AJA

Research Article

Comparing Spatial Release From Masking Using Traditional Methods and Portable Automated Rapid Testing iPad App

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Purpose: The purpose of this study was to compare speech identification abilities of individuals of various ages and hearing abilities using traditional methods and Portable Automated Rapid Testing (PART) iPad app.

Method: Speech identification data were collected using three techniques: over headphones using a virtual speaker array, using PART iPad app (UCR Brain Game Center, 2018), and using loudspeaker presentation in a sound-attenuated room. For all three techniques, Coordinate Response Measure sentences were used as the stimuli and "Charlie" was used as the call sign. A progressive tracking procedure was used to estimate the speech identification thresholds for listeners with varying hearing thresholds. The target sentence was always presented at 0° azimuth angle, whereas the maskers were colocated (0°) with the target or symmetrically spatially separated by ±15°, ±30°, or ±45°.

Results: Data analysis revealed similar speech identification thresholds for the iPad and headphone conditions and slightly poorer thresholds for the loudspeaker array condition across participant groups. This was true for all spatial separations between the target and the maskers.

Conclusion: Strong correlation between the headphone and iPad data presented in this study indicated that the spatial release from masking module in the PART iPad app can be used as a clinical tool to assess spatial processing ability prior to audiologic evaluation in the clinic and can also be used to make recommendations for and to track progress with aural rehabilitation programs over time.

The purpose of this study was to collect normative data on the spatial release from masking (SRM) module using the Portable Automated Rapid Testing (PART; UCR Brain Game Center, 2018) iPad app and to compare it to the data collected using traditional methods such as using loudspeaker array or using a virtual speaker array (VSA). SRM is the increase in speech understanding that occurs when the target signal and the masking signal(s) are at different locations in the listening environments (Arbogast et al., 2005; Best et al., 2013; Yost, 2017). Researchers have determined that SRM is primarily due to better-ear listening and access to binaural listening cues (Arbogast et al., 2002; Best et al., 2006), which are not very useful for older individuals and individuals with hearing impairment (Ellinger et al., 2017).

Research on SRM using speech stimuli has been completed by many researchers using spatial arrays (Gallun et al., 2013; Helfer & Freyman, 2008; Jakien, Kampel, Stansell, et al., 2017; Kidd et al., 2010; Yost, 2017). Similar studies of SRM have been conducted using VSAs presented via headphones (Ellinger et al., 2017; Füllgrabe et al., 2015; Gallun et al., 2013; Ihlefeld & Shinn-Cunningham, 2008; Jakien & Gallun, 2018; Jakien, Kampel, Gordon, et al., 2017; Srinivasan et al., 2016). The Coordinate Response Measure (CRM) corpus (Bolia et al., 2000) has been used extensively by many researchers for SRM testing in a spatial array or VSA over headphones (Brungart, 2001; Gallun et al., 2013; Kidd et al., 2010; Marrone et al., 2008a, 2008b; Srinivasan et al., 2016). Researchers who have compared the performance of CRM testing in a spatial array and over headphones have found similar results between the two conditions (Gallun et al., 2013; Jakien, Kampel, Stansell, et al., 2017; Kidd et al., 2010). Common methods used for spatial array and headphone test conditions, however, are limited in

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Editor-in-Chief: Ryan W. McCreery
Editor: Ann Clock Eddins

Received May 29, 2020
Revision received August 6, 2020
Accepted September 2, 2020
https://doi.org/10.1044/2020_AJA-20-00078

Disclosure: *The authors have declared that no competing interests existed at the time of publication.*

their clinical application because they require large anechoic chambers, speaker arrays or MATLAB software, and take an average of 3–4 hr to complete (Gallun et al., 2013; Marrone et al., 2008a, 2008b).

