Published in final edited form as:
J Am Acad Audiol. 2009 June ; 20(6): 381–390.

A Comparison of Presentation Levels to Maximize Word Recognition Scores

Leslie A. Guthrie and **Carol L. Mackersie**
School of Speech, Language and Hearing Sciences San Diego State University

Abstract

Background—While testing suprathreshold word recognition at multiple levels is considered best practice, studies on practice patterns do not suggest that this is common practice. Audiologists often test at a presentation level intended to maximize recognition scores, but methods for selecting this level are not well established for a wide range of hearing losses.

Purpose—To determine the presentation level methods that resulted in maximum suprathreshold phoneme-recognition scores while avoiding loudness discomfort.

Research Design—Performance-intensity functions were obtained for 40 participants with sensorineural hearing loss using the Computer-Assisted Speech Perception Assessment. Participants had either gradually sloping (mild, moderate, moderately severe/severe) or steeply sloping losses. Performance-intensity functions were obtained at presentation levels ranging from 10 dB above the SRT to 5 dB below the UCL (uncomfortable level). In addition, categorical loudness ratings were obtained across a range of intensities using speech stimuli. Scores obtained at UCL – 5 dB (maximum level below loudness discomfort) were compared to four alternative presentation-level methods. The alternative presentation-level methods included sensation level (SL; 2 kHz reference, SRT reference), a fixed-level (95 dB SPL) method, and the most comfortable loudness level (MCL).

For the SL methods, scores used in the analysis were selected separately for the SRT and 2 kHz references based on several criteria. The general goal was to choose levels that represented asymptotic performance while avoiding loudness discomfort. The selection of SLs varied across the range of hearing losses.

Results—Scores obtained using the different presentation-level methods were compared to scores obtained using UCL – 5 dB. For the mild hearing loss group, the mean phoneme scores were similar for all presentation levels. For the moderately severe/severe group, the highest mean score was obtained using UCL - 5 dB. For the moderate and steeply sloping groups, the mean scores obtained using 2 kHz SL were equivalent to UCL - 5 dB, whereas scores obtained using the SRT SL were significantly lower than those obtained using UCL - 5 dB. The mean scores corresponding to MCL and 95 dB SPL were significantly lower than scores for UCL - 5 dB for the moderate and the moderately severe/severe group.

Conclusions—For participants with mild to moderate gradually sloping losses and for those with steeply sloping losses, the UCL – 5 dB and the 2 kHz SL methods resulted in the highest scores without exceeding listeners' UCLs. For participants with moderately severe/severe losses, the UCL - 5 dB method resulted in the highest phoneme recognition scores.

Keywords

Hearing loss; presentation level; speech audiometry; speech discrimination; speech recognition testing

Speech recognition measures are widely recognized as an important component of the audiological test battery. Although there are professional guidelines for administering speech recognition threshold tests (American Speech-Language-Hearing Association, 1988), procedures related to suprathreshold speech recognition testing have never been standardized. It has been argued that the best approach to speech recognition testing is to present stimuli over a range of levels (Boothroyd, 1968; Ullrich and Grimm, 1976; Beattie and Warren, 1982; Beattie and Raffin, 1985; Beattie and Zipp, 1990; Boothroyd, 2008). This argument is supported by evidence that the level corresponding to maximum word recognition scores varies considerably across individuals. Beattie and Raffin (1985), for example, reported that levels corresponding to maximum recognition scores can vary from 20 to 60 dB SL.

While these studies provide evidence that testing speech recognition in quiet at multiple levels is the best practice, the use of multiple presentation levels is not common in clinical settings (Martin and Forbis, 1978; Martin and Morris, 1989; DeBow and Green, 2000). In a study on the practice patterns of Canadian audiologists, 89% of the respondents reported that they did not test at multiple presentation levels (DeBow and Green, 2000). In another study on practice patterns of audiologists, 74% of the respondents reported using a single SL; however, the level used was not specified (Martin and Morris, 1989). Martin and Morris (1989) also reported that "several" respondents reported using more than one level in speech recognition testing, with the most common levels being most comfortable level (MCL) and 90 dB HL.

When a single presentation level is used to assess suprathreshold word recognition abilities during routine diagnostic testing, a common objective is to test at a level that will result in maximum performance. With this objective in mind, a presentation level that results in maximum performance may be considered the "optimal presentation level." Methods for determining the presentation level for suprathreshold speech testing fall into three broad categories: (1) methods based on SL, a fixed level above a reference threshold; (2) methods based on a fixed sound pressure level (SPL); and (3) methods based on loudness measures (e.g., most comfortable loudness level).

The most popular approach is to set the presentation level at a particular SL above the speech recognition threshold (SRT). Martin and Morris (1989) noted that over half of the 74% of audiologists who used a single presentation level chose a level of 40 dB SL re SRT, while 30% used a level of 30 dB SL re SRT. In a later survey, Martin et al (1998) also noted that 67% of audiologists used a level referenced to the SRT, but a specific SL was not reported. Similar to their 1989 survey, Martin et al (1994) reported that 75% of audiologists tested at a specified SL, typically 40 dB SL. It is important to note, however, that the 40 dB SL presentation level re SRT is likely to reach uncomfortable loudness levels for the majority of people with an average hearing loss greater than 50 dB HL (Kamm et al, 1978).

Kamm and her colleagues suggested using a fixed level of 95 dB SPL (75 dB HL) as an alternative to 40 dB SL (Kamm et al, 1983). For listeners with mild to moderate sensorineural hearing loss, Kamm et al reported that maximum word recognition scores were obtained for only 60% of the participants when the 40 dB SL re SRT method was used, but maximum word recognition scores were obtained for 76% of the participants when a presentation level of 95 dB SPL was used.

