# Hearing loss and auditory processing ability in people with aphasia

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RUNNING HEAD: Hearing loss in aphasia

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## ABSTRACT

*Background*: Hearing loss can add to the linguistic deficits present in aphasia to make comprehension of speech difficult. Although some studies document a relatively high prevalence of hearing loss in adults with aphasia, many people with aphasia do not have their hearing tested. Self-reported disability measures offer a possible alternative to pure-tone audiometry when this service is not readily available.

*Aims*: This study aims to investigate the prevalence of hearing loss in a group of people with aphasia and to determine the usefulness of self-reported measures to screen for hearing impairment.

*Methods & Procedures:* Hearing ability was measured using pure tone audiometry and five measures of auditory processing, which looked at speech perception in quiet and noise, for 21 individuals with aphasia recruited from a community clinic and 21 age-matched individuals without aphasia. The Speech, Spatial and Qualities of Hearing Scale (SSQ) and a brief questionnaire exploring whether they had experienced hearing difficulties, were used to measure self-perception of hearing acuity. Differences in scores between the groups were analyzed. Correlations and regressions were used to establish the relationship between self-perception of hearing and measures of hearing ability.

*Outcomes & Results:* Despite minimal impairment and a non-significant difference between performance on pure tone audiometry for participants with and without aphasia, participants with aphasia performed significantly worse on measures of speech perception in noise than participants without aphasia. They also had a significantly greater degree of perceived hearing disability. Although SSQ scores were correlated with some behavioural measures for the participants with aphasia, the SSQ only predicted the hearing status and speech in noise performance of control participants.

*Conclusions*: The results suggest that the prevalence of hearing loss for people with aphasia (at least for this group) is no greater than the general population. However, they are significantly more affected in their recognition of speech in noise and experience greater disability in listening situations than people without aphasia. The latter problems were not predicted by pure tone audiograms or sound-in-noise performance. The brief questionnaire was not effective in identifying hearing impairment, indicating the need for a regular hearing screen to ensure provision of the most effective rehabilitation. Ideally, the screen should include disability and behavioural measures, as our results suggest they cannot replace each other. These findings should assist clinicians in setting realistic goals and delivering interventions in the most effective way for people with aphasia.

# INTRODUCTION

Adults with acquired aphasia frequently report difficulties understanding what others are saying, particularly in challenging sound environments. It would be easy for health care providers to attribute these difficulties solely to the person's aphasia. However, other factors may be the cause of or contributing to the difficulties, for example; cognitive problems, emotional problems (such as anxiety) and/or sensory impairments (such as hearing loss). Accurate identification of the factors that contribute to a person's difficulty in understanding speech would help to establish the nature and severity of an individual's aphasia, assisting us in finding better ways of supporting the person and ensuring that the right treatment is given where necessary. For example, if the individual's comprehension problems were caused by or exacerbated by hearing loss then they might be expected to benefit from the provision of a hearing aid.

The incidence of hearing loss in adults is high and increases with age. For example, according to Action on Hearing Loss (AOHL, 2011) over 40% of adults in the UK over the age of 50 and over 70% of those over 70 have some degree of hearing loss. These are similar figures to those reported for the US (ASHA, n.d.) and Australia (Wilson, Walsh, Sanchez et al., 1999). Individuals with aphasia can be expected to be at least as likely as those without aphasia to have a hearing loss. In some people this would be a pre-existing problem prior to the aphasia while in others the hearing loss may occur many years after their brain injury.

Recent research suggests that impaired hearing may affect not only the processing of the auditory signal but also higher level linguistic and cognitive processing. For example, it has been found that even when older people with hearing loss were able to repeat speech accurately, they were unable to recall the information, possibly because they allocated attentional resources to interpreting the auditory signal that was degraded due to their hearing loss (Tun, McCoy, & Wingfield, 2009). Similar suggestions have been made to account for the problems experienced by people with aphasia: this population has greater difficulty understanding speech when listening tasks are complex; for example, dividing attention in a dual task, such as monitoring spoken words when completing a card sorting task (Erickson, Goldinger, & Lapointe, 1996) or in the context of an unfamiliar accent (Bruce, To & Newton, 2012).

It is therefore reasonable to predict that in aphasia, in which linguistic processes are impaired and information processing speed reduced, attentional reserves may also be compromised (see, for example, Connor, Albert, Helm-Estabrooks & Olber, 2000), causing further difficulty in disentangling the complex relationships between language, speech and hearing. If we are to understand fully the nature of an individual's comprehension problems, then speech and language therapists need to take account of lower-level peripheral processes such as auditory acuity and higher-level cognitive processes such as attention and memory, in addition to language.

The prevalence and nature of hearing loss associated with aphasia are not fully understood, partly because there has been little research focusing on this topic, but also because of discrepancies in the way that hearing loss is quantified and detected. Although cardiovascular disease, including stroke (e.g., Torre III, Cruickshank, Klein, & Nondahl, 2005), has been shown to be associated with hearing loss,  Formby, Phillips, and Thomas, 1987), using the Pure Tone Average (PTA) loss (i.e., the average hearing threshold level across 500, 1000 and 2000 Hz ), found no specific relationship between aphasia and hearing loss. According to this study, stroke patients with aphasia do not have disproportionately greater hearing losses than those without aphasia. In contrast, an earlier study conducted by Street (1957), using stricter criteria across a much wider frequency range (i.e., 125 to 12000 Hz), found that hearing loss was more common in people with aphasia than expected in the general population. Most of the patients (88%), with ages ranging from 19 to 70 years old, had a hearing loss, with fewer and less severe speech frequency hearing losses occurring in the younger patients with aphasia. Such a high incidence of hearing loss in this study could be accounted for by the fact that many of the participants were war veterans who may have lacked effective hearing protection on active duty, and that approximately a quarter of the participants were head injury patients and so would be likely these days to be identified as having cognitive communication disorder, rather than aphasia. However, these findings do suggest that this is an area requiring further investigation.

It is often noted that in the general population hearing loss goes undetected (e.g., Arlinger, 2003). People do not seek a hearing evaluation for a variety of reasons, including perceived stigma, being unaware of their hearing loss and uncertainty of the benefits of using a hearing aid (Duijvestijn, Hoek, & Anteunis, 2003). There are likely to be additional problems for some individuals with aphasia in recognizing that they have a hearing loss, as they may mistake their difficulties understanding speech for a memory or language problem.

The prevalence of hearing loss in older adults and its relation to language comprehension and cognition suggest that screening for hearing loss should be a routine part of care for people with aphasia, with those being detected as having problems being referred to an audiologist for more detailed testing. Although organisations who work with people with hearing loss recommend hearing screening for adults (for example, for those over 50 in the US (ASHA, n.d.), and for people over 60 in the UK (AOHL, 2011)), these screening programmes are considered voluntary in the US and are not offered in the UK. Adults in the UK who are concerned that they are losing their hearing must request a hearing test. Thus speech and language therapists working in such countries need to ensure that the hearing acuity of people with acquired communication difficulties is considered and investigated. However the tests which should be used for this may not be simply a matter of standard pure tone screening.  Our study compares results from a wider range of tests than those conventionally used in order to explore which measures are most informative in the context of aphasia.