Because of these difficulties, Gallun et al. (2013) created a new rapid and automated version to measure SRM called progressive tracking technique. The progressive tracking technique is similar to the QuickSIN test. This simpler and quicker tracking technique entails presenting two trials at 10 different target-to-masker ratios (TMRs) totaling to 20 trials per run. Each run starts at a TMR of +10 dB and ends at a TMR of −8 dB in decreasing steps of 2 dB. The TMR threshold was estimated by subtracting the number of correct responses from 10. Speech identification thresholds using progressive tracking technique and traditional Levitt adaptive tracking procedures (Levitt, 1971) revealed positive significant correlations between the two thresholds, indicating that the thresholds obtained using progressive tracking technique was a good estimate of the actual threshold. However, it should be noted that the progressive tracking technique underestimates the thresholds at edges. For example, when an individual's threshold is better than −10 dB (individual got correct responses for all presented 20 trials), the threshold estimated would be −10 dB. Also, when an individual's threshold is worse than +8 dB (individual got incorrect responses for all presented 20 trials), the threshold estimated would be +10 dB. Jakien, Kampel, Stansell, et al. (2017) assessed the test–retest reliability of the rapid, automated test of SRM over headphones. The authors presented CRM sentences over headphones (denoted by SR2 in Jakien, Kampel, Stansell, et al., 2017) or in an anechoic chamber (denoted by SR2A in Jakien, Kampel, Stansell, et al., 2017). For both presentation techniques, a progressive tracking technique was used to estimate thresholds. The results indicated that the rapid, automated test over headphones accurately depicted an individual's ability to obtain release from masking when the target and the maskers are spatially separated. Also, the thresholds obtained by presenting stimuli using loudspeakers in an anechoic chamber and over headphones using VSA were similar and the thresholds were not impacted by practice for both the techniques. The results of Gallun et al. (2013) were better in the anechoic chamber compared to the headphone presentation because the listeners in the anechoic chamber had poorer average pure-tone average thresholds compared to the listeners in the headphone presentation condition and different presentation levels (fixed sound-pressure level when the thresholds were measured in the anechoic chamber compared to fixed SL when the thresholds were measured using VSA) were used for both the experiments. Jakien, Kampel, Stansell, et al. (2017) examined the effects of audibility and bandwidth and showed that audibility indeed had as much as 3-dB effect on speech identification thresholds. Following up the previous work, Jakien, Kampel, Stansell, et al. (2017) investigated the effects of practice on speech identification when the target and maskers were either colocated or symmetrically spatially separated and found that practice improved both colocated and separated speech identification thresholds by about 1 dB.

Given the excellent preliminary validity and reliability of this testing procedure, Gallun et al. (2018) created the PART, a free iPad app that has a range of psychoacoustical tasks including SRM, gap discrimination, binaural sensitivity, and spectrotemporal modulation. One of the goals of the PART iPad app was to make the various psychoacoustic tasks available in the app to be available for routine clinical use. The goal of this study was to collect speech identification thresholds on listeners varying in age and hearing ability using a loudspeaker array, VSA, and the SRM module on the PART iPad app.

Method

Participants

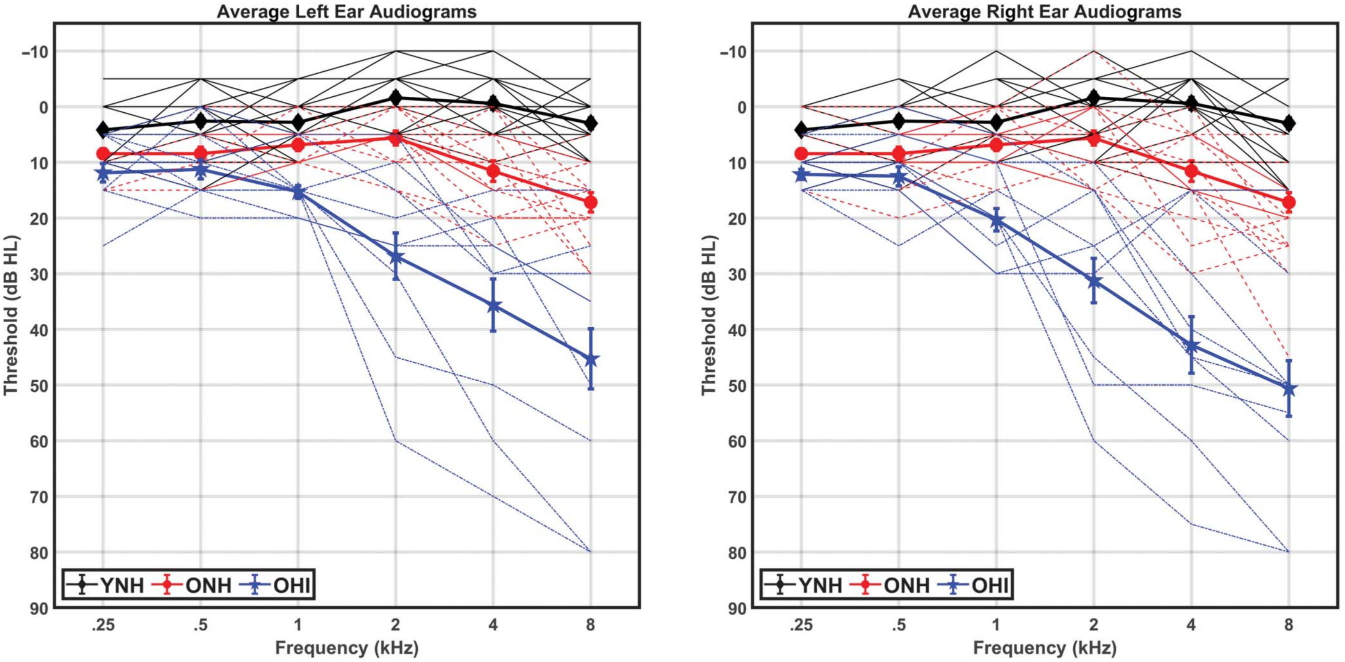
A total of 57 adult participants participated in this study. The participants were separated into young adult listeners with normal hearing (YNH), older adult listeners with normal hearing (ONH), and older adult listeners with hearing loss (OHI) based on their age and hearing thresholds. A 40 years age cutoff was used to separate the younger and older groups so that the results obtained could be compared to existing literature (Srinivasan et al., 2016, 2017). Figure 1 shows the individual and group average audiometric thresholds for the right and left ears of the listeners participated in this experiment. The YNH group consisted of 25 participants, ranging in age from 20 to 25 years (M = 21.36 years, SD = 1.41), and had an average 4-frequency (.5, 1, 2, and 4 kHz) pure-tone average (PTA) of 0.85 dB HL (SD = 1.78). The ONH group consisted of 16 participants, ranging in age from 46 to 83 years (M = 56.56 years, SD = 10.79), and had an average 4-frequency PTA of 8.25 dB HL (SD = 2.71). The OHI group consisted of 16 participants, ranging in age from 43 to 75 years (M = 56.375 years, SD = 9.91), and had an average 4-frequency PTA of 23.40 dB HL (SD = 12.04). Average speech reception thresholds (SRTs) for the three participant groups were 1.00 dB HL (SD = 3.92) for the YNH group, 7.19 dB HL (SD = 3.25) for the ONH group, and 13.61 dB HL (SD = 7.33) for the OHI group.