As noted earlier, some clinicians also test at both the most comfortable loudness level (MCL) and a higher level approaching the uncomfortable loudness level (UCL). Testing at MCL seems logical given that "comfortable loudness" is a rationale underlying several hearing aid fitting prescriptions. There is little evidence, however, to support the MCL approach for testing word recognition in individuals with hearing loss, if finding the maximum speech recognition score is the goal. While maximum scores are generally obtained at MCL for listeners with normal

NIH-PA Author Manuscript

NIH-PA Author Manuscript

hearing, higher levels are often needed for individuals with hearing loss (Ullrich and Grimm, 1976; Beattie and Warren, 1982; Beattie and Raffin, 1985; Beattie and Zipp, 1990).

There is inconsistent support for the use of speech UCL as a presentation level. In two studies, Beattie and his colleagues reported that the level corresponding to maximum recognition scores was the same as the UCL for 79–90% of the cases (Beattie and Warren, 1982; Beattie and Zipp, 1990). Dirks et al (1981) reported, however, that recognition scores for words presented below the listeners' UCLs were equal to or better than scores presented at UCL.

Most of the work evaluating different methods for obtaining the maximum word recognition score has been conducted using patients with mild to moderate hearing losses. The present study extends the work of previous investigators described above by evaluating a wider range of hearing losses and by examining additional methods for determining the optimal presentation level for suprathreshold speech recognition testing. For the purposes of this study, the “optimal presentation level” was defined as the level that produced the maximum speech recognition score without exceeding the participant's UCL. Listener groups consisted of people with gradually sloping mild, moderate, and moderately severe/severe losses. In addition, a group of individuals with steeply sloping losses was included to examine the impact of hearing loss configuration.

Five different presentation levels were evaluated:

1) A fixed level of 95 dB SPL as recommended by Kamm et al. (1983)

2) The individually-determined MCL

3) 5 dB below the individually-determined UCL

4) A sensation level referenced to the SRT

5) A sensation level referenced to the 2-kHz threshold

The choice of sensation levels varied with the degree of hearing loss and was determined from several criteria including UCL (described below). A sensation level referenced to 2-kHz was evaluated as an alternative to the sensation level re: SRT due to the importance of 2-kHz for consonant recognition (French and Steinberg, 1947). A sensation level referenced to the 2-kHz threshold rather than the SRT may result in better audibility in the high-frequency regions, particularly for individuals with steeply sloping losses. The UCL-5 dB was evaluated because it should maximize audibility while avoiding the problem of loudness discomfort. To the extent that maximum audibility corresponds to maximum intelligibility, the UCL-5 dB level may serve as the “gold standard” against which the other methods can be compared.

The general approach used in the present study was to measure phoneme recognition over a range of levels. Recognition scores were then extracted for the five different presentation-level methods of interest. Based on the importance of the 2-kHz region for speech intelligibility, it was predicted that the scores obtained using a sensation level referenced to the 2-kHz threshold would result in scores equivalent to those for UCL- 5 dB. Based on previous research, it was also expected that scores for MCL would be lower than for UCL-5 dB for one or more participant groups. Specific predictions were not formulated for the other presentation levels.

METHODS

Participants

Forty adults with sensorineural hearing loss participated in the study. The mean age of the participants was 71.7 years, with a range of 45–90 years. Participants were categorized according to the degree and configuration of their hearing loss. Thirty participants with gradually sloping hearing loss had less than a 20 dB difference between 1- and 2-kHz thresholds. The participants with gradually sloping loss were further classified based on their three-frequency (0.5, 1, 2-kHz) pure-tone averages (PTA) into mild (PTA of 26–40 dB HL), moderate (PTA of 41–55 dB HL), or moderately-severe/severe (PTA of 56–75 dB HL) hearing loss groups. Ten participants were included in each group.

Ten participants with steeply sloping audiometric configurations were also evaluated. Participants with steeply sloping high-frequency hearing loss had a 20 dB or greater difference between 1 and 2-kHz thresholds, a mean PTA of 48 dB HL, and a mean Fletcher average of 28 dB HL. The Fletcher average is the average of the two lowest pure-tone thresholds at octave frequencies between 0.5 and 2-kHz. This average is often used in lieu of the pure-tone average when there is a greater than 20 dB difference between two adjacent frequencies in the pure-tone average (Fletcher, 1950). Mean pure-tone thresholds for the four participant groups are shown in Figure 1.

Procedures

Air and bone conduction pure-tone thresholds were obtained for both ears using the standard Hughson-Westlake procedure (Hughson and Westlake, 1944). Pure-tone stimuli were delivered through a Grason-Stadler 61 audiometer and were routed to TDH-50 headphones and a B-71 bone oscillator.

For all remaining procedures, participants were tested monaurally. The test ear was chosen randomly. The speech-recognition threshold (SRT) was obtained using the Downs and Minard (1996) procedure. The Downs and Minard procedure is an ascending speech recognition threshold search. Following a familiarization phase, one word was presented at each level and the level was increased in 10 dB steps until one word was repeated correctly. The level was then reduced by 15 dB and two, three or four words were presented at each level. The level was increased in 5 dB steps until the participant repeated two words correctly at a given level. This level was taken as the SRT. This procedure was chosen for its efficiency and high correlation with the pure-tone average (Downs and Minard, 1996). Speech stimuli for the SRT consisted of spondees digitized from the Department of Veterans Affairs Speech Recognition and Identification Materials Compact Disc 2.0 (Wilson and Strouse, 1998). Stimuli were played from a computer using custom-written software and were routed through the speech channel of an audiometer to TDH-50 headphones.

