Effects of signal intensity level and noise-simulated hearing loss on auditory language processing persons with aphasia

BACKGROUND

By definition (McNeil & Pratt, 2001), all persons with aphasia (PWA) have difficulty processing acoustic speech and linguistic information. This definition also specifies that sensory deficits can co-exist, but cannot account for these auditory linguistic processing deficits. However, it is likely that many PWA also have sensory hearing loss because the prevalence of peripheral hearing loss is high in adults; especially among those with histories of vascular disease and stroke, and particularly among those of the age-cohort in which strokes most frequently occur. The nature of linguistic specific auditory processing deficits is believed to be due, at least in part, to a deficit of information processing (McNeil, Odell, & Tseng, 1991). As such, anything that either diminishes the integrity of the signal to be processed or that diverts processing resources (e.g., divided attention or processing a structurally degraded signal) should increase the processing demands and further degrade language processing in PWA. Hearing loss has the potential to reduce the acoustic information and degrade the integrity of speech signals, and therefore, may compete for processing resources; a situation that could challenge the auditory language processing system of PWA. Sensory hearing loss also has the potential to compromise speech and language ability in PWA due to the reduced integrity of the signal that is forwarded to the language processor, which can result in increased cognitive effort for perceptual resolution. There are several clinical consequences of this situation. First, the undetected interaction of sensory hearing loss with aphasia can prevent the accurate determination of the nature and severity of a person's aphasia. Secondly, if the language deficits are caused by, or augmented by hearing loss, treatment directed at the wrong level of the processing system might be inefficient. Similarly, the co-morbidity of hearing loss and aphasia may reduce the benefits of fitting auditory prostheses on persons who also have aphasia.

The *Revised Token Test* (*RTT*, McNeil & Prescott, 1978) has been computerized (*C-RTT* (McNeil & Pratt, in development)) so that the commands are presented acoustically via computer, and participants respond by manipulating tokens using a touchscreen computer monitor. The program provides on-line multidimensional scoring of all of the items, including millisecond timing of events; removing administration inconsistencies and training, as well as inter- and intra-judge administration and scoring reliability issues.

The purpose of this study was to assess the role of presentation level and high-frequency audibility in auditory processing of PWA. PWA and NBIP completed multiple runs of the *C-RTT* at varying intensity levels within quiet and simulated hearing loss conditions. Hearing loss simulations were used to separate hearing loss effects from the influence of the neurogenic disease on auditory language processing. The interaction of high-frequency hearing loss and language processing in PWA is virtually unknown despite its clinical and theoretical importance. Its exploration and resolution hold the promise of increased efficiency and effectiveness in the treatment of PWA and concomitant hearing loss.

METHOD

The participants consisted of two groups of older adults: one group of PWA (N = 14) and the other group of NBIP (N = 21). The PWA met the definition of aphasia as described by McNeil and Pratt (2001) and determined by their performance on the *Porch Index of Communicative Ability* (*PICA*, Porch, 1981). The NBIP reported negative histories for brain pathology, neurological disease, and speech or language disorders, and demonstrated normal performance on the *PICA*. All participants had no greater than a 30% decrease on the delayed versus immediate story retell subtests of the *Arizona Battery for Communication Disorders of Dementia* (Bales & Tomeda, 1993). All participants had normal peripheral hearing bilaterally, and based on a battery of electrophysiological tests, their central auditory pathways were considered largely intact for processing nonlinguistic information. Speech perception skills were consistent with age and puretone thresholds (Dubno et al., 1995). Biographical and inclusion data are summarized in Table 1 for the PWA.

All participants sat in a sound-booth facing a touchscreen monitor set 18" from the participant's head. The *C-RTT* commands were presented acoustically from a computer via two loudspeakers set at 45 and 315 degrees azimuths. A range of signal intensity levels were used, allowing for the construction of performance-intensity functions. The participants listened in two acoustic conditions: quiet and simulated hearing loss. In the simulated hearing loss condition, spectrally-shaped white noise was introduced to simulate a high-frequency sensorineural hearing loss (Humes et al., 1987), and was applied to both ear canals with insert earphones using a tube fitting. Intensity levels, order of subtests, and acoustic condition were randomized for each participant. For each acoustic condition, asymptotic performance was established, as was the level at which maximum performance occurred.

The participants used their non-dominant hand when manipulating the *C-RTT* tokens on the screen in response to the test commands. Their hand rested at a specified position before responding to each command. Administration of the 55-item version of the *C-RTT* followed practice. The program analyzed performance online and recorded the *C-RTT* Overall and Efficiency Scores (which incorporate response time).