All participants were recruited from Towson University's Speech-Language Pathology and Audiology Department, the Towson University Hearing and Balance Center, and by word of mouth. All participants signed an informed consent form prior to all testing procedures. All participants were given the Department of Veterans Affairs St. Louis University Mental Status examination orally and scored ≥ 25 (YNH: 28.64; ONH: 27.67; OHI: 27), indicating no cognitive decline (Tariq et al., 2006). All testing procedures were reviewed and approved by the Institutional Review Board for the Protection of Human Participants at Towson University, and all participants were compensated for their time.

Experimental Conditions

Three experimental conditions were used to measure speech identification thresholds in this experiment: speaker

Figure 1. Mean left and right ear audiometric thresholds for the three listener groups. Black diamonds indicate younger listeners with normal hearing (YNH), red circles indicate older listeners with normal hearing (ONH), and blue stars indicate older listeners with hearing-loss (OHI). Error bars are ±1 standard error of the mean.



array, headphone, and iPad. In the speaker array condition, the participants were seated in a sound attenuating booth and all stimuli were presented via calibrated standing speakers (Orb Mod1) arranged in a semicircular array at a distance of 1.4 m from the listener. There were 13 speakers separated by 15º in azimuth in the array. The presentation of stimuli in the headphone condition was similar to the methods used in Jakien, Kampel, Stansell, et al. (2017) with the only difference being that the speech stimuli were presented using circumaural headphones (Sennheiser HD650). Sennheiser HD 280 Pro headphones were used to present the stimuli in the iPad condition. Details about the calibration of the iPad with the headphones and presentation of the stimuli were similar to Gallun et al. (2018).

Stimuli

Three male talkers from the CRM (Bolia et al., 2000) speech corpus were used as speech stimuli for this experiment. The fourth male talker in the CRM corpus was excluded due to a slower rate of speech when compared to the other three male talkers in the corpus. CRM sentences were of the format “Ready (CALL SIGN) go to (COLOR) (NUMBER) now” and contain eight call signs, four colors, and eight numbers. The target call sign was always “Charlie” and always located at 0° azimuth in front of the listener. On each trial, the listener was presented with a CRM sentence in the presence of two masker sentences. The goal was to attend the sentence identified by the call sign “Charlie.” The target talker and the masker talkers varied from trial to trial.

Four spatial separations were used in all experimental conditions: The target was always presented at 0° azimuth speaker in front of the listener, and the maskers were either colocated with the target (0°) or spatially separated by ± 15°, ± 30°, and ± 45°. For the headphone and iPad conditions, head-related impulse responses were convolved with the CRM stimuli to simulate the colocated and spatially separated conditions as described in Gallun et al. (2013). For the speaker array conditions, the target and the maskers were presented from the actual speaker locations. The target stimulus was presented at 20 dB SL (re: SRT), and the two masking sentences were presented simultaneously and at various intensity levels scaled in SL relative to the target level. No listener was presented with maskers whose overall level exceeded 90 dB SPL.

Procedure

Participants were seated in a sound attenuating booth located in Van Bokkelen Hall at Towson University for all testing procedures. The test session consisted of an audiologic evaluation including otoscopy, pure-tone audiometry of both air and bone conduction, SRT testing, cognitive assessment using Veterans Affairs St. Louis University Mental Status questionnaire, and three experimental testing conditions. The order of the three experimental conditions was randomized to reduce any order effects. All participants completed three repetitions at each of the four spatial separations in all three experimental conditions resulting in 36 threshold estimates.

Speech identification thresholds were obtained using a progressive tracking procedure (Gallun et al., 2013). This procedure presents 20 trials per condition, two at each TMRs in 2-dB steps starting at 10 dB and decreasing to −8 dB. Responses were recorded by the participant using a touch screen monitor located in the test booth directly in front of the listener. Feedback in the form of "correct" or "incorrect" was displayed on the monitor following each trial. Speech identification threshold was calculated by subtracting the number of correct responses from 10.