Categorical loudness ratings were completed to determine MCL and UCL. Participants were asked to rate the subjective loudness of brief (½ second) speech stimuli (female talker saying `ah-ah') using a procedure described by Hawkins, Walden, Montgomery, and Prosek (1987). The loudness of the speech stimuli was rated on a categorical scale ranging from `cannot hear' to `uncomfortably loud'. Loudness categories and numerical anchors were as follows: 1 = `cannot hear', 2= `very soft', 3 = `soft', 4 = `comfortable, but slightly soft', 5 = `comfortable', 6 = `comfortable, but slightly loud', 7 = `loud, but ok', and 8 = `uncomfortably loud'. The initial presentation level was set at 10 dB above the participant's SRT, and the level of the voice was increased in 5 dB steps until the participant rated the level as `uncomfortably loud' (UCL). The participant's rating and the corresponding level were recorded for each presentation. This procedure was then repeated using a varied starting level of ±10 dB from the starting level of the initial estimate. If the level corresponding to `uncomfortably loud' on the second trial differed by more than 5 dB from the first trial, the procedure was repeated a third time. The higher of the two values within 5 dB of each other was taken as the UCL. Values were within 5 dB for all participants by the second or third trial. A rating of `5' was used as MCL. If more than one level was rated as a `5' within an ascending series, the midpoint of the range was used if there were an odd number of levels with the same rating and the highest value was used if there were an even number of levels with the same rating. The final estimate of MCL was taken as the highest of the values that was rated as a `5' across the two to three trials. The levels corresponding to MCL were within 5 dB for all participants by the second or third trial.

Supra-threshold speech recognition testing was completed using the Computer-Assisted Speech Perception Assessment (CASPA) (Boothroyd, 1999; Boothroyd, 2008; Mackersie, Boothroyd and Minniear, 2001). The CASPA consists of twenty lists of ten monosyllabic consonant-vowel-consonant (CVC) words. Sixteen of the twenty lists were used. The sixteen lists used have been shown to be equivalent in difficulty (Mackersie, Boothroyd and Minnear, 2001). In addition, the order in which the lists were presented was randomly selected for each listener. This software allows for computer-assisted phoneme scoring by having the examiner assign one point to each phoneme repeated correctly in the word for a total of three points per word and 30 phonemes per list. The speech stimuli were routed through the speech channel of the audiometer to the TDH-50 headphones.

Test presentation levels ranged from 10 dB above the SRT to 5 dB below the UCL. A practice list was presented at a level corresponding to 10 dB below the most comfortable loudness level (MCL). Following the practice list, the presentation level was increased in 10 dB steps from MCL to a maximum level of 5 dB below the UCL. The presentation level was then decreased in 10 dB steps in order to complete testing at the levels not used in the ascending run, with the final list presented at a level of 10 dB above the SRT. A step size of 5 dB was used when an increase of 10 dB would have exceeded UCL or when a decrease of 10 dB would have been below the minimum test level. The resulting performance-intensity level function provided phoneme recognition in 5-dB steps. For example, if a participant's SRT was 35 dB HL, MCL was 60 dB HL and the UCL was 90 dB HL, the order of presentation levels would be: 60, 70, 80, and 85 dB HL (ascending) followed by 75, 65, 55, 50, and 45 dB HL (descending). Contralateral masking was used as needed.

Determination of Sensation Levels for Analysis of Recognition Scores

Separate sensation levels were chosen for the 2-kHz and SRT references. It is important to note that for the purposes of this study, the term "*2-kHz sensation-level reference*" refers to the audiometer dial settings for a speech signal. The true sensation level of the speech signal at 2-kHz would be different because at a given dial setting, there are differences between the speech and pure-tone energy at 2-kHz.

After determining the sensation levels of interest, corresponding recognition scores from the performance/intensity function were used for subsequent analysis. The general goal was to choose the highest sensation level possible within the constraints of three criteria. These criteria were:

1) The level was below UCL for all participants

2) The choice of sensation level for different degrees of hearing loss resulted in a monotonic relationship between the range of reference thresholds (2-kHz, SRT) and the corresponding increase in dB HL output. That is, as the reference threshold increased, the output value in dB HL (after adding the sensation level) always increased or stayed the same; the output never decreased.

3) Whenever possible, the sensation levels chosen represented mean asymptotic performance for each of the reference threshold ranges. For the purposes of this study, mean asymptotic performance was defined as mean scores within 5 percentage points of the individual participant's maximum score. That is, the level chosen should correspond to ceiling-level performance. In some instances it was not possible to evaluate this criterion without exceeding a listener's UCL.

RESULTS

UCL Levels and Hearing Loss

The sensation levels corresponding to uncomfortable loudness levels were determined separately for the SRT and the 2-kHz references. The values in Table 1 indicate the number of participants whose uncomfortable loudness levels were reached or exceeded for SRT sensation levels ranging from 20 to 40 dB (top) and for 2-kHz sensation levels ranging from 10–30 dB.

For an SRT sensation level of 40 dB, UCL was reached for 69% (20/29) of the participants with speech recognition thresholds of 35 dB HL and higher. These results suggest that the conventional 40 dB SL presentation level would exceed the UCL of the majority of participants. The majority of participants with SRTs of 55 dB HL and higher were unable to tolerate speech levels greater than 25 dB SL. For the 2-kHz reference, as the 2-kHz thresholds increased, there was a steady decrease in the sensation levels tolerated by all participants. All participants with 2-kHz thresholds of 55 dB HL or less were able to tolerate sensation levels of up to 20 dB HL.

For the fixed level method of 95 dB SPL, UCL was reached for two participants, one with a gradually sloping loss (PTA = 37 dB HL) and one with a steeply sloping loss (PTA = 38 dB HL). These participants were not included in the subsequent analyses of the phoneme recognition scores.

Determination of Sensation Levels

Four sensation levels were provisionally chosen for both SRT and 2-kHz references to satisfy the first two of the three criteria described earlier (below UCL, monotonic function). To satisfy the third criterion, it was necessary to determine whether the sensation levels chosen would correspond to mean asymptotic performance. Mean scores for the four SRT and 2-kHz threshold ranges are shown in Figure 2 as a function of sensation level. The filled symbols indicate the chosen sensation level for each range. As shown in left panel of Figure 2, for the 2-kHz reference, the chosen sensation levels for the four 2-kHz threshold ranges did correspond to asymptotic performance. For sensation levels above the chosen values, mean scores either decreased or increased by less than five percentage points. For the SRT reference (*right panel*), scores for the chosen sensation levels were also within five percentage points of the maximum score except for the 45–50 dB HL range (5.8 percentage points below maximum). Although listeners with SRTs between 45–50 dB HL were able to tolerate a sensation level of 30 dB, increasing this criterion would result in a non-monotonic function with increasing hearing loss (see criterion #2). Therefore, a sensation level of 25 dB SL was used for SRTs of 45–50 dB HL. For the highest SRT range, it was not possible to evaluate the sensation level above the chosen value because this level exceeded the uncomfortable loudness level for several participants.