Simply asking whether an individual has a hearing problem in the initial interview may be helpful (Gates, Murphy, Rees, & Fraher, 2003), although the issues raised by the studies above suggest that more probing techniques might be required. One way to gain more detailed information about a person's hearing is to use questionnaires. Self-report measures assessing hearing handicap in elderly people, such as the Hearing Handicap Inventory for the Elderly (HHIE) (Ventry & Weinstein, 1982) and the Speech, Spatial and Qualities of Hearing Scale (SSQ) (Gatehouse & Noble, 2004), which have well-documented reliability and validity, might be useful with people with aphasia. While these questionnaires are reported to be easy for older adults to complete, there is some evidence that the most reliable results are obtained using an interview method rather than self-administration (Singh & Pichora-Fuller, 2010). The interview method may be particularly important for people with aphasia, as previous research has found that they may have difficulties completing self-report measures (Engell, Hutter, Willmes, & Huber, 2003). Self-report measures assessing hearing handicap have been used with elderly people in a range of settings, but it is not known whether they are sufficiently sensitive and reliable to identify hearing loss in adults with aphasia. Moreover, the wording of questions may cause issues with validity. For example, in the SSQ, the question, 'Can you easily have a conversation on the telephone?' is likely to be straightforward for people without aphasia, and be primarily related to the ability to hear the speech. In the case of an individual with aphasia, both hearing and language issues may underlie a negative response to this and similar questions. The comparison of reported ability with objective measures should provide a way of disentangling this complexity.

Based on these considerations, the present study aimed to determine the extent of hearing loss in people attending a community clinic for adults with acquired communication difficulties, to assess the reliability and sensitivity of the SSQ in the context of aphasia and to determine whether scores on the SSQ relate to objective measures of hearing ability. Responses to the questionnaire were compared with measured hearing loss on a range of audiological tests, including pure-tone air conduction audiometry.

# METHOD

## Participants

Twenty one adults with aphasia (13 male; eight female) and 21 adults without aphasia (five male; 16 female) participated in the study, which was approved by a University Departmental Ethics Committee. The control group included partners or family members where possible, to provide a level of matching for life experience/family-cultural variables, though this reduced the opportunity for gender matching and resulted in a significant difference in gender distribution ($\chi^2$ (1, N=42) = 6.22, $p$=.013). The inclusion criteria were pragmatic, with ages above 18 years and any national and ethnic origins being included, providing that they were or had been fluent speakers of English (having lived in the UK and used English as their primary language at least in the workplace, for a minimum of twenty years). All participants with aphasia stated that, post-stroke, English was their dominant language in both frequency and domains of use. All had normal or corrected-to-normal vision and if they had aphasia were at least six months post-stroke. All participants had a reliable yes/no response (no less than 16/20 on Western Aphasia Battery (WAB) Yes/No Questions, Kertesz, 1982).

Participants with aphasia were recruited, through posters and by word of mouth, from a London community clinic; some control participants were family members of the participants with aphasia, others were recruited from a local college. Results of an independent samples t-test indicated that there was no statistically significant difference between the two groups with respect to age ($p$ = 0.519), with a mean age of 58.6 years for aphasic participants (SD = 11.72) and a mean age of 56.0 for the control group (SD = 12.9). Six of the experimental group (and two of the controls) had English as a second language but fitted the inclusion criteria for English usage given above. Participants with aphasia presented with a range of communication difficulties and severity of aphasia, as determined by the WAB (Kertesz ,1982) (see table 1). Control participants were adults with no history of neurological deficit.

Table 1. Details of people with aphasia.

| Participant | Gender | Age (years) | First language English Y/N | Months post-stroke | Aphasia type | AQ[1] | ACS[2] max=200 |
|---|---|---|---|---|---|---|---|
| A1 | F | 65 | Y | 88 | Anomia | 91.6 | 200 |
| A2 | M | 58 | Y | 53 | Anomia | 95.0 | 184 |
| A3 | M | 47 | Y | 18 | Broca's | 31.0 | 194 |
| A4 | F | 61 | N (Serbian) | 61 | Anomia | 93.2 | 192 |
| A5 | M | 67 | Y | 240 | Conduction | 65.6 | 170 |
| A6 | M | 49 | Y | 28 | Broca's | 46.6 | 152 |
| A7 | M | 58 | Y | 23 | Wernicke's | 68.2 | 126 |
| A8 | M | 32 | N (Polish) | 15 | Anomia | 68.8 | 176 |
| A9 | M | 71 | Y | 42 | Anomia | 81.2 | 169 |
| A10 | M | 76 | Y | 122 | Conduction | 71.4 | 154 |
| A11 | F | 52 | N (Yoruba) | 24 | Anomia | 82.2 | 188 |
| A12 | M | 53 | Y | 49 | Broca's | 98.0 | 200 |
| A13 | F | 65 | N (Krio) | 50 | Anomia | 87.3 | 171 |
| A14 | F | 52 | Y | 56 | Anomia | 87.2 | 200 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A15 | M | 52 | N (Dutch) | 57 | Broca's | 48.1 | 121 |
| A16 | M | 56 | N (Polish) | 84 | Anomia | 89.8 | 200 |
| A17 | M | 74 | Y | 22 | Broca's | 48.4 | 174 |
| A18 | M | 42 | Y | 51 | Anomia | 92.7 | 197 |
| A19 | F | 77 | Y | 82 | Conduction | 56.6 | 164 |
| A20 | F | 65 | Y | 24 | Broca's | 14.2 | 106 |
| A21 | M | 45 | Y | 9 | Conduction | 79.3 | 175 |

[1]AQ = Aphasia Quotient on the WAB; [2]ACS = WAB Auditory Comprehension score.

## Measurements

*Hearing Screening.* Participants' air conduction thresholds (250, 500, 1000, 2000, and 4000 Hz) were measured using a Kamplex Clinical Pure Audiometer KD29 with TDH-49 Supra-Aural headphones. The Audiometer was calibrated according to the BS EN 60645-1: 2001 and BS ISO 389-1:2000 standards. Otoscopic examination was carried out for all participants to ensure that both ears were free from wax. One participant with aphasia was subsequently referred to her GP for wax removal prior to testing. Hearing loss was defined in two ways: i) the speech frequency pure-tone average (PTA) (≥25 dB average hearing loss at 500, 1000, and 2000 Hz in the better ear), and ii) the high-frequency pure-tone average (HF-PTA) (≥25 dB average hearing loss at 1000, 2000, and 4000 Hz in the better ear) (WHO, n.d.). Both measures have been used in previous research (PTA: Stewart & Wingfield, 2009; HF-PTA: Hazan, Messaoud-Galusi, Rosen, Nouwens, & Shakespeare, 2009).