Results

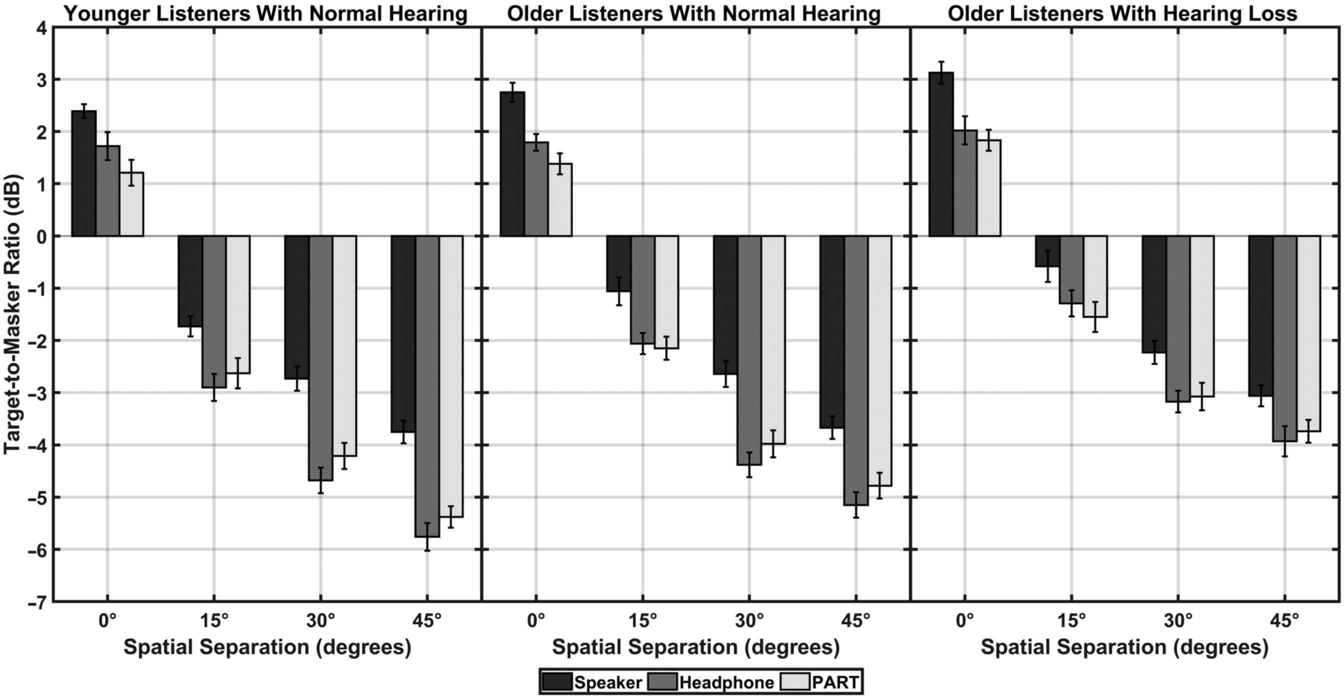
Speech Identification Thresholds

Speech identification thresholds are the TMRs at which the participant was correctly able to identify the color/number combination that corresponds with the target call sign "Charlie." Figure 2 shows the mean speech identification thresholds for the three experimental conditions at four spatial separations for the three groups tested.

A repeated-measure analysis of variance (ANOVA) was conducted with spatial separations (collocated, ± 15°, ± 30°, and ± 45° separations) and experimental conditions (speaker, headphone, and PART) as within-subject factors and age (younger and older) and hearing status (normal hearing and hearing impaired) as between-subjects factors. Significant main effects were observed for all the four factors, experimental condition: $F(2, 108) = 21.62$, $p < .001$, partial $\eta^2 = .29$, indicating a medium effect size; spatial separation: $F(3, 162) = 463.66$, $p < .001$, partial $\eta^2 = .90$, indicating a large effect size; age: $F(1, 54) = 5.05$, $p = .03$, partial $\eta^2 = .09$, indicating a small effect size; hearing status: $F(1, 54) = 8.59$, $p = .005$, partial $\eta^2 = .14$, indicating a small effect size. Identification thresholds were significantly lower for the separated conditions compared to the colocated condition. Identification thresholds were significantly lower for the younger group compared to the older group and were significantly lower for the normal-hearing group compared to the hearing-impaired group. There was a significant interaction between experimental conditions and spatial separations on identification thresholds, $F(6, 324) = 2.63$, $p = .02$, partial $\eta^2 = .05$. Also, there was a significant three-way interaction between experimental conditions, spatial separations, and hearing status, $F(6, 324) = 2.28$, $p = .03$, partial $\eta^2 = .03$. All the other interactions were nonsignificant. To further examine the significant interactions between the variables, separate repeated-measures ANOVAs were conducted with spatial separations and experimental conditions for each of the three listener groups.