Based on these analyses, the sensation levels provisionally selected for the SRT and 2-kHz references satisfy the criteria discussed earlier. The final SRT and 2-kHz references used in the phoneme recognition analyses were as follows:

1) SRT reference:

   a. SRT < 35 dB HL: 35 dB SL

   b. SRT 35–40 dB HL: 30 dB SL

   c. SRT 45–50 dB HL: 25 dB SL

   d. SRT greater than 50 dB HL: 20 dB SL

2) 2 kHz reference:

a. 2-kHz thresholds < 50 dB HL: 25 dB SL

b. 2-kHz thresholds 50–55 dB HL: 20 dB SL

c. 2-kHz thresholds 60–65 dB HL: 15 dB SL

d. 2-kHz thresholds 70–75 dB HL: 10 dB SL

We applied the above criteria to select the phoneme recognition scores obtained at various levels of the performance/intensity function. These scores were used in subsequent analyses for each of the four participant groups (mild, moderate, moderately-severe/severe, steeply sloping).

The means, standard deviations and ranges of levels in dB HL are shown in Table 2 for MCL, UCL-5 dB, SL re: SRT, and SL re: 2-kHz. It can be seen that mean presentation levels increase with increasing hearing loss and vary up to 25 dB within listener groups. For mild, moderate, and moderately-severe/severe losses, the mean level in dB HL corresponding to the sensation levels for the 2-kHz and SRT methods were similar. However, for the majority of participants, there were differences between the 2-kHz and SRT HL levels of up to 15 dB for participants with mild, moderate, and moderately-severe/severe losses. For some groups, these differences may have had a greater impact on recognitions scores than for other groups. For example a difference of 10 dB in presentation levels may not affect phoneme recognition if performance is already at ceiling level. However, a 10 dB difference in presentation level may affect phoneme recognition within the linear portion of the PI function. In the next section, analyses of the recognition scores for the different presentation level are presented in detail.

Phoneme recognition

The five presentation level methods were analyzed to determine if there were significant differences among the mean recognition scores. Mean phoneme recognition scores for the four participant groups are shown in Figure 3. The mean scores for the mild hearing loss group were similar using the five methods. Differences among the five methods were apparent for the other participant groups.

A two-way repeated-measures analysis of variance (ANOVA) was completed using the different presentation-level methods (95 dB SPL, MCL, UCL-5 dB, SL re: SRT, SL re: 2-kHz) and hearing loss severity or configuration as factors (mild, moderate, moderately-severe/severe, steeply sloping). Phoneme scores were arcsine transformed before data analysis to stabilize the error variance (Studebaker, 1985). As noted previously, a level of 95 dB SPL was uncomfortably loud for one person with a mild gradually sloping loss and one person with a steeply sloping loss. Based on the criteria adopted for this study, this level would not be appropriate because it exceeded the UCL. The analyses run with and without the 95 dB SPL scores were similar. Therefore, for illustrative purposes, scores for 95 dB SPL were included in the analyses reported here. A significant interaction was observed between presentation level method and hearing loss [$F(12, 147) = 2.55$, $p < .01$].

Newman-Keuls post-hoc analyses were completed to further evaluate differences among the five methods. The focus of the post-hoc analyses was to determine if the various presentation level methods differed from the UCL-5 dB approach, which was designated the "gold standard" for this study. A significance level of .05 was used in all analyses. In Figure 3, significant differences between UCL-5 dB and the other four methods are indicated by asterisks and connecting arrows. For the mild hearing loss group there were no significant differences between the phoneme recognition scores obtained using any of the methods ($p > .05$). For the moderate group, mean scores for all methods except the 2-kHz SL reference were significantly lower than scores for UCL-5 dB. For the steeply sloping group, only scores obtained in the SRT reference method were significantly lower than scores for UCL-5 dB. Finally, for the moderately-severe/severe group, scores for UCL-5 dB were significantly higher than scores for all the other presentation levels.

Based on these results, any of the five methods should produce equivalent results for mild gradually-sloping hearing loss. For moderately-severe/severe losses, only UCL-5 dB resulted in maximum recognition scores. Only the 2-kHz SL reference was equivalent to UCL-5 dB in the remaining two participant groups.

Individual scores

Figure 4 illustrates individual recognition scores for UCL-5 dB plotted against scores for the alternative presentation levels. Data points below the diagonal indicate nominally higher scores for UCL-5 dB. The shaded area represents the 90% confidence intervals of the binomial distribution. It can be seen that comparison methods are clustered fairly close to the diagonal (similar to UCL-5 dB scores) for mild, moderate, and steeply sloping losses. For moderately-severe/severe losses, larger deviations are apparent. The largest deviations from the UCL-5 dB scores are for the 95 dB SPL presentation level (moderately-severe/severe losses) and for the SRT reference (steeply sloping losses).

DISCUSSION

As a first step in determining the presentation level for maximal performance without discomfort, UCLs for speech were examined for different sensation levels. It was determined that a presentation level of 40 dB SL re: SRT exceeded UCL for 69% of those with an SRT of 35 dB HL or greater. Kamm, Dirks, and Mickey (1978) also found that 40 dB SL re: SRT exceeded UCL for the majority of participants with hearing loss greater than 50 dB HL. Based on the results of the current study, the commonly used presentation level of 40 dB SL re: SRT would exceed the loudness discomfort levels for many individuals with hearing loss. Even a more conservative level of 30 dB SL would exceed the tolerance levels of listeners with SRTs of 55 dB HL and greater.