*Auditory processing tasks.* Test materials for all measures were delivered binaurally (in order to simulate everyday listening situations) through Sennheiser HD25-1 headphones via a calibrated desktop computer at a sensation level of 65 dB SL, i.e., 65 dB above the average pure tone hearing threshold level (500, 1000 and 2000 Hz) of the participant in their better ear. Most of the speech perception tasks used in this study involved connected speech to assess skills in a ‘real life’ context. All were presented via computer. All auditory processing tasks were preceded by a practice trial that allowed participants to become familiar with the task demands. In the speech perception in noise tasks, practice trials initially were conducted without noise and then noise was gradually introduced until participants practiced on trials that were similar to the actual test trials.

- *Auditory processing in quiet*. To assess auditory discrimination ability in optimum conditions (without noise), participants completed a computerised minimal pair task comprising 18 pairs of monosyllabic object names (from Dunton, Bruce, & Newton, 2011), distinguished by a single vowel or consonant. Consonants differed by the type (voice, place or manner) and the number of features contrasted (voice, place and manner). Vowels differed in the degree of phonetic contrast (close versus distant). The target was presented at the end of a carrier sentence (e.g., “My friend borrowed my van/fan”), and participants selected by pointing at the picture that matched the target word they had heard.

- *Auditory processing in noise*. Speech perception in noise was tested, varying only the signal-to-noise ratio. Participants completed three tasks, one at word level and two at sentence level, using different masking conditions (speech noise or single speaker distractor) to investigate underlying processes at peripheral and central levels. Energetic masking (i.e., using speech noise), which occurs when some or all of a target signal becomes inaudible as a result of the target signal and masker overlapping in time and frequency, typically reflects peripheral processing limitations (Brungart, Simpson, & Freyman, 2005). Conversely, informational masking (i.e., using a single speaker as the masker), which arises when the listener has difficulty separating the audible acoustic components of a perceptually similar speech masker, indicates central auditory processing deficits (Brungart et al., 2005).

The words in noise task ‘Who is right?’ (from Lancaster, 2009) comprised 42 highly frequent monosyllabic words. A picture of the target word was presented with three identical faces displayed beneath it. The participants heard a recording of an adult male speaker saying the target’s name. Then each of the faces spoke in turn (heard as a female voice) over simultaneously presented steady-state speech noise. One face produced the target word whilst the other two faces produced non-word foils which differed by a single feature of voice, place or manner (e.g., target word ‘bird’ was heard, then the options to choose from were given as ‘pird’ (voice foil), ‘dird’ (place foil) and ‘bird’ (target)). Participants clicked on the face they thought had produced the target word. The speech to noise ratio (SNR) began at +20 dB. This task used a two-down, one-up adaptive procedure (with stimulus level decreased after every two correct responses and increased after every error) in order to vary SNR and to track 71% correct responses The speech reception threshold (SRT) was recorded as the mean of the reversals.

For the Words in Noise in Connected Speech task (WiNiCS; Hazan et al., 2009) participants followed instructions involving a dog, a colour and a number presented in a carrier phrase, e.g., ‘show the dog where the pink four is’. A picture of a dog and six grids of different coloured numbers (from one to nine, excluding seven) were presented. Participants clicked on the number in the colour they heard. Target sentences were spoken by a female speaker and the SRT was measured in two different masking conditions: i) speech (a male speaker) (henceforth, ‘WiNiCS-single speaker’) and ii) continuous speech noise with the same long term average spectrum as speech (‘WiNiCS-speech noise’). In the single speaker condition the presentation of the male talker distracter was randomised, ensuring that the animal, colour and number were different from the target. As with ‘Who is Right?’ the SNR began at +20 dB and varied according to participants' responses. Testing for both types of masker ended when participants achieved a tracked mean of 80% correct at one SNR and completed either six reversals or 32 trials. Testing stopped after 32 trials regardless of number of reversals.

The final speech in noise task was the Bamford-Kowal-Bamford Sentence test (BKB; Bench & Bamford, 1979) which consisted of 21 lists of 16 phonetically-balanced sentences containing three target words (e.g., 'The clown had a funny face'). Participants repeated each sentence which was presented in a background of continuous speech noise. The SNR commenced at 0 dB and varied according to participants' responses. If participants correctly identified two or three of the key words the SNR was reduced by 3 dB. If they identified one or no key words correctly the SNR was increased by 3 dB. Testing was completed when participants had achieved a tracked mean of 71% correct at one SNR.

*Questionnaires.* The perception of the participants with aphasia regarding the impact of any hearing difficulties on their everyday life was assessed using two questionnaires; the Speech, Spatial and Qualities of Hearing questionnaire (SSQ; Gatehouse & Noble, 2004) and the Hearing Questionnaire, a short five-item questionnaire adapted from the 1977 National Health Interview Survey (Ries, 1982). The latter explores whether an individual has experienced hearing difficulties at any time, including the key question 'Do you have a hearing problem now?' and other questions to reveal the nature of an identified difficulty, for example, tinnitus and use of a hearing aid. It was included in order to establish whether this short format provided a reliable measure of hearing difficulties. Several studies have found that a single screening question, such as 'Do you feel you have a hearing loss?' was nearly as accurate as a more detailed hearing loss questionnaire or a hand-held audiometric device for detecting hearing loss among older adults without aphasia (see Chou et al, 2011). Control participants in our study only completed the SSQ because we were interested in gaining more detailed information about specific difficulties in hearing situations, which we could compare with the participants with aphasia. All questions were presented auditorily to all participants, in an interview format (as used by Sing & Pichora-Fuller, 2010). Questions were repeated and ratings checked (by the researcher saying, for example, ‘So you’re saying that you are not able to do this task now’) to ensure that the rating given accurately reflected the experience of the participant.

The SSQ consists of 49 questions across three subscales: the Speech subscale ($SSQ_{SPEECH}$) with 14 items assessing the ability to hear speech in real-life contexts (e.g., ‘Can you easily have a conversation on the telephone?’); the Spatial subscale ($SSQ_{SPATIAL}$) with 17 items assessing spatial listening abilities (e.g., ‘Can you tell from a person’s voice or footsteps whether the person is coming towards you or going away?’) and the Qualities subscale ($SSQ_{QUALITY}$) with 18 items assessing different qualities of hearing (e.g., ‘Can you assess another person’s mood from the sound of their voice?’). Participants rated each question on a ten point scale with end points labelled as ‘not at all’ and ‘perfectly’. Scores for all listening situations were summed to determine a total score (max=490), with higher scores corresponding to better self-reported ability. According to Demeester et al. (2012), an average rating across the three subtest scores that falls below 7.25 (out of a maximum of 10) indicates a significant degree of hearing disability[1]. Scores for the three subscales of the SSQ were also examined separately to investigate whether they were related to the objective auditory measures.