Table 1 shows the repeated-measures ANOVA statistics for the three listener groups. For all the three listener groups, there was a significant main effect of spatial separation, significant main effect of experimental condition, and

Figure 2. The left, center, and right panels show the speech identification thresholds (measured in target-to-masker ratios) at the four spatial separations for the younger listeners with normal hearing, older listeners with normal hearing, and older listeners with hearing loss. In all the groups of bars, the left bars indicate the thresholds when stimuli were presented through speaker array, the middle bars indicate the thresholds when stimuli were presented over headphones, and the right bars indicate thresholds when Portable Automated Rapid Testing (PART) iPad app was used to present the stimuli. Error bars are ±1 standard error of the mean.



a significant spatial separation by experimental condition interaction. Post hoc analyses with Bonferroni correction for multiple comparisons indicated that the identification thresholds improved as the separation between the target and the maskers increased. Also, the identification threshold for the speaker array experimental condition was significantly poorer than the identification thresholds for the headphone and PART experimental conditions. However, there was no significant difference in identification thresholds between the headphone and PART experimental conditions. This was indeed true at all four spatial separations tested.

SRM

The amount of release from masking due to spatially separating the maskers from the target was calculated by subtracting the speech identification threshold at each spatial separation from the colocated speech identification threshold. Repeated-measures ANOVAs were conducted for each spatial separation within each participant group to determine the effects of spatial separation on the amount of release from masking. The results revealed the same trend as identification thresholds for all the three listener groups: amount of release from masking increased as the spatial separation between the target and the maskers increased, the amount of release from masking for the speaker array experimental condition was significantly lower than the amount of release from masking for the headphone and PART experimental conditions, and there was no significant difference in the amount of release from masking between the headphone and PART experimental conditions.

Correlation and Reliability Between Listening Conditions

Correlation analyses were conducted to determine the identification threshold's relationship between the three experimental conditions and the four spatial separations (colocated, 15°, 30°, and 45°) tested in the experiment. Figure 3 depicts the scatter plots of the identification thresholds and corresponding correlation values for the headphone and PART experimental conditions. Table 2 shows the correlation value and the corresponding significance values for speaker array and headphone speech identification thresholds, speaker array and PART speech identification thresholds, and headphone and PART speech identification thresholds at all spatial separations tested. All the identification thresholds were significantly and positively correlated, and Pearson correlation value (r) ranged between .24 (speaker array vs. PART at colocated condition) and .74 (headphone vs. PART at 30° separation).

There was a moderately significant positive correlation between age and SRT, $r(55) = .59$, $p < .\ 001$. To further analyze the effects of age and hearing loss on the amount of release from masking, multiple regression analyses were performed predicting SRM for the three experimental conditions for various spatial separations with age and SRT as predictors. The results of these various regression analyses are shown in Table 3.

A single multivariate model was formed to predict the amount of release from masking with age, amount of hearing loss, separation between the target and the maskers, and experimental conditions as predictors. The model was significant, $F(5, 507) = 148.97$, $p < .001$, and accounted for 59.5% of variance in the amount of release from masking. SRT ($\beta = -.495$, $t(507) = -11.57$, $p < .001$), separation ($\beta = .417$, $t(507) = 12.13$, $p < .001$); and experimental condition (iPad vs. headphones: $\beta = .043$, $t(507) = 1.09$, $p = .27$; iPad vs. speaker array: $\beta = .143$, $t(507) = 3.60$, $p < .001$) contributed to the model, whereas age did not, $\beta = .076$, $t(507) = 1.77$, $p = .08$.