Contrary to the prediction, the 2-kHz SL reference chosen for this study did not result in phoneme recognition scores equivalent to scores for UCL-5 dB for all participant groups. Scores for the 2-kHz SL reference were significantly lower than scores for UCL-5 dB for one of the four participant groups (moderately-severe/severe). The variability of UCLs for the different 2-kHz ranges and criteria adopted for this study prevented the use of a higher 2-kHz sensation level. Nevertheless, the findings support the use of the 2-kHz reference for all participant groups except those with moderately-severe/severe hearing loss. For the moderately-severe/severe group, only the UCL-5 dB level resulted in maximum phoneme scores.

For mild hearing losses, all five presentation levels resulted in similar phoneme scores. The sensation level re: SRT resulted in lower phoneme recognition scores than those obtained using UCL – 5 dB for all of the remaining participant groups and MCL resulted in lower phoneme recognition scores than UCL-5 dB for the moderate and moderately-severe/severe groups. The results from the present study are consistent with studies by Beattie and colleagues (Beattie and Raffin, 1985; Beattie and Warren, 1982; Beattie and Ziff, 1990), who found that maximal speech recognition scores were obtained at or near UCL rather than at MCL.

The finding that scores using the SRT sensation level reference were lower than UCL-5 dB for three of the four groups may be related to the choice of sensation levels and the constraints imposed by the criteria selected. Higher sensation levels may have been used, but would have violated criteria related to the UCL, the monotonic function, or both. The lower scores for the SRT reference may be related to the fact that the SRT typically reflects the low- to midfrequency hearing sensitivity. Thus, a level referenced to SRT may not ensure audibility at important higher frequencies such as 2-kHz. For steeply sloping hearing losses, in particular, basing the presentation level on the SRT can result in lower presentation levels, essentially filtering out crucial speech information at 2-kHz. Despite the popularity of using presentation levels referenced to the SRT, the results of the current study do not support the use of this reference level if the objective is to maximize scores for a wide range of hearing losses.

The fixed-level method (95 dB SPL) reached UCL for two participants and was, therefore, not considered optimal based on the criteria used in the study. Of the remaining 38 participants, 26% had scores for 95 dB SPL that were significantly lower than UCL-5 dB. The mean scores obtained using the 95 dB SPL method were significantly lower than those obtained using UCL – 5 dB for both the moderate and moderately-severe/severe hearing loss groups. The findings for moderate hearing loss contrast with those of Kamm et al. (1983) who found that 95 dB SPL corresponded to maximum recognition performance for most participants with mild-moderate hearing loss. However, a direct comparison is difficult because they combined mild and moderate hearing losses in their analyses.

There are several additional factors that should be considered when choosing a presentation level. One factor is related to test efficiency. For clinicians who do not routinely include speech UCL measures as part of the diagnostic battery, the use of the 2-kHz reference avoids the need for additional testing. In addition, the UCL measure is more variable than threshold measures and may require several repetitions to stabilize (Morgan and Dirks, 1974). Finally, UCL-5 dB may not result in maximum word recognition scores for people whose recognition scores decrease at higher levels (i.e. rollover). A significant decrease in scores at UCL – 5 dB (based on 90% confidence intervals of the binomial distribution) was observed in two of the 40 participants in the current study. Given the potential trade-offs between efficiency and optimization of recognition scores, a hybrid method may be the best approach. This method would consist of using the 2-kHz reference for people with less than a moderately-severe/severe hearing loss and UCL – 5 dB for listeners with more severe losses. The 2-kHz reference could be used as a starting level for measuring the speech UCL with the goal of testing at UCL-5 dB.

It is important to bear in mind that results are based on data for a relatively small number of participants. No single rule will work for all listeners. As such, administration of word recognition tests at multiple presentation levels should still be considered “best practice”. Testing at multiple levels allows for the optimal listening range to be determined (Boothroyd, 2008). Because phoneme scoring increases the number of scoreable items in a word list without increasing test time, it is possible to use shorter 10-word lists without compromising test sensitivity. Using this approach, measurement of phoneme recognition over a range of intensity levels becomes a clinically viable option.

While the population of participants in the present study represented a fairly wide range of sensorineural hearing losses, generalization of the findings to all degrees and configurations of hearing loss is not possible. Participants with steeply sloping losses in the present study, for example, had pure-tone averages in the mild to moderate hearing loss range. It is not known whether similar results would be found for those with more severe steeply sloping hearing losses. In addition, it is likely that the optimal presentation level, as defined in this study, would be different for people with a conductive component to the hearing loss, people with rising configurations, and people with severe to profound hearing loss. Further work should be extended to these populations.

SUMMARY

1. For mild to moderate gradually sloping losses and for steeply-sloping losses, two presentation levels for suprathreshold word recognition testing resulted in the highest scores without exceeding listeners' UCLs. Both provided equivalent results.
    - **a.** One method is to set the level to 5 dB below the speech UCL
    - **b.** The second method is to set the dial level above the nominal 2-kHz threshold as follows:
        - 2-kHz threshold < 50 dB HL: Use 25 dB SL re: 2-kHz
        - 2-kHz threshold 50–55 dB HL: Use 20 dB SL re: 2-kHz
        - 2-kHz threshold 60–65 dB HL: Use 15 dB SL re: 2-kHz
        - 2-kHz threshold 70–75 dB HL: Use 10 dB SL re: 2-kHz
2. For listeners with moderately-severe/severe losses, UCL-5 dB resulted in the highest phoneme recognition scores.
3. A fixed level of 95 dB SPL and the conventional method using a sensation level referenced to the SRT are not supported by the results of this study if the goal is to maximize recognition scores while avoiding loudness discomfort.

Abbreviations

CASPA	Computer-Assisted Speech Perception Assessment
MCL	most comfortable level
PTA	average of pure tone thresholds for .5, 1, and 2 kHz
SL	sensation level
UCL	uncomfortable level

REFERENCES

American Speech-Language-Hearing Association. Guidelines for determining threshold level for speech. ASHA 1988:85–89. [PubMed: 3155355]

Beattie RC, Raffin MJ. Reliability of threshold, slope, and PB max for monosyllabic words. J Speech Hear Dis 1985;50:166–178.