Participants with aphasia also completed the Hearing Questionnaire, involving general questions about self-perceived hearing status, starting with the question “Do you have a hearing problem now?”. Participants responded to each question by answering ‘yes’ or ‘no’.

Participants who answered ‘yes’ to any of the questions answered two further questions giving more detail about their perception of their hearing in each ear.

## Procedures

Testing was conducted in a sound-treated room. Participants carried out all hearing measures before completing the questionnaires in an interview format. The interview format allowed for clarification of any situations that were misconstrued. Information and instructions were given orally with supplementary written information. Participants were given the opportunity to ask questions prior to commencing each task. For participants with aphasia, the data were collected over two sessions, each lasting an hour. The control participants completed the whole test battery in one one-hour session. All auditory processing data and questionnaire responses were collected by the first author, who is a trained speech and language therapist.

Descriptive and inferential statistical analyses of the data were carried out to determine the effect of aphasia on performance on measures of hearing ability and the relationship between perceived hearing loss and hearing ability, and to establish if there was a relationship between perceived communication handicap and performance on the WAB.

# RESULTS

Results for all participants are shown in tables 2 and 3 respectively. Six participants with aphasia did not get a single trial correct on the WiNiCS task in either one or both conditions and so the programme did not generate an SRT score for them. Furthermore, due to coexisting speech production difficulties, such as apraxia of speech, some participants with aphasia were unable to complete the BKB task. Data from these individuals were, therefore, excluded from analyses considering performance on these tasks. All the remaining participants were able to complete all the speech-in-noise tasks sufficiently for establishment of a signal-to-noise ratio.

When data met the assumption of normality, independent samples *t*-tests were used to examine group differences on measures of hearing ability. When scores were not normally distributed, Mann-Whitney *U* nonparametric tests were used. These analyses were completed with calculations of effect size. Additionally, correlations and multiple regression analyses examined the relationship between self-perception of hearing status and behavioural measures of hearing ability in adults with and without aphasia, and to establish whether behavioural measures of hearing ability were related to total SSQ scores and the different SSQ subscales.

## Hearing Acuity

Results indicate that hearing acuity was within normal limits for the majority of participants. However, hearing loss ≥25 dB in the better-hearing ear as assessed by PTA was present in one participant with aphasia and two participants without aphasia, and using HF-PTA in four participants with aphasia and three participants without aphasia. Although three participants with aphasia indicated they had a hearing problem in response to the question ‘Do you have a hearing problem now?’, the criterion level of hearing loss was recorded for only two of them.

Table 2.Pure tone audiometry, auditory processing and questionnaire scores for participants with aphasia.

| Participant | PTA (dB HL) | HF PTA (dB HL) | Auditory Discrimination (max=18) | Who is right? (SRT in dB HL) | WiNiCS speech noise (SRT in dB HL) | WiNiCS speaker (SRT in dB HL) | BKB (SRT in dB HL) | SSQ Total | HQ |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.00 | 5.00 | 18 | -4.67 | -6.00 | -3.33 | -7.50 | 334.0 | N |
| A2 | 5.00 | 8.33 | 16 | -9.33 | -5.33 | -7.67 | -7.17 | 314.5 | N |
| A3 | 0.00 | 6.67 | 18 | -1.90 | | 22.00 | | 411.0 | N |
| A4 | 36.67 | 41.67 | 17 | -1.62 | -3.67 | 5.33 | -6.00 | 347.5 | Y |
| A5 | 15.00 | 18.33 | 18 | -3.90 | | | | 245.5 | N |
| A6 | 8.33 | 11.67 | 18 | -7.50 | | | | 274.0 | N |
| A7 | 13.33 | 21.67 | 18 | -4.30 | 5.00 | 10.00 | | 301.0 | Y |
| A8 | -3.33 | -5.00 | 18 | -8.29 | -2.67 | 16.33 | -6.00 | 429.0 | N |
| A9 | -1.67 | 3.33 | 18 | -2.30 | -6.00 | 4.67 | -5.83 | 334.5 | N |
| A10 | 21.67 | 33.33 | 18 | -1.30 | -0.67 | 10.00 | 6.00 | 294.0 | N |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A11 | 8.33 | 6.67 | 18 | -6.75 | -0.33 | 1.00 | -6.83 | 416.0 | N |
| A12 | 11.67 | 23.33 | 18 | -6.63 | -0.67 | 13.00 | | 462.0 | N |
| A13 | 6.67 | 6.67 | 18 | -10.50 | -6.00 | -9.67 | -5.50 | 413.0 | N |
| A14 | 1.67 | 3.33 | 18 | -7.60 | -6.00 | 4.50 | -7.50 | 351.5 | N |
| A15 | 15.00 | 16.67 | 18 | -6.18 | 28.67 | | | 178.5 | N |
| A16 | 1.67 | 11.67 | 17 | -3.25 | -4.67 | -0.67 | -5.50 | 467.5 | N |
| A17 | 8.33 | 28.33 | 10 | 3.20 | | | | 307.0 | N |
| A18 | 3.33 | 5.00 | 18 | -10.75 | -6.33 | -6.67 | -6.83 | 286.0 | N |
| A19 | 23.33 | 38.33 | 16 | -0.27 | 0.40 | 4.33 | 10.67 | 216.5 | Y |
| A20 | 16.67 | 15.00 | 18 | -1.63 | | | | 397.0 | N |
| A21 | 5.00 | 10.00 | 14 | -1.50 | -3.00 | -0.33 | | 351.0 | N |

(grey box) = Participants unable to carry out CCRM/BKB tasks

Table 3.Pure tone audiometry, auditory processing and questionnaire scores for participants without aphasia.

