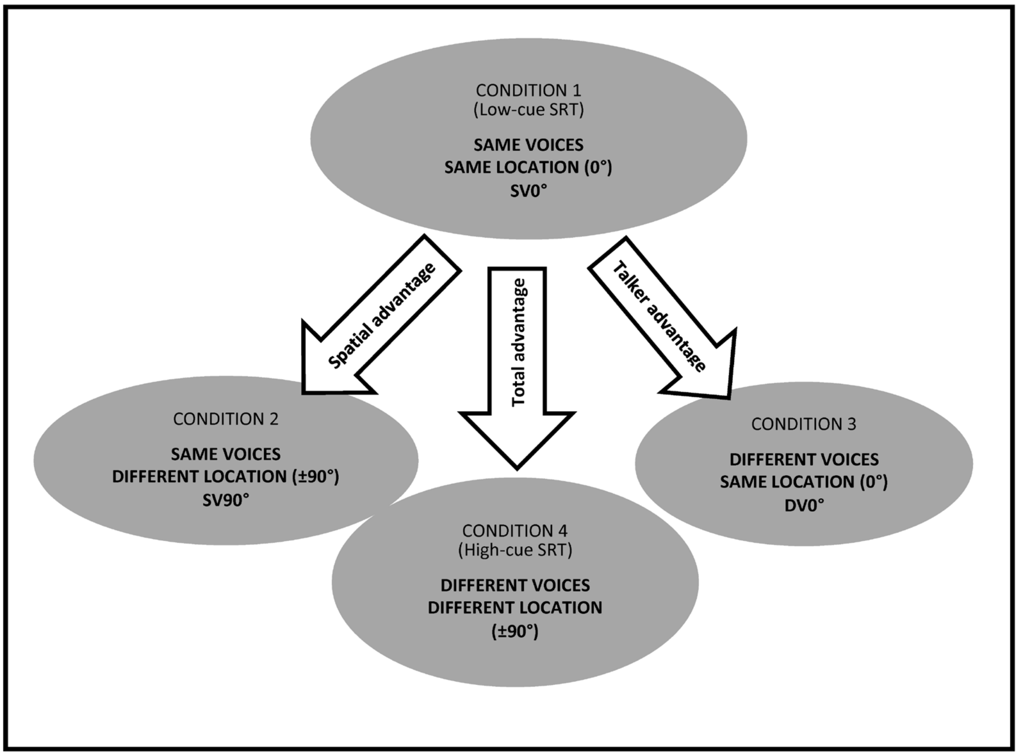

Figure 1- Representation of each one of the four LiSN-S conditions and advantage measures.

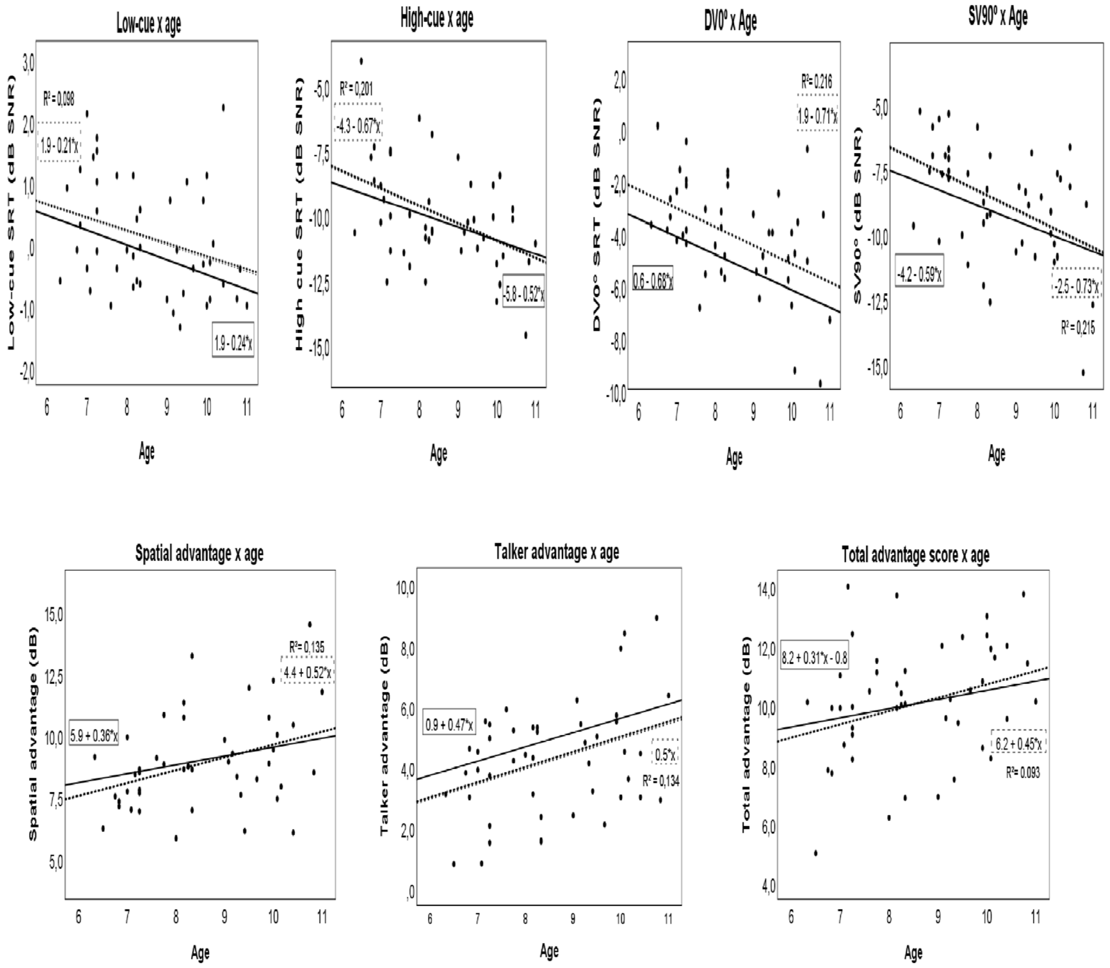

Figure 2 - Speech reception threshold for the low-cue and high cues conditions, and the three advantage measures, as a function of age. The solid line represents the average performance as a function of age, based on the published NA data. The dotted line fits the current data with the respective function (y).