Beattie RC, Warren VG. Relationships among speech threshold, loudness discomfort, comfortable loudness, and PB max in the elderly hearing impaired. Am J Otol 1982;3:353–358. [PubMed: 7081412]

Beattie RC, Zipp JA. Range of intensities yielding PB max and the threshold for monosyllabic words for hearing-impaired subjects. J Speech Hear Dis 1990;55:417–426.

Boothroyd A. Developments in speech audiometry. Brit J Audiol 1968;2:3–10.

Boothroyd, A. Computer-Assisted Speech Perception Assessment (CASPA). Version 3.0. 1999. computer software

Boothroyd A. The performance/intensity function: an underused resource. Ear Hear 2008;29:479–491. [PubMed: 18469711]

DeBow A, Green W. A survey of Canadian audiological practices: pure tone and speech audiometry. J Speech Path Audiol 2000;24:153–161.

Downs D, Minard P. A fast valid method to measure speech-recognition threshold. Hear J 1996;49:39–44.

Dirks DD, Kamm CA, Dubno JR, Velde TM. Speech recognition performance at loudness discomfort level. Scand Audiol 1981;10:239–246. [PubMed: 7323674]

Fletcher H. A method of calculating hearing loss for speech from an audiogram. J Acoust Soc Am 1950;22:1–5.

French NR, Steinberg JC. Factors governing the intelligibility of speech sounds. J Acoust Soc Am 1947;19:90–119.

Hawkins DB, Walden BE, Montgomery A, Prosek RA. Description and validation of an LDL procedure designed to select SSPL90. Ear Hear 1987;8:162–169. [PubMed: 3609512]

Hughson W, Westlake H. Manual for program outline for rehabilitation of aural casualties both military and civilian. Trans. Am. Acad. Opthamol. Otolaryngol 1944;48(Suppl):1–15.

Kamm CA, Dirks DD, Mickey MR. Effect of sensorineural hearing loss on loudness discomfort level and most comfortable loudness judgments. J Speech Hear Res 1978;21:668–681. [PubMed: 745368]

Kamm CA, Morgan DE, Dirks DD. Accuracy of adaptive procedure estimates of PB max level. J Speech Hear Dis 1983;48:202–209.

Mackersie CL, Boothroyd A, Minniear D. Evaluation of a computer-assisted speech perception assessment test (CASPA). J Am Acad Audiol 2001;12:390–396. [PubMed: 11599873]

Martin FN, Champlin CA, Chambers JA. Seventh survey of audiometric practices in United States. J Am Acad Audiol 1998;9:95–104. [PubMed: 9564671]

Martin FN, Forbis NK. The present state of audiometric practice: A follow-up study. Asha, 1978;20:531–541. [PubMed: 678307]

Martin FN, Morris LJ. Current audiological practices in the United States. Hear J 1989;42:25–42.

Morgan D, Dirks D. Loudness discomfort levels under earphone and in the free field: the effects of calibration. J Acoust Soc Am 1974;56:172–178. [PubMed: 4853044]

Studebaker G. A “rationalized” arcsine transformation. J Speech Hear Res, 1985;28:455–462. [PubMed: 4046587]

Ullrich K, Grimm D. Most comfortable listening level presentation versus maximum discrimination for word discrimination material. Audiol, 1976;15:338–347.

Wilson, R.; Strouse, A. Speech recognition and identification materials; Disc 2.0. Department of Veterans Affairs, VA Medical Center; Mountain Home, TN: 1998. compact disc

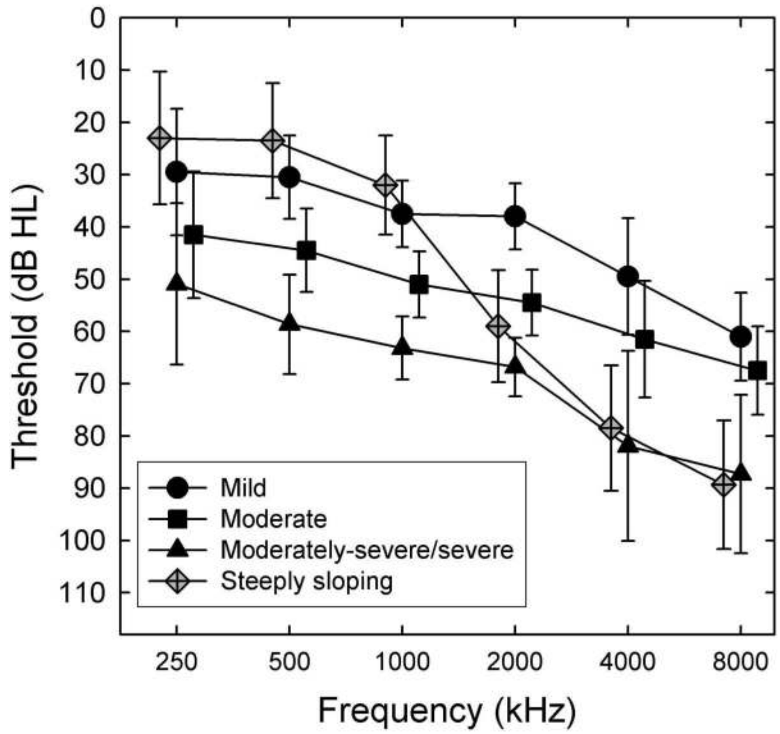

Figure 1.
Mean audiograms for the four participant groups. The error bars indicate ± 1 SD.