| Participant | PTA (dB HL) | HF PTA (dB HL) | Auditory Discrimination (max=18) | Who is right? (SRT in dB HL) | WiNiCS speech noise (SRT in dB HL) | WiNiCS speaker (SRT in dB HL) | BKB (SRT in dB HL) | SSQ Total |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.33 | 16.67 | 18 | -5.30 | -5.67 | -9.00 | -7.50 | 305.0 |
| 2 | 8.33 | 8.33 | 18 | -11.80 | -5.00 | -8.00 | -8.17 | 429.5 |
| 3 | 30.00 | 40.00 | 11 | -4.50 | -5.00 | -10.40 | -5.83 | 353.5 |
| 4 | 35.00 | 38.33 | 18 | 7.14 | -6.00 | -12.00 | -7.50 | 358.5 |
| 5 | 23.33 | 18.33 | 18 | -7.20 | -7.33 | -14.80 | -8.17 | 460.0 |
| 6 | 15.00 | 31.67 | 18 | -6.50 | -4.00 | -2.00 | -3.50 | 339.0 |
| 7 | 1.67 | 1.67 | 17 | -8.20 | -7.00 | -12.40 | -8.83 | 458.0 |
| 8 | 15.00 | 10.00 | 18 | -8.27 | -6.00 | -8.33 | -7.83 | 421.0 |
| 9 | 0.00 | -3.33 | 18 | -13.67 | -7.00 | -5.50 | -7.33 | 452.0 |
| 10 | 1.67 | 1.67 | 18 | -9.14 | -9.33 | -11.67 | -8.17 | 384.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11 | 11.67 | 13.33 | 18 | -8.75 | -7.33 | -8.00 | -7.17 | 466.0 |
| 12 | 11.67 | 18.33 | 18 | -7.30 | -7.20 | -3.00 | -5.83 | 316.0 |
| 13 | 5.00 | 6.67 | 18 | -11.57 | -6.00 | -11.33 | -8.17 | 468.0 |
| 14 | 13.33 | 16.67 | 18 | -9.50 | -7.67 | -12.00 | -7.83 | 405.0 |
| 15 | 3.33 | 0.00 | 18 | -11.70 | -9.33 | -9.00 | -9.50 | 405.5 |
| 16 | 6.67 | 5.00 | 18 | -9.40 | -9.00 | -9.67 | -9.83 | 485.0 |
| 17 | 1.67 | 0.00 | 18 | -11.50 | -6.67 | -9.00 | -9.33 | 409.0 |
| 18 | 0.00 | -3.33 | 18 | -10.00 | -10.00 | -19.00 | -10.83 | 450.0 |
| 19 | 20.00 | 13.33 | 18 | -12.00 | -7.67 | -11.50 | -7.83 | 462.0 |
| 20 | 8.33 | 13.33 | 18 | -7.50 | -8.00 | -2.67 | -7.83 | 255.0 |
| 21 | 3.33 | 0.00 | 18 | -8.85 | -6.00 | -8.67 | -5.83 | 484.0 |

## Comparison of measures of hearing ability between the two groups.

There was no significant difference between the two groups in PTA ($t(41)=-.53$, $p=.96$) or HF-PTA ($t(41)=-.78$, $p=.96$) . Consequently, only the HF-PTA was included in further analyses as it was thought to be a more sensitive measure of hearing acuity than PTA. There was also no statistically significant difference between the groups on the auditory discrimination test (U(41)=178.5, $p=.12$): the majority of participants performed at or near ceiling, although a few individuals in both groups (none of whom had English as a second language) had marked difficulties when asked to distinguish between minimal pairs in quiet. The scores from this test were therefore dropped from further analyses. There were, however, significant differences in the thresholds between the two groups for all speech-in-noise tests (‘Who is right?’ (U(41)=88.5, $p=.001$),WiNiCS-speech noise (U(36)=36, $p<.001$), WiNiCS-single speaker ($t(36)=5.26$, $p<.001$) and BKB (U(32)=39, $p<.001$)), showing that participants with aphasia required speech to be significantly louder than the noise if they were to understand the words and sentences (when analyses were repeated excluding individuals with hearing loss, this did not alter the results). Moreover, Cohen’s effect size values for WiNiCS-speech noise ($d$ = -.67) and for WiNiCS-single speaker ($d$ = 1.78) suggested that these differences were of practical significance. Further analyses of the data from the WiNiCS tests revealed that participants with aphasia were more adversely affected than those without aphasia by a competing speaker than continuous speech-spectrum noise ($t(14)=3.55$, $p=.003$): they performed significantly better in the WiNiCS-speech noise condition. In contrast, participants without aphasia performed significantly better in the WiNiCS–single speaker condition ($t(20)=-3.03$, $p=.007$)  than those with aphasia.

Finally, analyses of the SSQ data indicate that participants with aphasia perceived a greater hearing handicap than participants without aphasia. 67% of the participants with aphasia, but only 24% of participants without aphasia reported a significant degree of disability. There was a significant difference in the $SSQ_{TOTAL}$ scores for the group with aphasia (M=339.57, SD=78.02) and the control group (M=407.90, SD=64.95); $t$ (40) = 3.08, $p$= 0.004 (see tables 2 and 3). For all participants, the mean $SSQ_{SPEECH}$ score was lower (greater disability) than the $SSQ_{SPATIAL}$ and $SSQ_{QUALITY}$ scores (6.19, 7.15 and 7.56 respectively for participants with aphasia: 7.88, 8.1 and 8.97 participants without aphasia). For participants with aphasia the highest ratings were for one-to-one and group conversations in quiet where all speakers are visible, whereas for participants without aphasia they were for one-to-one conversations in quiet and on the telephone. The items providing lowest ratings for participants with aphasia were talking on the telephone in competitive conditions followed by trying to process two speech streams simultaneously, whereas for participants without aphasia they were conversations in noise or where not every speaker was visible followed by processing two speech streams simultaneously.

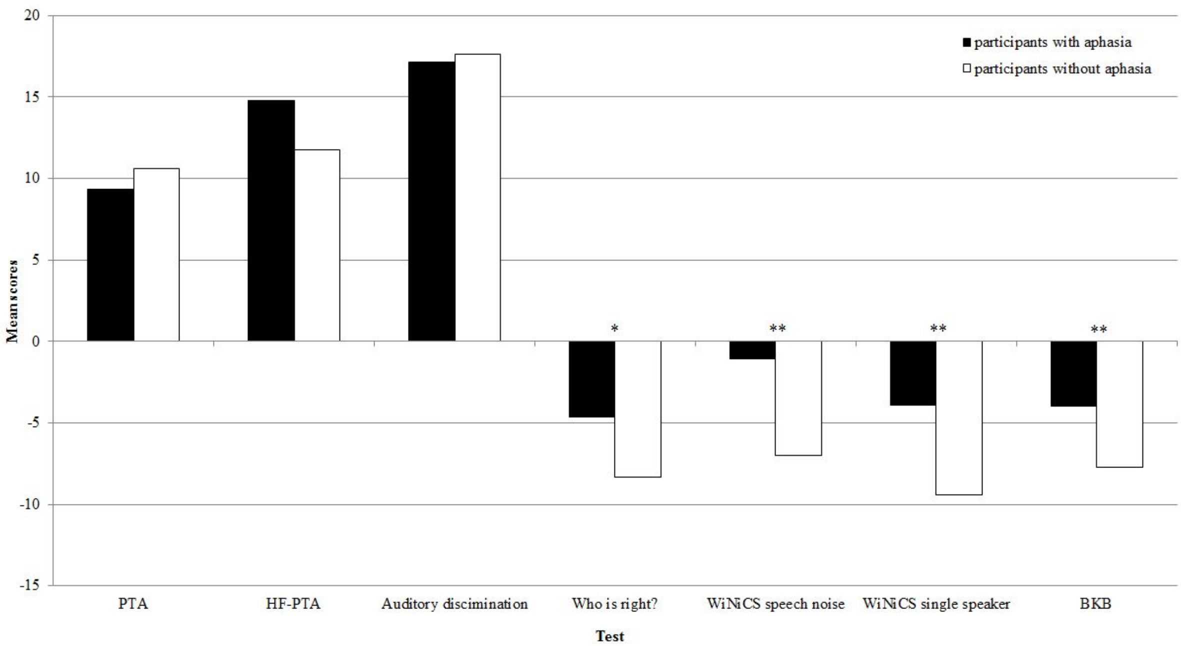


Figure 1. Mean scores of participants with and without aphasia on measures of hearing ability (asterisks indicate statistically significant differences; *$p$<.01; **$p$<.001).