RESULTS

A three-way ANOVA with repetition on presentation level and acoustic condition was applied to the *C-RTT* scores. As expected, the main effects of group ($F=56.267$, $df=1,33$, $p=.000$), presentation level ($F=179.017$, $df=6,198$, $p=.000$), and acoustic condition ($F=53.995$, $df=1,198$, $p=.000$) were significant. Group by level ($F=9.769$, $df=6,198$, $p=.000$) and level by acoustic condition ($F=16.394$, $df=1,198$, $p=.000$) interactions were significant, which were consistent with decreased performance intensity (PI) function slopes associated with the PWA group and also with simulated hearing loss. However, there was no significant group by acoustic condition interaction, nor was the three-way interaction significant, suggesting that the PWA responded to simulated hearing loss in a manner similar to the NBIP.

When referenced to the maximum *C-RTT* scores obtained (*C-RTT* Max), the level needed to obtain *C-RTT* Max differed by acoustic condition ($F=10.175$, $df=1,33$, $p=.003$) but not by group. The average presentation level required in quiet was 47.25 dB SPL, while the level in high-frequency noise was 57 dB SPL. Furthermore, the *C-RTT* Max did not differ by acoustic condition. The overall pattern was similar for the Efficiency Scores. As expected, the correlation between aphasia severity (as reflected by overall *PICA* score) and *C-RTT* Max was .83 in quiet and .85 in high-frequency noise. Similarly, the correlation between *PICA* score and the *C-RTT* Maximum Efficiency Score was .82 in quiet and .86 in high-frequency noise.

DISCUSSION

The results imply that after adjusting presentation level to fully accommodate reduced high-frequency audibility; simulated hearing loss does not differentially affect *C-RTT* performance in NBIP and PWA. About 10 dB additional gain was required to produce comparable performance across acoustic conditions for both groups. The reduced slope associated with simulated hearing loss and aphasia suggests that near-threshold level performance is compromised by hearing loss and aphasia. This finding argues persuasively that acoustic presentation level is critical when administering the *C-RTT* and likely all other auditory clinical and experimental tasks. Although the PI functions produced in this study can safely be applied only to the *C-RTT* stimuli, the results have implications for the fitting of hearing aids on PWA and add additional support for the need to account for hearing loss when administering auditory-based tasks (tests and clinical materials) to PWA.

REFERENCES

Bayles, K.A., & Tomoeda, C.K. (1993). *Arizonia Battery for Communication Disorders of Dementia*. Tucson, AZ: Canyonlands Publishing, Inc.

Dubno, J., Lee, F., Klein A.J., Matthews, L., Mills, J., & Lam, C. (1995). Confidence limits for maximum word recognition scores. *Journal of Speech and Hearing Research, 38*, 490-502.

Humes, L.E., Dirks, D.D., Bell, T.S., & Kincaid, G.E. (1987). Recognition of nonsense syllables by hearing-impaired listeners and b noise-masked normals. *Journal of the Acoustical Society of America*, *81*, 765-773.

McNeil, M.R., Odell, K.H., & Tseng, C-H. (1991). Toward the integration of resource allocation into a general theory of aphasia. *Clinical Aphasiology*, *20*, 21-39.

McNeil, M.R. & Pratt, S.R. (2001). Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology*, *15*, 901-911.

McNeil, M.R. & Prescott, T.E. (1978). *The Revised Token Test*. Pro Ed. Austin, TX

McNeil, M.R. & Pratt, S.R. Computerized Revised Token Test (in development).

Porch, B.E. (1981). *Porch Index of Communicative Ability.* Palo Alto, CA: Consulting Psychologists Press.

Table 1. Biographical and criteria information for participants with aphasia

Subject	Gender	Age (Yrs.)	Education (Yrs.)	Better Ear 3-Freq PTA	WRS	PICA OA Percentile	MPO
400	F	82	12	23	72*	48	64
401	M	62	16	15	100	80	41
402	M	66	12	18	92	71	182
404	F	59	12	10	88	59	101
405	F	60	15	12	96	68	14
406	F	63	13	8	100	83	468
407	F	68	12	18	100	69	21
408	M	43	14	12	100	82	89
409	F	48	16	10	96	76	71
411	M	60	16	18	92	67	29
413	F	69	12	17	88*	46	81
414	F	70	12	12	100	87	122
415	F	44	14	8	92*	52	14
416	M	38	14	15	88*	53	24
Mean	(9 F; 5 M)	59.43	13.57	14	93.14	67.21	94.36
Range		38-82	12-16	8-23	72-100	46-87	14-468
SD		12.24	1.65	4.44	7.75	13.70	117.71

3-Freq PTA = *Pure Tone Average of better ear at 500 Hz, 1k Hz & 2k Hz*
PICA= *Porch Index of Communication Ability* (Porch 1981)
WRS = *Word Recognition Score using NU-6 (* required administration of Picture Identification Test)*
MPO = *Months Post Onset*

C-RTT PI Functions by Group and Acoustic Conditions