Across Tests Reliability

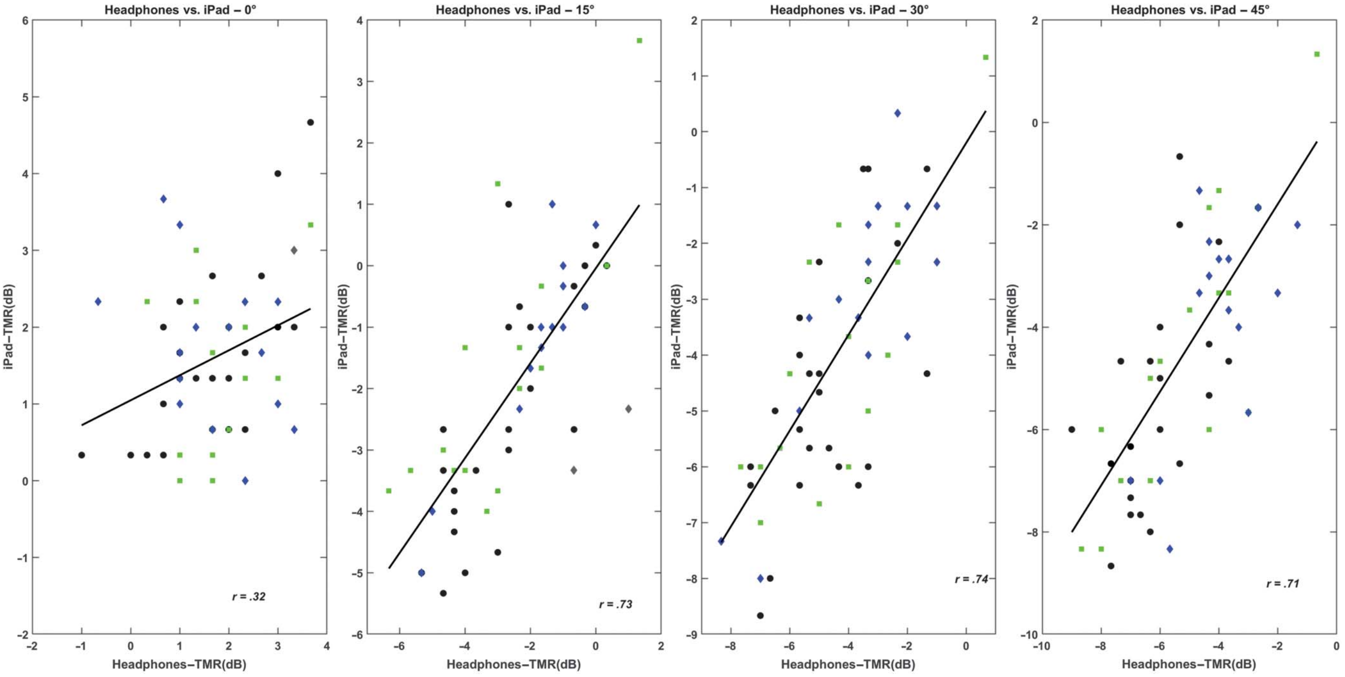
To address the extent to which the TMR thresholds measured using the three techniques were reliable, test–retest reliability was measured using limits of agreement (Altman & Bland, 1983). Figure 4 shows the limits of agreement of speech identification thresholds and the corresponding bias values for the headphone and PART experimental conditions. The solid red line in all the panels of Figure 4 indicates the mean difference between the two experimental conditions for the spatial separation tested. Any deviation of this mean difference line from 0 indicates the measurement bias. The cyan dotted lines indicated 95% limits of

Table 1. Repeated-measures analysis of variance results for the three listener groups.

Variable	YNH	ONH	OHI
Separation	$F(3, 72) = 455.86$, $p < .001$, partial $\eta^2 = .95$	$F(3, 45) = 123.05$, $p < .001$, partial $\eta^2 = .89$	$F(3, 45) = 77.78$, $p < .001$, partial $\eta^2 = .84$
Experimental condition	$F(2, 48) = 7.55$, $p = .001$, partial $\eta^2 = .24$	$F(2, 30) = 39.59$, $p < .001$, partial $\eta^2 = .73$	$F(2, 30) = 5.89$, $p = .007$, partial $\eta^2 = .28$
Separation × Experimental Condition	$F(6, 144) = 2.76$, $p = .01$, partial $\eta^2 = .10$	$F(6, 90) = 2.40$, $p = .03$, partial $\eta^2 = .14$	$F(6, 90) = 3.13$, $p = .008$, partial $\eta^2 = .17$

Note. YNH indicates the young adult listeners with normal hearing group, ONH indicates older adult listeners with normal-hearing group, and OHI indicates older adult listeners with hearing loss group.

Figure 3. The first, second, third, and fourth columns show the scatter plot between headphone and Portable Automated Rapid Testing speech identification thresholds at all separations tested. Within all panels, the black circles denote younger listeners with normal hearing, green squares denote older listeners with normal hearing, and blue diamonds denote older listeners with hearing loss. The line within each panel indicates best fit line to the data. TMR = target-to-masker ratio.



agreement (mean difference between the experimental conditions ±1.96 × standard deviation of the mean difference between the experimental conditions). Table 2 shows the bias estimate for all relevant comparisons. As seen from Figure 4, most of the data points fall within the limits of agreement. Also, the bias estimate (shown in Table 2) between headphone and PART experimental conditions was much smaller than the bias estimates for speaker array versus headphone and speaker array versus PART comparisons suggesting similar speech identification threshold estimates when using either headphone or PART experimental conditions.

Discussion

The purpose of this study was to compare speech identification thresholds obtained using the PART iPad app to traditional methods—using speaker array and using virtual spatial array. Fifty-seven listeners varying in age and hearing thresholds participated in this experiment. Overall, thresholds measured using PART app and using virtual spatial array were similar and were significantly better than the thresholds measured using speaker array. This was true for the four spatial separations and three listener groups tested in this experiment. The colocated thresholds in the headphone condition (*M* = 1.82 dB, *SD* = 1.23 dB) and PART condition (*M* = 1.52 dB, *SD* = 1.1 dB) were similar to the thresholds reported in the Gallun et al. (2013) study (headphone condition: *M* = 2.13 dB, *SD* = 2.2 dB) and Gallun et al. (2018; PART condition: *M* = 1.85 dB, *SD* = 1.7 dB). This was true for spatially separated thresholds at 45° as well (headphone: *M* = −5.08 dB, *SD* = 2.27 dB; PART: *M* = −4.51 dB, *SD* = 2.73 dB; Gallun et al. [2013]

Table 2. Pearson correlation and Altman–Bland bias estimates between the target-to-masker ratios thresholds measured in the experimental conditions.

