Running head: PRODUCTION OF PROSODIC CUES BY BRAIN-DAMAGED PATIENTS

Use of Prosodic Cues in the Production of Idiomatic and Literal Sentences by Individuals with Right- and Left-Hemisphere Damage

Nathalie Bélanger, Shari R. Baum

School of Communication Sciences & Disorders, McGill University, and Centre for Research on Language, Mind and Brain, Montreal, Canada

&

Debra Titone

Department of Psychology, McGill University, and Centre for Research on Language, Mind and Brain, Montreal, Canada

Corresponding Author

Dr. Shari R. Baum

1266 Pine Avenue West

Montreal, Quebec, H3G 1A8, CANADA

shari.baum@mcgill.ca

TEL: 514-398-7385 FAX: 514-398-8123

(4996 words)

Abstract

The neural bases of prosody during the production of literal and idiomatic interpretations of literally plausible idioms was investigated. Left- and right-hemisphere-damaged participants and normal controls produced literal and idiomatic versions of idioms (*He hit the books*.) All groups modulated duration to distinguish the interpretations. LHD patients, however, showed typical speech timing difficulties. RHD patients did not differ from the normal controls. The results partially support a differential lateralization of prosodic cues in the two cerebral hemispheres (Van Lancker & Sidtis, 1992). Furthermore, extended final word lengthening appears to mark idiomaticity.

Keywords: Brain damage, Prosody, Speech production, Idiom processing

Prosody is a collection of suprasegmental cues conveyed in speech by the modulation of temporal and spectral cues to express affective or linguistic information (Robin, Tranel & Damasio, 1990). Several hypotheses on the neural bases of prosody, primarily based on prosodic perception research, have emerged (see Baum & Pell, 1999; Van Lancker Sidtis et al., 2006 for reviews). Van Lancker and Sidtis (1992) have proposed that the LH preferentially processes temporal prosodic cues (duration) and that the RH preferentially processes spectral prosodic cues (fundamental frequency). Conversely, Poeppel (2003; see also Zatorre & Belin, 2001) has argued that the LH preferentially processes fast-changing parameters (voice onset time, etc), whereas the RH processes slow-changing acoustic parameters (sentence intonation, etc). Finally, Gandour and colleagues (2003) suggest that the LH and RH preferentially process acoustic prosodic parameters over linguistic units of variable lengths, rather than absolute time windows. Thus, the short prosodic domain (LH) may span over a syllable or a word, and the long domain (RH) may span across a phrase or sentence (Gandour et al., 2003; Baum & Dwivedi, 2003; Shah, Baum & Dwivedi, 2006).

Van Lancker and colleagues (Van Lancker, Canter & Terbeek, 1981) explored the use of prosodic cues in the disambiguation of literal and idiomatic meanings of literally plausible idioms in non-brain-damaged adults. Compared to their idiomatic counterparts, the literal versions of idiomatic phrases were produced with longer phrase durations, longer pauses between words and more rapid changes in F0 within words and phrases. This pattern held only if the speakers were instructed to emphasize the contrast between the two possible interpretations. Furthermore, individual content words of an idiomatic sentence produced in its literal sense were also longer than when produced with an intended idiomatic meaning. Van Lancker et al. (1981) suggested that medial words within an utterance have a special role in differentiating literal and idiomatic meanings of the spoken utterances. Overall, the results suggest that both temporal and spectral (F0) cues are used to distinguish literal and

idiomatic meanings of idiomatic phrases, at least when the speakers are encouraged to highlight the distinction. Van Lancker et al. (1981) suggested that the patterns of use of prosodic cues followed the structure of idioms and their literal counterparts, with idioms treated as holistic units, in contrast to literal interpretations, which were formed of several constituents containing their "usual lexical content-meaning" (p.334).

The main goal of the present research was to investigate the use of prosodic cues (duration and F0) in idiom production by brain-damaged individuals to distinguish literal from idiomatic interpretations of literally plausible idioms. To that end, the current study required left-hemisphere and right-hemisphere damaged patients and non-brain-damaged controls to produce both meanings (idiomatic and literal) of literally plausible idioms. However, to better control for the role of the medial word within the idiomatic sentences (as proposed by Van Lancker et al., 1981), the semantic decomposability (i.e. the degree to which the figurative meaning relates to the meaning of individuals words within the idiom) of the idioms was controlled and the medial word was always of the same grammatical category. There were four decomposability categories and all idioms were "(s)he verbed x noun" idioms, where "x" can be either an article, a preposition or a determiner and where either the noun or the verb (or both) contributed (or not) to the idiom's decomposability: 1) Noun and Verb High (*NVH*), 2) Noun and Verb Low (*NVL*), 3) Noun High (*NH*), and 4) Verb High (*VH* – see *Supplementary Materials* for the complete stimulus set).

For the present study, based on Van Lancker et al.'s (1981) results, we predicted that the same pattern of results for temporal measures would emerge for the non-brain-damaged participants (i.e., longer words and phrases in the literal versions of the stimuli). However, contrary to Van Lancker et al. (1981), who suggest that all idioms are treated as single lexical units, semantic decomposability of idioms was expected to interact with the production of the relevant prosodic cues such that differences

may emerge across idiom types with respect to individual content words within the idioms (Cutting & Bock, 1997; Titone & Connine, 1999).