## Relationship between self-perception of hearing status and measures of hearing ability in adults with and without aphasia

The data collected from most of the auditory processing measures was normally distributed at least once obvious outliers had been removed, which meant that parametric analyses could be applied. Outliers more than 1.5 times the interquartile range (IQR) were removed. The scores for two people with aphasia (A10 and A19) on the BKB test and the score for one person without aphasia (Participant 4) on the ‘Who is right?’ test were removed, as a marked increase in signal-to-noise ratio was required by them to understand speech in noise. Analyses were repeated including outliers but, unless otherwise stated below, this did not alter the results.

Table 4: Correlations for total scores on the SSQ and measures of auditory processing between the participants with and without aphasia.

| Measures of auditory processing | Participants with aphasia | Control participants |
|---|---|---|
| HF PTA | (n=21) -.36 | (n=21) -.51* |
| Who is right? | (n=21) -.13 | (n=20) -.55* |
| WiNiCS-speech noise | (n=16) -.55* | (n=21) -.21 |
| WiNiCS-single speaker | (n=16) .22 | (n=21) -.51* |
| BKB | (n=10) .58 | (n=21) -.38 |
| WAB auditory comprehension | (n=21) .54* | |

Pearson correlations were used for all auditory processing measures apart from the WAB, for which the Spearman’s rho correlation was used

* Correlation is significant at the 0.05 level (2-tailed).

Table 4 shows that the $SSQ_{TOTAL}$ scores for individuals without aphasia were associated with more measures of hearing ability than the scores of individuals with aphasia. For individuals without aphasia, there were significant negative correlations between the $SSQ_{TOTAL}$ and performance on all measures of hearing ability apart from the BKB and the WiNiCS-speech noise task. For participants with aphasia, there were only significant correlations between the $SSQ_{TOTAL}$ and the WiNiCS-speech noise test and the auditory comprehension component of the WAB (with outliers included the BKB scores also showed a significant correlation with the $SSQ_{TOTAL,}$ (n=12, *r*=-.601, *p*=.04)). Of all the SSQ subsections, only the $SSQ_{SPEECH}$ scores were significantly correlated with behavioural tasks: they were positively correlated with SRT scores for the BKB (n=10, *r*=.706, *p*=.02) (though with outliers included this correlation was not found), and with scores on the auditory component of the WAB (n=21, *r*=.454, *p*=.04); individuals with aphasia who reported greater hearing disabilities had lower auditory comprehension scores.

The degree of handicap reported by participants with aphasia, as reflected in the $SSQ_{TOTAL}$ scores and the scores obtained for the three SSQ subsections, were not related to degree of hearing loss, as reflected in the HF PTA scores. However, higher scores on the $SSQ_{TOTAL}$ and the $SSQ_{SPEECH}$ (*r*=-.522, *p*=.02) were associated with greater hearing impairment for control participants. In contrast, individuals in both groups who reported greater difficulties with hearing in daily life tended to have difficulties hearing speech in noise, although it was only participants without aphasia whose $SSQ_{TOTAL}$ scores were related to difficulty perceiving speech in the presence of a competing talker (WiNiCS-single speaker) (see table 4).

Significant positive Spearman's rho correlations were found for participants with aphasia between HF-PTA and Who is right? (n=21, *r*=.619, *p*=.003) and WiNiCS-speech noise (n=16, *r*=.602, *p*=0.14). For participants without aphasia, HF-PTA was associated with scores on Who is right? (n=20, $r$=.717, $p$<.001) and BKB (n=21, $r$=.610, $p$=.003). Thus for both groups there was a relationship between hearing ability and auditory discrimination tasks in noise.

Hierarchical multiple regression analysis was used to investigate the extent to which $SSQ_{TOTAL}$ scores and the scores on the different sections of the questionnaire could be predicted from the measures of auditory processing. Separate analyses were conducted for participants with and without aphasia using the same approach. Variables were entered into the regression in conceptually organised blocks. There were four blocks for participants with aphasia, but only three blocks for participants without aphasia as they had not completed the WAB. Block 1 included HF-PTA. Block 2 included WAB (for participants with aphasia only). Block 3 included WiNiCS–single speaker. Block 4 included the other speech in noise variables (BKB, WiNiCS–speech noise and Who is right?).

Results of the hierarchical regression analyses for the control group for the $SSQ_{TOTAL}$ scores and the subscales of the SSQ showed that where there was a significant relationship, the model including Blocks 1, 3 and 4 provided the best fit. When the $SSQ_{TOTAL}$ score was the dependent variable, this model accounted for 51% of the variation in perception of hearing disability and the overall relationship was significant ($R^2$ = .64, $F$(5, 14) = 4.89; $p$= .008). However, only performance on WiNiCS-single speaker significantly predicted the $SSQ_{TOTAL}$ score ($t$ (19)= -3.33, $p$= .005). Participants who had problems understanding speech when another person was speaking reported greater hearing disability. When the $SSQ_{SPEECH}$ was the dependent variable the model overall accounted for 52% of the variance in reported hearing disabilities and was a significant fit of the data ($R^2$ = .65, $F$(5, 14) = 5.17; $p$= .007). The results show that there was a statistically significant relationship between performance on WiNiCS-single speaker ($t$ (19)= -2.23, $p$ = .043) and HF-PTA ($t$ (19)= -2.49, $p$ = .026) and scores on the $SSQ_{SPEECH}$. Participants who had problems understanding speech in noise reported greater hearing disability in challenging, real-life environments. There was no significant relationship between the scores for the $SSQ_{SPATIAL}$ and measures of auditory processing. However, when the $SSQ_{QUALITY}$ was the dependent variable, the overall relationship was significant ($R^2$ = .53, $F(5, 14) = 3.14$; $p$= .042) with WiNiCS-single speaker being the only significant predictor of $SSQ_{QUALITY}$ responses ($t$ (19)= -2.78, $p$=.015). Participants who had problems understanding speech when another person was speaking reported greater difficulty in separating sounds from one another.

In contrast, the hierarchical regression analyses for the participants with aphasia revealed no significant relationships between either the $SSQ_{TOTAL}$ scores or the scores for the different subscales of the SSQ and measures of auditory processing. None of the auditory measures predicted which participants would report having marked hearing disability in daily life, and this could not be attributed to high levels of multicollinearity as the predictors in the regression models were only weakly related.