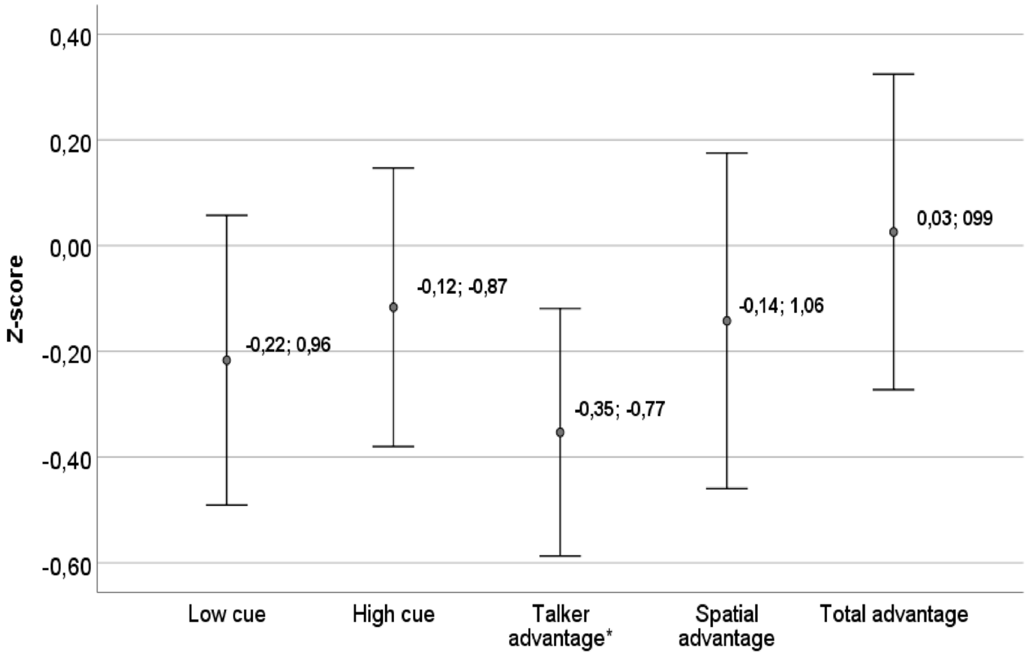

Figure 3 – Z-score for each one of the measures. The error bars show the 95% confidence interval. The inset numbers show the mean and the standard deviation, respectively.

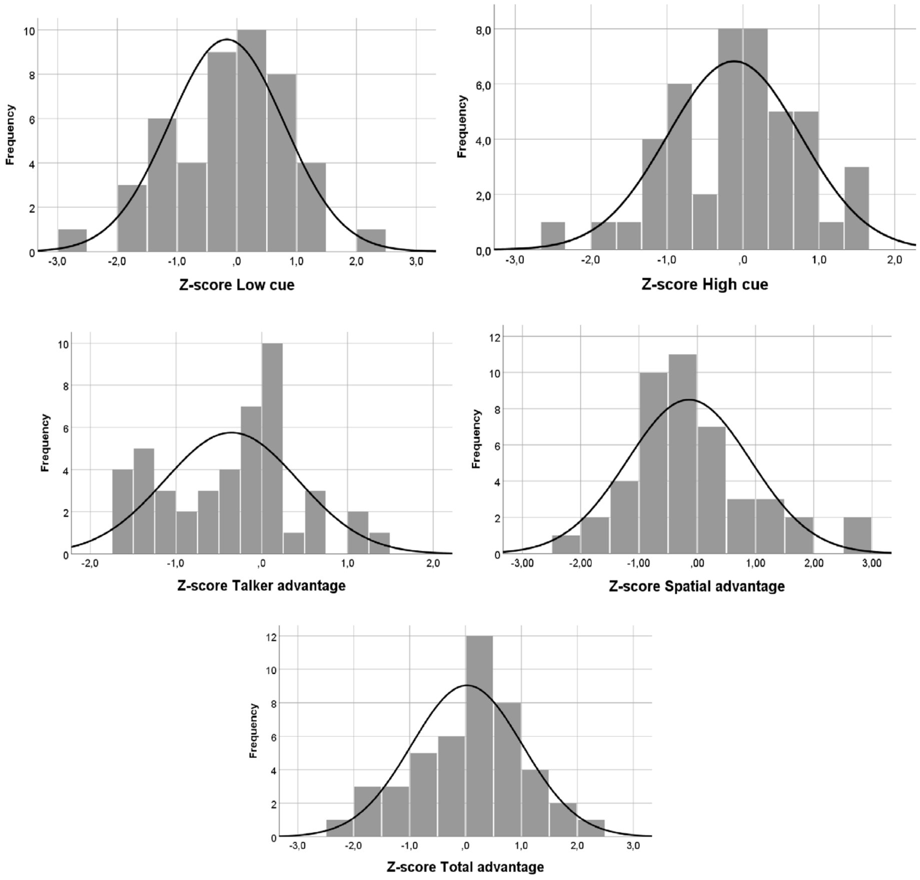

Figure 4- Histograms representing distribution for each LiSN-S measure.