BACKGROUND

Real-time language processing research has shown that when a lexical item (e.g., a noun) is encountered in a sentence, its various properties, including its meaning(s), are activated. Activation decays as the sentence – and time – unfold, and the meaning component appears to disappear at approximately ½ second after the appearance of the noun (Swinney, 1982). In constructions that contain syntactic dependencies (i.e., anaphors, and displaced Noun Phrases), the noun is *re*-activated at the licensed position (e.g., at the anaphor or at the "gap") (Nicol, & Swinney, 2008**)**.

This typical time-course of activation – immediate access, decay, then re-access at particular syntactic positions – is not observed in studies exploring on-line language processing with individuals who have aphasia. Specifically, individuals with Broca's aphasia appear to show delayed activation of a noun's meanings during sentence processing. That is, lexical access does not appear to occur until approximately ½ second past the appearance of the noun, and this pattern has been observed using the cross-modal priming task (CMP; Love, et al., 2008) as well as with the visual-world eye tracking method (Thompson & Choy, 2009). Furthermore, in complex sentences that contain filler-gap dependencies, slowed *re*-access for Broca's aphasia is also observed: re-access of the displaced NP is not observed until well after the gap has been encountered (Love et al., 2008; Prather, et al., 1997). This latter finding suggests that the 'syntactic' comprehension disorder observed in Broca's aphasia might have its roots in a lexical access deficit; a slowed lexical activation system may result in lexical information "feeding" syntactic processing too slowly, leading to breakdowns of automatic structure-building and the particular syntactic deficits seen in Broca's aphasia.

There are at least two important considerations, essentially limitations, to the patterns described above. First, there has been no study that has investigated the time-course of initial activation with more than three probe positions, most having had two (ignoring, for the moment, eye tracking), and second, the bulk of the evidence in aphasia has come from investigations of complex filler-gap constructions, as described above. This combination yields the following questions that we address in the current study: 1) Does activation of a noun's meaning decay, and 2) if so, is this decay linear or is it non-linear and U-shaped, essentially showing reactivation in sentences without syntactic dependencies? These questions are critical to accounts of sentence processing (both in adults without brain damage and those with aphasia) for the following reason: Several studies have suggested that, through a process called 'integration', a word's meaning is merged into the context of the sentence (Cairns, et al., 1981; Swaab, et al., 1997); otherwise, during sentence processing we would have a series of individual and isolated word meanings. Yet, how does integration occur if the word's meaning decays quickly after the word is encountered?

To address these issues, we present a CMP study using simple active sentence constructions to map out the time course of lexical activation throughout a sentence in both college-age unimpaired listeners and language impaired agrammatic aphasics.

METHOD

Data from 58 unimpaired listeners (mean age=21.1, SD=3.4) were included. All unimpaired subjects were all right-handed, monolingual English speakers with no history of neurological disease. 7 agrammatic aphasic individuals completed testing. All aphasic subjects survived a single unilateral left hemisphere stroke, and were right handed, monolingual English speakers prior to stroke (demographic information summarized in **Table 1**).

In this experiment we used an on-line cross-modal picture priming (CMPP) task (e.g. Love, 2007; Swinney & Prather, 1989), with sentences presented at a normal rate of speech. The test items consisted of 40 experimental active sentences like the following:

The guide carried the student[1] *during* [2]*the ut*[3]*terly ex*[4]*hausting hike to the summit.*

Sentences were presented aurally over headphones, and participants were required to listen to the sentences for meaning while also making a decision on a picture probe. In this matched sentence CMPP study, participants made a binary (human/not human) decision to the visually presented pictures (visual probes). Two visual probe pictures were chosen for each sentence: a related visual probe represented the object of the first clause (*student*) and a control probe (*guitar player*) - that was unrelated to any lexical item in the test sentence, but was related to the object in another experimental sentence. Priming was measured by comparing response times to the related and control probes – faster response times to the related probes indicate a priming effect, thus activation of the lexical item.

In order to establish the time course of activation of the lexical item, a visual probe was presented at one of four positions during the ongoing auditory sentence (indicated approximately by superscript numerals in the example above), with the initial position occurring at the offset of the direct object noun (e.g., *student*), and with each of the three subsequent probe positions placed 400ms after the previous one (in other sentences; again, there was only one probe/sentence). Experimental sentences were designed so that there would be no other nouns presented that could potentially interfere with the priming pattern during this interval (another limitation of previous experiments). In addition to these experimental sentences, 60 filler sentences were created. Finally, there were an equal number of "yes" and "no" responses to the probes, reducing the possibility of expectations formed by the participants.