In summary, there was no significant difference in the prevalence of hearing loss, as measured by pure-tone audiometry, between the two groups. However, presenting auditory materials in noise, particularly speech, had a larger detrimental effect on the performance of participants with aphasia than it did for participants without aphasia. Some measures of auditory processing were related to the extent of hearing handicap in daily life for participants without aphasia. In contrast, for participants with aphasia, degree of hearing difficulty, as measured by tests of auditory processing, was not related to their perception of difficulties in everyday listening situations.

# DISCUSSION

This study investigated the prevalence of hearing loss in individuals with aphasia attending a community clinic for people with acquired communication difficulties. In addition, the extent to which self-perceived hearing status correlated with, and could be predicted by, hearing ability was examined with routine pure-tone screening and a more extensive battery of tests, including measurements of perception of speech-in-noise.

## Sensory measures

The results showed that the participants with aphasia did not have significantly poorer hearing acuity than age-matched controls**.** Indeed, in this study, using HF-PTA with a pass criterion of 25 dB HL, only four individuals with aphasia and three without aphasia were identified with a hearing loss. These results differ from the findings of Street (1957), which may reflect the nature of the participants in that study who may have had additional cognitive deficits and have been exposed to harmful noise, but they are in line with those of Formby et al. (1987). Despite both groups in our study having a similar overall level of hearing when measured over the WHO-recommended (n.d.) and often used 'higher frequency PTA range' (1K,2K and 4K), there are reasons for caution in interpreting this finding regarding prevalence of hearing loss because, while the prevalence is the same between groups, the impact of hearing loss may not be the same. It is possible that a damaged linguistic and/or cognitive system is more sensitive to changes in pure-tone thresholds: someone with aphasia may need to have a peripheral sensory system that is operating as effectively as possible because they cannot afford to allocate resources to yet another task that requires additional effort (beyond cognitive-linguistic processing). Moreover, previous research suggests that individuals without aphasia but with high frequency steeply sloping audiograms may have more difficulty understanding speech in noise than in quiet (Noble, Sinclair, & Byrne, 1998). Thus, future research may usefully investigate this further and include 8000Hz in the pure tone audiometry to establish whether loss at this level affects performance on tests of auditory processing.

Participating in this study was beneficial for the seven individuals whose previously unreported hearing loss was identified. Although the number of people with hearing loss was relatively small, for those who had hearing problems it was important that they were identified so that they could receive appropriate audiological care. Following the hearing screening, they were referred for a full diagnostic evaluation and two of the participants with aphasia and one without aphasia were fitted with hearing aids. The others were given strategies to improve listening and increase their communication effectiveness. The finding that participants in both groups had hearing problems adds weight to the argument that hearing screens should be performed regularly both for older people and for all people with aphasia. This may be particularly important for the latter group as hearing problems may have a disproportionate effect on individuals with aphasia who rely on sensory input to compensate for some of their language and cognitive difficulties.

## Cognitive-linguistic issues

This study also showed that auditory discrimination testing in quiet conditions did not differentiate between participants with and without aphasia. Few participants in either group had difficulties with this task. In contrast, participants with aphasia had considerably more difficulty understanding speech in noise than the control group, regardless of whether the background noise was continuous speech noise or a single speaker; thresholds in noise for participants with aphasia were significantly higher than for participants without aphasia on Who is right?, WiNiCS–speech noise, WiNiCS–single speaker and BKB. This is clearly a problem for people with aphasia as much of the time they will be listening to speech in the presence of irrelevant sounds. This pattern of results - where individuals performed badly in noise even though they did not have much pure tone loss - was found by Banh, Singh, & Pichora-Fuller (2012) with older adults. It is also consistent with previous studies reporting auditory processing difficulties in individuals with aphasia (Strauss Hough, Downs, Cranford, & Givens, 2003; Winchester & Hartman, 1955). Furthermore, the significant difference between groups for Who is right?, which looks specifically at phonetic discrimination in noise, is in line with Winchester and Hartman (1955) who found that individuals with aphasia had difficulty discriminating speech in noise but not in quiet.

WiNiCS–speech noise, WiNiCS–single speaker and BKB tap different underlying processes. WiNiCS–speech noise and BKB use speech noise as a masker (i.e., energetic masking, which reflects peripheral processing limitations). Conversely, the WiNiCS–single speaker condition uses a single other talker as masker (i.e., informational masking, reflecting difficulty with higher level auditory processing such as seen in central auditory processing deficits, or comprehension impairments such as seen in aphasia). The results of this study, therefore, suggest significantly greater peripheral and central auditory processing deficits in participants with aphasia in comparison to those without aphasia, even though there was no significant difference in hearing sensitivity between the two groups. Moreover, contrary to the patterns shown by participants without aphasia (better performance with a single speaker masker than continuous speech-spectrum noise) and in other studies (e.g., Cooke, 2006), participants with aphasia performed worse with a competing speaker than in speech noise, suggesting that they were more adversely affected by informational masking.

One reason for speech masking causing additional problems for participants with aphasia might be changes in cognitive function arising from stroke, such as reduced selective attention. Possibly because attentional resources are diverted by processing the single speaker masker, participants with aphasia appear to be less able than those without aphasia to make use of speech when it is affected by fluctuating background noise. Similar findings have been reported in studies of older people (Cooke, 2006), and there is evidence that people with aphasia have impairments in selective attention (Murray, 2012). Another possibility is that the language processing difficulties contribute to the problems experienced by participants with aphasia in challenging listening conditions, as these difficulties increase the effort involved in performing the task. There are interesting parallels between the listening performance of older people and individuals with aphasia, not all of whom are elderly, suggesting that a reduction in processing resources (including the resources involved in decoding and interpreting the acoustic signal as well as attentional resources) may underlie the difficulties of both groups. However, it is unclear whether the difficulties experienced by the individuals with aphasia were a result of the language deficits arising from their brain damage or their brain damage alone. Future research might usefully attempt to disentangle the factors involved in speech recognition in noise (e.g., attention, working memory, executive function) by comparing the performance of individuals who have had a stroke with and without aphasia.

Another area that would benefit from further investigation is the influence of bilingualism (or multilingualism) on performance on speech perception tasks in people with aphasia. The pragmatic approach to recruitment used in this study meant that the groups with and without aphasia reflected the cosmopolitan make-up of London, so that both groups included participants for whom English was not their first language. Although we only included participants whose primary language was English (i.e. dominant in both frequency and domains of use), it is possible that participants' first language may have impacted their performance (see, for example, Rogers, Lister, Febo, Besing & Abrams, 2006 for possible effects of bilingualism for people without aphasia). However, there is no clear evidence of this in our data: only one participant (who had aphasia) performed at the lower end of the range of scores.