	Colocated		±15°		±30°		±45°	
Variable	***r*(55)**	**bias**	***r*(55)**	**bias**	***r*(55)**	**bias**	***r*(55)**	**bias**
PART vs. headphone	.32	0.11	.73	−0.5	.74	−0.42	.71	−0.47
Speaker array vs. headphone	.33	0.87	.34	1.09	.45	1.7	.37	1.66
Speaker array vs. PART	.24	0.97	.34	0.57	.36	1.29	.39	0.99

Note. All correlations were significant at $p < .05$. PART = Portable Automated Rapid Testing.

Table 3. Multiple regression models predicting spatial release from masking at the three spatial separations for the three experimental conditions.

				Standardized regression coefficients (β)	
Condition	**Separation**	**R^2**	**Model statistics**	**Age**	**SRT**
Speakers	15°	12.5	*F*(2, 54) = 3.87, *p* = .027	0.07	−0.389*
	30°	26.7	*F*(2, 54) = 9.82, *p* < .001	0.19	−0.607**
	45°	33.1	*F*(2, 54) = 15.16, *p* < .001	0.23	−0.678**
Headphones	15°	23.3	*F*(2, 54) = 8.20, *p* = .001	0.02	−0.472*
	30°	37.5	*F*(2, 54) = 16.23, *p* < .001	0.25	−0.738**
	45°	44.6	*F*(2, 54) = 21.73, *p* < .001	0.20	−0.764**
iPad	15°	24.5	*F*(2, 54) = 8.77, *p* < .001	0.01	−0.438*
	30°	36.2	*F*(2, 54) = 17.23, *p* < .001	0.14	−0.699**
	45°	45.4	*F*(2, 54) = 21.55, *p* < .001	0.04	−0.787**

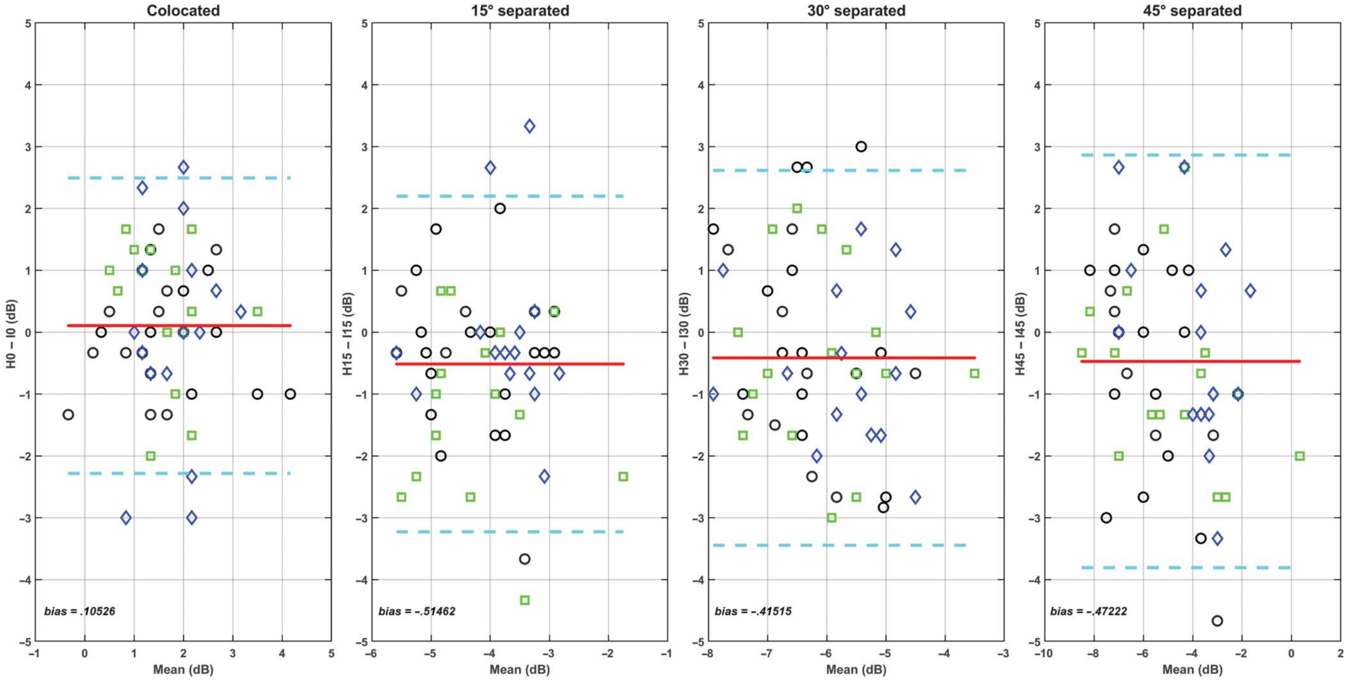
Note. SRT = speech reception thresholds.