RESULTS

Only correct data were used in the analysis below (errors or reaction times below 300ms or above 1500ms [for controls] or 2000ms [for aphasics]). A priori paired one tailed t-test results for college-aged unimpaired listeners, illustrated in **Figure 1**, demonstrated priming at the offset of the noun at probe point one ($t_{30}=2.87$, $p=.0035$), which slowly tapered off throughout the probe positions 2, 3 and 4 ($p>.05$ for all 3 test points).

Results for agrammatic participants (see also **Figure 1**) demonstrated a protracted pattern whereby there was no evidence of priming at probe point one (PP1, $p>.05$); however, priming becomes evident 400ms later at PP2 ($t_6=2.11$, $p=.04$). Following this activation is a much more accelerated decay through PPs 3 and 4 ($p>.05$ for both test points).

DISCUSSION

The patterns of priming demonstrated in this study for our neurologically intact participants suggest initial activation of the direct object noun, and then decay across the next 1200ms. Given the issues we set up in our background, the decay does indeed appear to be linear and relatively gradual, and no re-activation appears in canonical constructions. Our participants with Broca's aphasia evinced a different pattern, with late initial activation and almost immediate decay. This protracted time-course for lexical access in Broca's aphasia corroborates what has been established in the literature (Love et al., 2008, and references therein). However, the immediate decay suggests subsequent difficulty with lexical integration. That is, the word's meaning might not be available to be integrated within the ongoing context and hence, we haven't observed an 'integration problem' per se' (see Thompson & Choy, 2009), but instead it is the late activation and fast decay that makes the lexical item unavailable for integration. We will entertain other possibilities for these patterns within our discussion.

REFERENCES

Cairns, H.S., Cowart, W., Jablon, A.D. (1981). Effects of prior context upon the integration of lexical information during sentence processing. *Journal of Verbal Learning and Verbal Behavior*, 20, 445-453.

Goodglass H, Kaplan E, Barresi B. (2000). *Boston Diagnostic Aphasia Examination-Third Edition (BDAE-3).* Psychological Corporation, San Antonio, TX.

Love, T. & Oster, E. (2002). On the categorization of aphasic typologies: The SOAP (a test of syntactic complexity). *Journal of Psycholinguistic Research*, 3, 5,503-529.

Love, T., Swinney, D., Walenski, M., & Zurif, E. (2008). How left inferior frontal cortex participates in syntactic processing: evidence from aphasia. *Brain and Language*. 107: 203-219.

Miller, J. & Chapman, R. (1998). *SALT: Systematic analysis of language transcripts, Windows versions 1.0-5.0.* Madison, WI: Language Analysis Laboratory. Waisman Center, University of Wisconsin.

Nicol, J. L. and Swinney, D. A. (2008). The Psycholinguistics of Anaphora. In A. Barss (Ed.), *Anaphora: A Reference Guide* . Blackwell Publishing Ltd, Malden, MA.

Prather, P. A., Zurif, E., Love, T., & Brownell, H. (1997). Speed of lexical activation in nonfluent Broca's aphasia and fluent Wernicke's aphasia. *Brain and Language*, *59*, 391-411.

Thompson, C.K. & Choy, J. J. (2009). Pronominal resolution and gap filling in agrammatic aphasia: Evidence from eye movements. *Journal of Psycholinguistic Research*, 38, 3, 255-283.

Swaab, T., Brown, C., Hagoort, P. (1997). Spoken sentence comprehension in aphasia: Event-related potential evidence for a lexical integration deficit. Journal of Cognitive Neuroscience, 9,1,39-66.

Swinney, D., & Prather, P. (1989). On the comprehension of lexical ambiguity by young children: Investigations into the development of mental modularity. In D. Gorfein (Ed.), Resolving semantic ambiguity (pp. 225–238). New York: Springer.