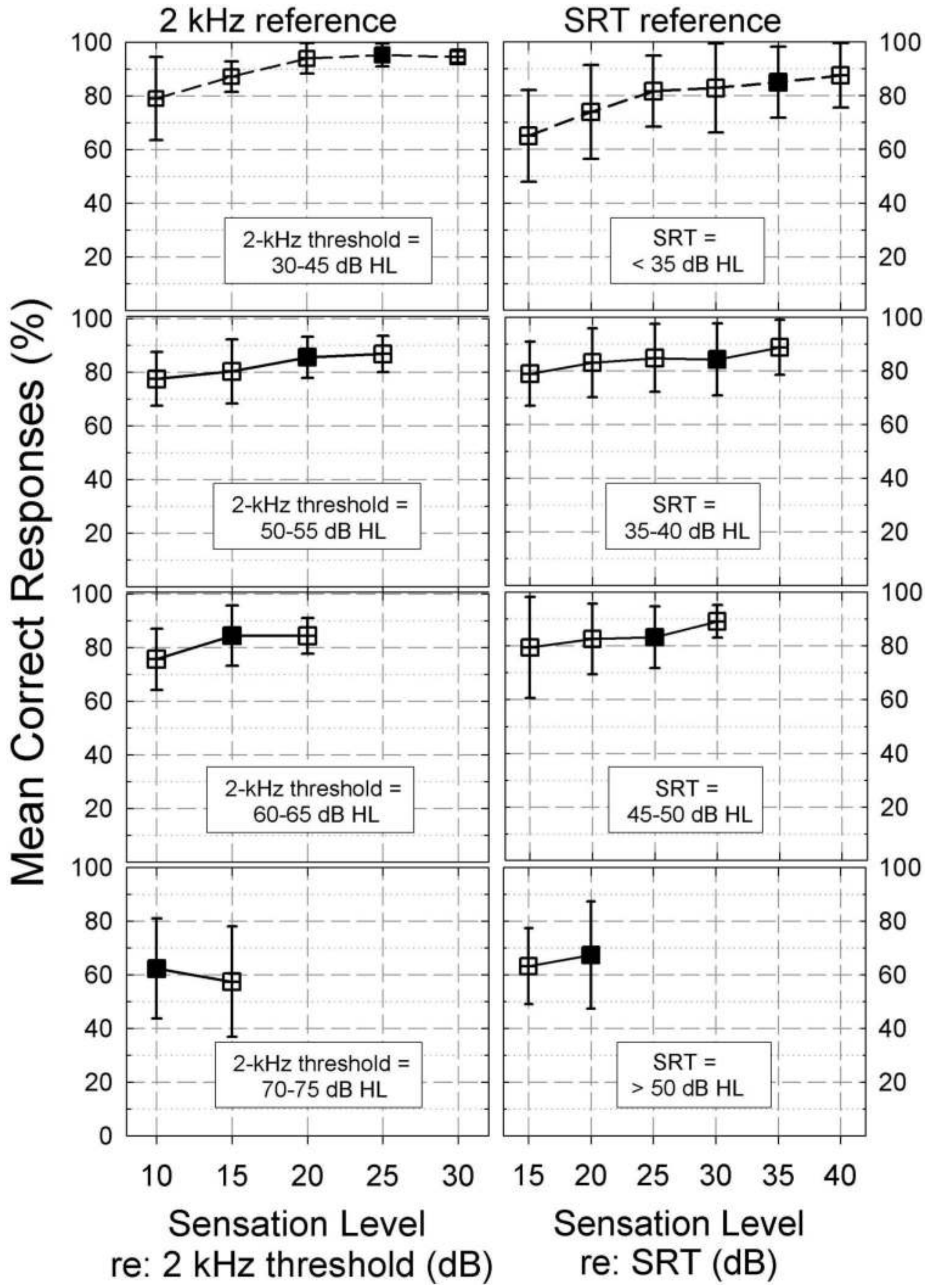

Figure 2.

Mean phoneme recognition scores obtained at the different sensation levels for the 2-kHz reference (left) and SRT reference (right). The chosen sensation levels for each hearing loss range are represented by the filled symbols. The error bars represent ± 1 standard error.

