Introduction

Although many people with aphasia (PWA) have trouble understanding sentences, the underlying impairment is poorly understood. One fundamental question is whether sentence comprehension impairments affect the spoken and written modalities in the same ways. A small number of studies have compared reading and auditory comprehension in PWA, but they report conflicting patterns of results (Gallaher & Canter, 1982; Gardner et al., 1975; Peach et al., 1988). Further, none of these studies used on-line measures of sentence processing, meaning that their results did not reflect the moment-by-moment processes underlying sentence comprehension. The present study revisited the issue of modality effects on comprehension in PWA using on-line measures of sentence processing.

Modality differences in lexical access are likely to affect sentence comprehension. However, even PWA who perform well on untimed word picture matching tasks often complain of difficulty understanding written or spoken sentences. One possibility is that aphasia affects the speed with which the semantic system is accessed from auditory and visual representations. This type of lexical deficit would have little to no effect on word picture matching tasks, but might interfere with the rapid lexical activation necessary for normal sentence processing. If accessing words is relatively slow in one modality, then variables that influence lexical activation should have a greater effect in the impaired modality.

Word frequency is a well-studied variable that affects lexical access time. The finding that low frequency words take longer to access than high frequency words has been demonstrated across modality, population, and level of processing (e.g., word & sentence) (e.g., Ferreira et al., 1996; Just et al.,1982). PWA show frequency effects of at least the same magnitude as controls in single words (e.g., Kittredge et al., 2008; Varley, 1999, but cf., Nickels & Howard, 1995). At the sentence level, Shewan and Canter (1971) suggested that word frequency influences off-line measures of auditory sentence comprehension in PWA. These tasks demonstrate that PWA are sensitive to word frequency, but do not speak to the presence of on-line effects in either modality. Importantly, there is no a priori reason to expect modality differences in effects of lexical frequency.

The present study compared processing of written and spoken sentences containing high and low frequency words using two on-line measures of sentence processing, self-paced listening and self-paced reading. If PWA show differences in lexical access as a function of modality, then the frequency effects will differ in the two tasks. If spoken and written lexical access do not differ, then the frequency effects should be equivalent.

Methods

Participants

Eight PWA (mean = 49 years) and 8 age-matched controls (mean = 50 years) participated. The PWA completed background testing to ensure adequate word comprehension to complete the tasks and characterize their aphasia.

Stimuli

The stimuli were 21 sentence pairs that contained high and low frequency words. All items were followed by a comprehension question. Table 1 summarizes characteristics of the stimuli and Table 2 presents sample materials.

Tasks

Performance was compared on self-paced listening and self-paced reading, two tasks that permit a narrow comparison due to similar dependent measures (reading vs. listening time) and presentation style.

Self-paced listening: The stimuli were recorded by a native English speaker and divided into segments as depicted by the slashes in Table 2. Participants paced through each sentence one phrase at a time by pressing a button interfaced with a computer. The button box collected accuracy and reaction times for each button press.

Self-paced reading: The sentences were presented using the same segmentation as for self-paced listening. Each trial began with a series of dashes (-) marking the length and position of the words in the sentence. The participants pressed a button to reveal each segment. When they pressed the button, the previously revealed segment reverted to dashes and the next segment was revealed. The button box collected the same data as described for self-paced listening.

Procedures

The sentence pairs were tested in both tasks. The stimuli were divided into 2 lists so that the members of the sentence pairs were not tested in the same session. All participants were tested on both lists in both modalities in four separate testing sessions.

Results

Comprehension Questions: Table 3 presents the accuracy data for each condition and group. PWA answered more questions accurately in the self-paced listening than reading task, but the age-match controls did not show a significant effect of task, $F1(1, 14)=11.75$, $p<.01$, $F2(1, 40)=5.19$, $p<.05$. No other effects were significant by both subjects and items.

Response times: The dependent measure was the reading and listening times for the high and low frequency words. To control for effects of length, response times are typically reported as ms/character for reading and ms/segment for listening. An alternative approach, commonly used to control for frequency, was used to equate these measures. Raw response times were regressed against segment duration or number of letters, and the residuals of these analyses were used in ANOVAs. Note that this procedure results in negative response times when the observed response time is faster than the predicted response time. The analyses revealed that both PWA and controls had longer response times for low than high frequency words, $F1(1, 14)=5.96$, $p<.05$, $F2(1, 40)=3.71$, $p=.06$ (see Figure 1). There were no other significant results.

Of particular interest in this study is whether PWA show greater effects of word frequency than controls in one or both modalities. This question was addressed using Crawford and Garthwaite's (2005) method for analysis of case studies. In self-paced listening, three PWA showed significantly greater effects of word frequency than the controls. In self-paced reading, all eight PWA showed larger effects than the controls. However, four of these showed reverse frequency effects, that is, longer response time for high versus low frequency words.

Discussion

This experiment investigated whether PWA show similar effects of lexical frequency in listening and reading. The results show that, as a group, both PWA and non-brain-damaged controls have longer listening and reading times for low compared to high frequency words. The analysis of single cases suggests that PWA showed larger frequency effects in reading than listening. However, not all of the PWA showed the expected frequency effect. In general, these

results suggest that PWA may have more difficulty with reading than listening, possibly due to increased difficulty accessing words in the written modality.

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Tables and Figures

Table 1: Summary of Stimuli
High vs. Low Freq (mean: 143 vs. 1.35 per million)
Controlled for: 1.Words are equally unpredictable in sentence context 2.Word Length 3.Orthographic Neighborhood Density & Freq 4.Phonological Neighborhood Density & Freq 5.Phonotactic Probability (Biphone frequency) 6.Number of Syllables

Table 2: Sample Materials
Ralph / rested / in / **the village** / before he started / on his trip. (High Freq)
Ralph / rested / in / **the hammock** / before he started / on his trip. (Low Freq)
Comprehension Question: Did Ralph rest before his trip?

Table 3: Proportion Correct				
	Self-paced listening		Self-paced reading	
	High Freq	Low Freq	High Freq	Low Freq
People with aphasia	0.82	0.87	0.79	0.73
Controls	0.90	0.91	0.93	0.92