Swinney, D. (1982). The Structure and Time-Course of Information Interaction during Speech Comprehension: Lexical Segmentation, Access, and Interpretation. In Mehler, J., Walker, E.T.C., and Garrett, M. (Eds.) *Perspectives on Mental Representation,* Erlbaum Associates, Publishers, Hillsdale, N.J.

Table 1

Subject	Gender	Age (Yrs.)	Years Post CVA	Education (Yrs.)	SOAP (Canonical)	SOAP (Non-Canonical)	BDAE Severity
LHD009	M	49	9	17	65%	50%	3
LHD017	M	60	12	14	100%	90%	4
LHD019	F	60	15	12	90%	20%	2
LHD043	M	87	6	18	85%	60%	3
LHD101	M	61	3	21	80%	30%	2
LHD130	M	57	2	16	80%	55%	4
LHD135	F	81	1	17	95%	75%	1
Mean	(2_F;5M)	65	6.9	16.4	85%	54.3%	2.7
SD	0	13.7	5.3	2.9	11.5%	24.2%	1.1

Aphasia diagnosis was defined based on clinical consensus and performance on standardized aphasia assessment batteries (*Boston Diagnostic Aphasia Examination*, *3rd Edition* (BDAE-3), Goodglass,et al., 2000), non-standardized assessments of their offline comprehension measure of canonical and non-canonical sentence structure (*SOAP* , Love & Oster, 2002) and on analysis of spontaneous and structured language samples transcribed and analyzed using *SALT* (Miller & Chapman, 1998) software.

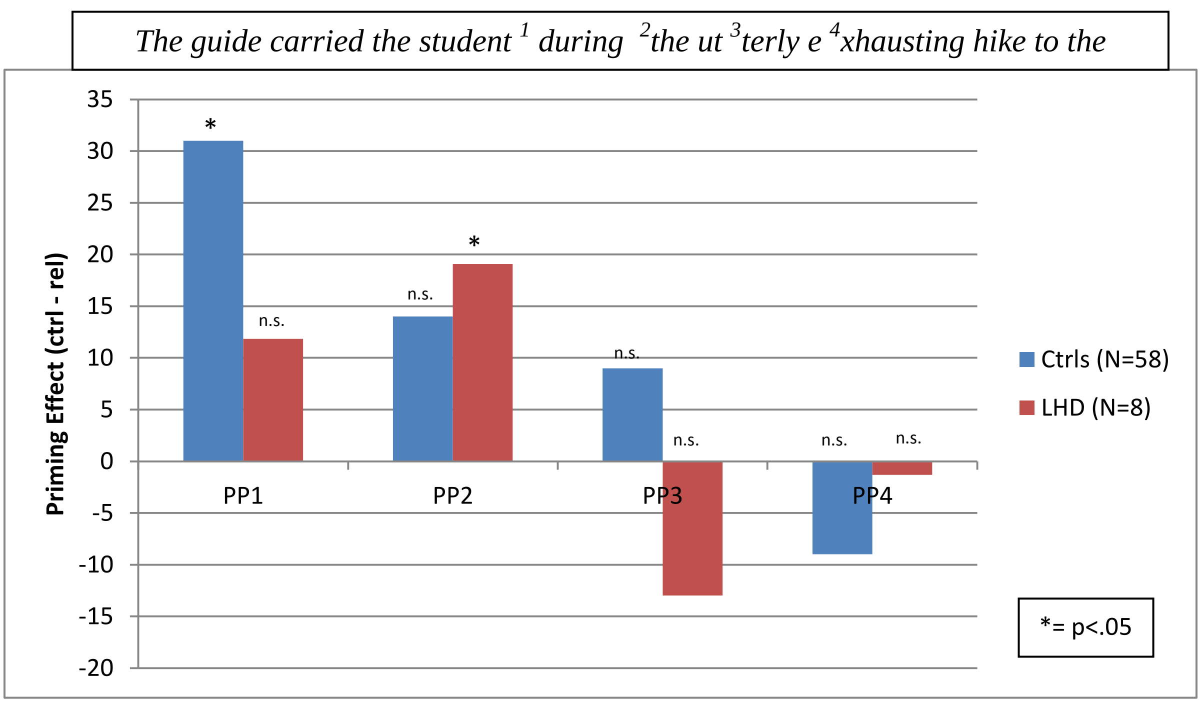

Figure 1. Priming effects for Unimpaired Controls and LHD patients.