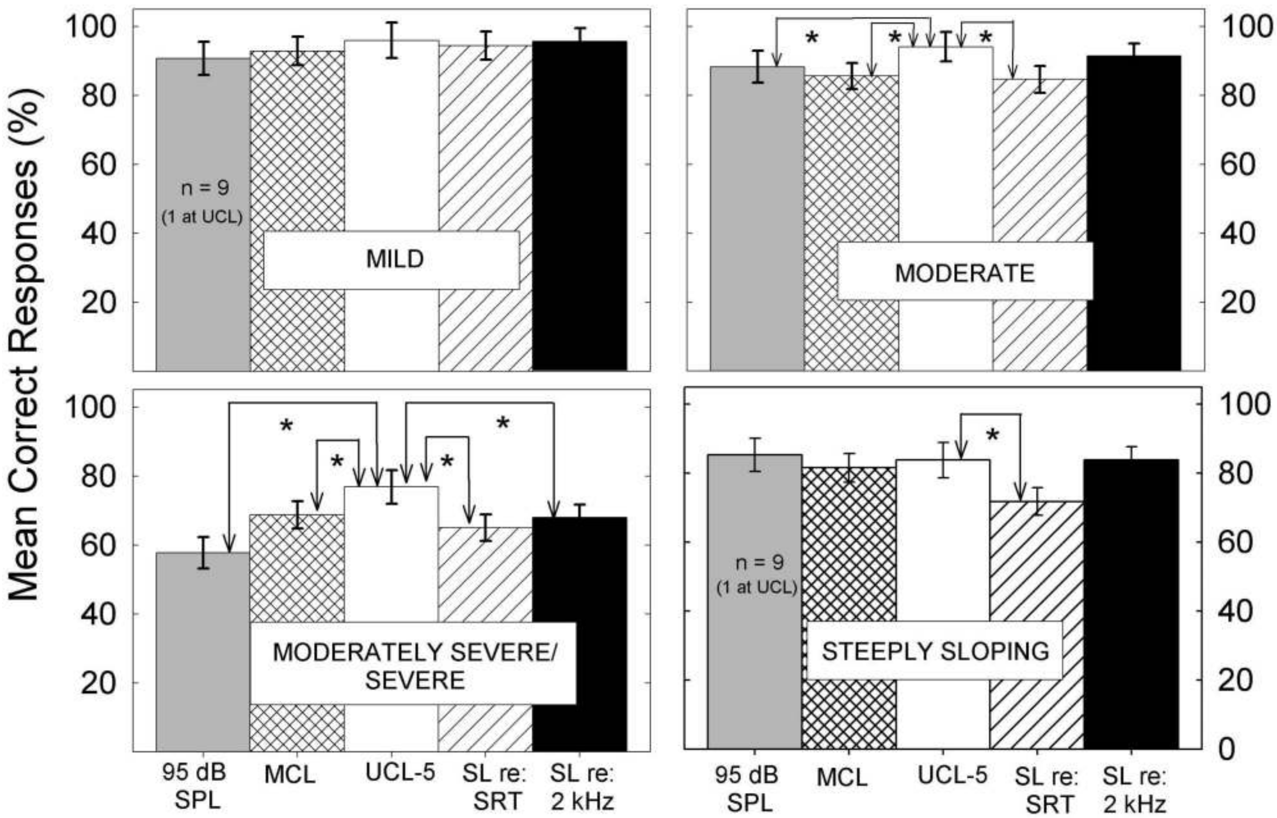

Figure 3.
Mean phoneme recognition scores obtained using the five different methods for the four different participant groups. The asterisks indicate a significant difference based on the post-hoc analyses. The arrows indicate which method is significantly different from UCL – 5 dB. The error bars represent ± 1 standard error.

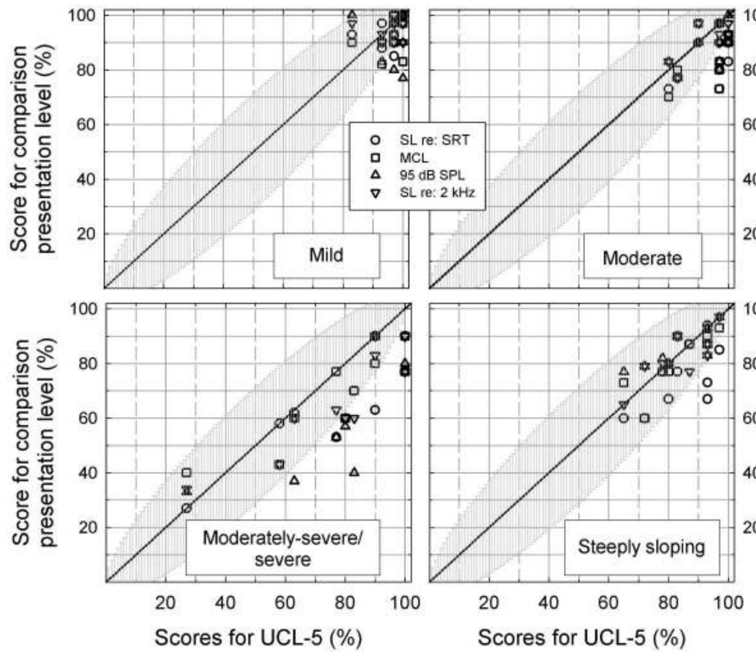

Figure 4.

Scatterplot of phoneme recognition scores obtained using the fixed level, MCL, SRT reference, and 2-kHz reference plotted against the scores obtained using the UCL – 5 dB method for the 4 participant groups. The shaded area indicates the 90% confidence intervals based on the binomial distribution.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 1

Number of participants for whom speech levels reached and/or exceeded UCL for the SRT sensation levels (top) and 2-kHz threshold (dial) sensation levels (bottom). The lines indicate the SRT or 2-kHz threshold values above which UCL was reached for at least one participant.

		SRT+20 dB	SRT+25	SRT+30	SRT+35	SRT+40
SRT	n	n =/ > UCL	n =/ > UCL	n =/ > UCL	n =/ > UCL	n =/ > UCL
10	1	0	0	0	0	0
20	3	0	0	0	0	0
25	3	0	0	0	0	0
30	4	0	0	0	0	0
35	5	0	0	0	0	1
40	5	0	0	0	0	4
45	4	0	0	0	0	0
50	4	0	0	0	1	3
55	5	0	1	1	3	4
60	1	0	1	1	1	1
65	2	0	1	1	2	2
70	2	0	2	2	2	2
75	1	0	3	1	1	3

		2k+10 dB	2k+15	2k+20	2k+25	2k+30
2-kHz threshold	n	n =/ > UCL	n =/ > UCL	n =/ > UCL	n =/ > UCL	n =/ > UCL
30	2	0	0	0	0	0
35	3	0	0	0	0	0
40	4	0	0	0	0	0
45	4	0	0	0	0	1
50	4	0	0	0	1	1
55	6	0	0	0	1	3
60	4	0	0	1	2	4
65	5	0	0	0	3	4
70	4	0	1	1	2	3

NIH-PA Author Manuscript

NIH-PA Author Manuscript

		2k+10 dB	2k+15	2k+20	2k+25	2k+30
2-kHz threshold	**n**	**n =/ > UCL**	**n =/ > UCL**	**n =/ > UCL**	**n =/ > UCL**	**n =/ > UCL**
75	4	0	2	2	4	4

Table 2

Means, standard deviations, and ranges for the presentation levels corresponding to MCL, UCL, the 2-kHz sensation level method, and SRT sensation level method. All presentation levels are shown in dB HL. A level of 75 dB HL corresponds to 95 dB SPL.

	MCL	UCL-5 dB	HL for SL re: 2 kHz	HL for SL re: SRT
Mild	62.0 (6.3)	83.5 (8.2)	63.0 (5.9)	65 (4.7)
(range)	(50–70)	(75–100)	(55–70)	(55–70)
Moderate	72.5 (5.4)	83.0 (6.8)	73.0 (5.37)	72.5 (2.6)
(range)	(65–80)	(80–100)	(65–80)	(70–75)
Moderately-severe	80.5 (5.5)	89.5 (7.3)	80.0 (3.2)	82.0 (8.2)
(range)	(70–85)	(80–105)	(75–85)	(70–95)
Steeply sloping	66.0 (8.4)	83.5 (8.5)	75.8 (5.2)	60.5 (7.2)
(range)	(50–75)	(75–105)	(70–85)	(50–70)
All	70.3	84.9 (7.9)	73.0 (8.1)	70.0 (10.2)
(range)	(50–85)	(75–105)	(55–85)	(50–95)