*Indicates *p* < .05. **Indicates *p* < .001.

headphone: *M* = −4.3 dB, *SD* = 3.8 dB; Gallun et al. [2018] PART: *M* = −4.33 dB, *SD* = 2.5 dB). Participants were tested using four spatial separations (colocated, ±15°, ±30°, and ±45°) when the speech was presented using one of three listening conditions (speaker array, headphones, and iPad). Speech identification thresholds for the participant groups improved as the spatial separation between target and masker increased, indicating that the listeners can use binaural cues arising from the separation of the target talker and the masker talkers regardless of age or hearing loss. This finding is in agreement with several other studies in the literature concluding that speech identification performance increased with increased spatial separations between target and maskers (Gallun et al., 2013; Glyde et al., 2013; Jakien, Kampel, Stansell, et al., 2017; Marrone et al., 2008b; Srinivasan et al., 2016).

Performance was influenced by the mode of presentation of the auditory stimuli, with poorer overall performance

Figure 4. The first, second, third, and fourth columns show the mean difference and limits of agreement for speech identification thresholds estimated using headphone and Portable Automated Rapid Testing at all spatial separations tested. Within all panels, the black circles denote younger listeners with normal hearing, green squares denote older listeners with normal hearing, and blue diamonds denote older listeners with hearing loss. The solid red line within each panel indicates the mean difference between the two experimental conditions. The broken cyan lines indicate limits of agreement (mean difference ±1.96 × standard deviation of the mean difference).



observed in the speaker array condition as compared to the headphone and iPad conditions. This was true for all the three listener groups. The thresholds in the speaker array condition was conducted in a sound-attenuated booth, and reverberation in the room could have contributed to the poorer thresholds in this condition compared to the other two conditions. The colocated thresholds obtained in the speaker condition were similar to the thresholds reported in the literature (Marrone et al., 2008b; Srinivasan et al., 2017), and the separated thresholds were similar to the thresholds obtained by Srinivasan et al. (2017).

Age and hearing loss were significantly negatively correlated to SRM at all separations tested in this experiment. Multiple regression analyses indicated that hearing loss, and not age, was a significant predictor of SRM, which agrees with the work of Srinivasan et al. (2016, 2017). However, the amount of variance accounted for by the predictors (age and SRT) in SRM was lower compared to the above-mentioned studies. It should be noted that the above-mentioned studies by Srinivasan et al. (2016, 2017) had listeners with more severe hearing losses compared to this study. In spite of less variability in the amount of hearing loss, age did not have unique contribution to the variance accounted for, whereas predicting SRM indicates that at the spatial separations tested in this experiment, the impact of hearing loss is so huge that it makes the contribution of aging not significant.

According to Gallun et al. (2018), when tested using the PART app for iPad, which contains a rapid, automated test of speech-on-speech masking similar to the Spatial Release iPad app, participants using the iPad were able to achieve similar SRM as compared to when they were tested in an anechoic chamber with an array of loudspeakers. This finding suggests that if testing for the current study were performed in an anechoic chamber rather than a sound-treated booth, results between the iPad and speaker array conditions might have had a stronger correlation.

One of the major limitations of the current study was that there was very little difference in audiometric differences between the ONH and OHI groups. Most of the audiometric differences between these two groups were only in the 2000–8000 Hz range. All participants had normal audiometric thresholds in the low frequencies. It is unknown how the thresholds would pan out if we had listeners who had significant losses in the low frequencies as well.

Conclusions

This is one of the first studies that compared SRM measured through traditional laboratory methods and the PART iPad app. Findings indicate that the test–retest reliability between the speech identification thresholds obtained using the headphone and iPad was high for all the three listener groups participated in this study. Due to the strong correlations of the good test–retest reliability between headphone and iPad threshold estimates, it could be concluded that the SRM module in the PART iPad app can be used as a strong clinical tool to assess spatial processing ability. Being able to test patients with an iPad and a pair of calibrated headphones would be a more time efficient and less expensive way to assess spatial processing in an audiology clinic. The data presented in this study and future studies on this app will aid clinicians in better quantifying spatial processing ability in a quick and cost-effective way.

Acknowledgments

This work was supported by the graduate student award awarded by Towson University's Office of Graduate Studies to A1llison Holtz and by the National Institute on Deafness and Other Communication Disorders Grant R01 DC015051, awarded to Frederick Gallun, David Eddins, and Aaron Seitz. Portions of this data were presented at the 177th Meeting of the Acoustical Society of America, Louisville, KY. The authors would like to thank all the participants who participated in this experiment.

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