## Self-report measures

In this study, where admittedly the prevalence of hearing loss was low, the single question ‘Do you have a hearing loss?’ was not particularly useful as it lacked sufficient sensitivity and specificity to identify individuals at risk. There were a few cases of mismatch between PTA results and response to the hearing problem question, which may reflect clients’ differing levels of insight into the cause of their difficulties or that different levels of hearing acuity may result in different everyday experiences. In contrast to the single question, the SSQ offered valuable insights into problems people had listening in daily life. With help, including repetition and rephrasing of questions, people with aphasia were able to complete the SSQ, identifying problems listening in everyday situations. Despite the fact that hearing thresholds were similar for both groups, the results indicate that participants with aphasia perceived themselves to be more disabled than participants without aphasia across all domains of the SSQ, with lowest scores being recorded in the $SSQ_{SPEECH}$ subscale. As with other studies (Demeester et al., 2012; Banh et al., 2012) participants in both groups showed greatest disability in the $SSQ_{SPEECH}$ subscale. Although the problems picked up by the SSQ for people with aphasia were correlated with WiNiCS–speech noise and the auditory comprehension score of the WAB, they were not correlated with hearing acuity or any of the other auditory processing measures. This contrasted with the participants without aphasia, whose scores on the SSQ were correlated with the HF-PTA and all but one auditory processing measure, but was similar to the pattern of results found by Banh et al. (2012) with older adults with normal hearing. Multiple regression analyses corroborate these findings, indicating that SSQ scores can be predicted from performance on measures of hearing ability for control participants at better than chance level but not for participants with aphasia.

These findings suggest that for participants with aphasia, low scores on the SSQ may not be attributed to decreased hearing acuity nor be easily attributed to poor auditory processing in noise or impaired linguistic processing. Instead, cognitive factors such as attention and working memory may play a part. Although further research is needed to elucidate the role of different levels of cognitive processing in determining the amount of hearing handicap, support for their involvement comes from the fact that items involving higher cognitive demands, such as processing two speech streams simultaneously, had the lowest ratings. These items require individuals to separate the mixed input into separate streams and to focus their attention on the target speech and/or inhibit the processing of the competing speaker. It is not possible to determine from these data which of these skills is impaired or why. Participants with aphasia reported less disability in situations when the speaker was visible, suggesting that they benefit from the additional information provided when they can both see and hear a speaker even in adverse listening conditions. This audiovisual benefit in the presence of competing speech has been found for older adults without aphasia (Jesse & Janse, 2012). The benefit for those with aphasia is as yet unclear, though there is some evidence that they may be aided by seeing the speaker in some tasks in quiet conditions (e.g. Hessler, Jonkers & Bastiaanse, 2010). Although the SSQ provided valuable information about individuals' perceptions, its utility in identifying hearing disability in people with aphasia remains questionable as this measure may capture their total communication experience, which includes their hearing, language and cognitive difficulties and their own personal responses, understanding and interpretation of all of those.

Health care providers need to be aware of the fact that people with aphasia may have increased difficulty processing information presented auditorily when listening conditions are sub-optimal (e.g., in the presence of background noise or other distractions). This should help them choose settings and deliver therapy in a way that is most conducive to success. For example, our findings suggest that even for people who show no obvious comprehension difficulties on language testing, health professionals should ensure that their speech is of an appropriate volume and that there is no one speaking in the background. However, individuals with aphasia need to operate in less than ideal conditions and therefore they may need a therapy programme that helps them to acclimatise to different types of background noise as well as developing specific listening strategies. Strategies may include learning to create the optimum listening environment and when possible thinking about the words and ideas that might arise in a conversation before it starts.

This study has expanded on past research exploring hearing in aphasia by not only investigating the prevalence of hearing loss in aphasia, but also establishing whether performance on measures of hearing ability correlated with self-reported hearing status in individuals with and without aphasia. However, although this study collected data on a wider range of measures of hearing ability than previous studies, the sample size was relatively small in comparison to previous similar research (Formby et al., 1987; Street, 1957). A larger sample size would provide a more representative sample of the wider population with aphasia and would potentially substantiate the results found in this study. Moreover, whilst the SSQ provides an in-depth account of an individual's hearing abilities in a wide range of listening situations, it is important to recognise that it may not be measuring the same constructs in people with aphasia as in other populations. In addition, the questions are quite lengthy and grammatically complex. This did not appear to be a problem for our participants: they were all able to complete the questionnaires without the necessity of changing question format or using additional illustration, though some explanation and checking by the researcher was required. However, the linguistic complexity may present a challenge for some people with aphasia, and even with support from a trained speech and language therapist it is possible that some of our participants with severe auditory comprehension difficulties may not have fully understood what was being asked. Consequently their responses to the questions, although appropriate, may not have truly represented their experiences. To explore further the functional ramifications of hearing loss with the use of a perceived hearing handicap scale, a questionnaire using a simpler question format and/or visual representation of scenarios would be helpful.

In summary, our results showed that individuals with aphasia did not have a higher prevalence of pure tone hearing loss or speech perception problems in ideal conditions than age-matched controls. However, they were more affected than participants without aphasia in their recognition of speech in adverse conditions, in particular when they also heard a single competing speaker. Participants with aphasia also reported significantly greater hearing disability, and although scores on the SSQ were correlated with hearing in speech noise and auditory comprehension they were not predicted by pure-tone results or performance on the auditory processing and auditory comprehension measures used in this study. Thus, the SSQ appears to be picking up other factors, such as attention and language ability, that determine how listeners function in real-life situations. Our results suggest that the SSQ is not a valid substitute for pure tone hearing testing, but may provide valuable additional information about real life experience (e.g., how people manage when they are in a group in different settings), though additional questioning may be required in order to understand fully what is contributing to these experiences for people with aphasia.

## CONCLUSIONS

As with other studies (Demeester et al., 2012; Banh et al., 2012), this study shows that the relationship between hearing loss, hearing disability and difficulty understanding auditory information is not always straightforward and that a number of different measures are needed to determine the degree of hearing impairment and how it affects everyday communication. This may be of particular importance for individuals with aphasia who, because of their existing difficulties in communicative situations, may be less sensitive to whether changes in auditory acuity are contributing to their problems. Moreover, significant others may also be unaware that comprehension difficulties may be associated with hearing loss and/or disability. It is, therefore, of paramount importance that professionals working with people with aphasia do not rely on those individuals to identify their own hearing problems. Rather, regular hearing screens need to be introduced for people with aphasia to ensure that potential hearing difficulties are identified and the most appropriate rehabilitation provided (as also recommended by Street (1957)). Our study indicates the need for a more extensive range of assessments, including both pure tone audiometry and speech-in-noise tests, tailored for individuals with aphasia, in order to obtain a fuller picture of the extent to which hearing loss and disability affect everyday communication in this client group.

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**Declaration of interest**

The authors report no conflicts of interest. The authors are responsible for the content and writing of the paper.

**Footnote**

1. In this paper, the term ‘hearing disability’ is used to refer to any difficulties experienced by individuals in hearing sounds in everyday life, in line with the definition of the International Classification of Impairments, Disabilities and Handicaps (WHO, 1980). ‘Hearing loss’ and ‘hearing impairment’ are used to refer to a reduction in hearing sensitivity as measured by pure tone audiometry.

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