As for the brain-damaged participants, in accordance with Gandour et al.'s (2003) cue-dependent hypothesis in which lateralization of function is partly dependent on the length of the prosodic or linguistic unit, one might hypothesize that if idioms are produced as a single lexical unit, LHD participants will have more difficulty than RHD and normal controls to produce a distinction between the literal and idiomatic meanings of idioms. In this case, the LHD participants' pattern of prosodic cues may differ according to the decomposability of the idioms (decomposable–NVH, NH, VH– versus non-decomposable–NVL). Alternatively, if idioms are represented and produced as sentences with internal syntactic and semantic structure (Cutting & Bock, 1997; Libben & Titone, 2008), then RHD participants may be at a disadvantage and have difficulty in producing the required prosodic cues to distinguish the literal and idiomatic meanings of idioms since the prosodic cues may span longer units within the sentences. Again, differential prosodic productions may be found across decomposability categories. Following Van Lancker and Sidtis' (1992) cue-dependent hypothesis, however, LHD individuals are expected to have a general problem controlling speech timing in their productions (see also Baum & Boyczuk, 1999; Danly & Shapiro, 1982; Gandour et al., 1994; Gandour, et al., 2000) and therefore may not be able to distinguish literal from idiomatic interpretations on the basis of temporal cues. Whether the RHD participants will have difficulty with the control of F0 is unclear, given mixed evidence about the lateralization of F0 (Baum & Pell, 1997; Pell, 1999; Schirmer et al., 2001; but see Danly & Shapiro, 1982; Van Lancker & Sidtis, 1992).

Methods

Participants

Participants were 6 individuals with left hemisphere lesions (LHD), 5 individuals with right hemisphere lesions (RHD), and 10 age- and education-matched non-brain-damaged individuals (NC), all of whom were native speakers of English. The brain-damaged patients had suffered a single unilateral lesion due to stroke at least four months prior to testing. Background information on the participants is available as *Supplementary Materials* (Table 1).

All patients underwent an extensive screening battery: auditory sentence comprehension test, auditory digit span test, auditory working memory test, spoken word-picture matching test, written word-picture matching test, the *Discourse Comprehension Test* (Brookshire & Nicholas, 1993), and the *Behavioural Inattention Test* (Wilson, Cockburn & Halligan, 1987). The LHD patients were administered sections of the *Boston Diagnostic Aphasia Examination* (Goodglass & Kaplan, 1983) and the *Boston Naming Test* (Kaplan, Goodglass & Weintraub, 1983) to better determine their verbal expression abilities. The RHD patients were administered the *Emotional Prosody Battery* (Baum & Pell, 1997) and sections of the *Test of Language Competence Expanded Edition* (Wiig & Secord, 1989) to evaluate their ability to draw inferences and to understand idiomatic language. The results of selected tests for the LHD and RHD participants are available as *Supplementary Materials* (Table 2).

Stimuli

Libben and Titone (2008) conducted a large scale rating study on 219 English idioms for verb and noun decomposability (and other factors). The results of such ratings were used to isolate 32 literally-plausible idioms, which were grouped into four categories according to the degree to which the noun or verb contributed to the semantic decomposability of the idiom: (1) Noun High (NH - e.g.: *He walked a tight-rope*.), (2) Verb High (VH – e.g.: *She rocked the boat*.), (3) Noun and Verb High (NVH – e.g.: *She covered her tracks*.), and (4) Noun and Verb Low (NVL – e.g.: *It hit the spot*.). The idioms were also controlled for dimensions such as familiarity and predictability of the idiom-final noun

(Libben & Titone, 2008). The nouns and verbs within each idiom did not differ across decomposability conditions in terms of number of segments or number of syllables.

For each idiom, two contexts were developed. For the phrase "He hit the books", one context lead to the idiomatic interpretation (Mike's exam was the next day, and he hadn't studied all semester.) and one context lead to the literal interpretation (Frank was walking through the library when he tripped and fell.) The figurative and literal contexts along with the related experimental sentence were presented on one page (one set per page) and were printed in large font with the target sentence to be produced in bold characters.

Procedure

Participants were informed that the target phrases had two possible interpretations. The order of presentation of the sentence pairs was counterbalanced across the four semantic decomposability classes. Participants were instructed to read both context sentences silently and then to read the target phrase aloud twice, once in its idiomatic interpretation and once in its literal interpretation (always in this order to minimize confusion), ensuring that they communicated the intended interpretation as best they could. All the brain-damaged participants had mild deficits and good comprehension skills (see Table 2 in *Supplementary Materials*), therefore it was not expected that they would have difficulty performing the task.

Recordings were made in a quiet room using a head-mounted AKG Acoustics C420 directional microphone to ensure a constant microphone-to-mouth distance.

Acoustic analyses

To assess temporal cues, the duration of each target sentence was first calculated. The durations of the two content words (verb and noun) were then measured using standard landmarks. To assess spectral cues, F0 contours were extracted for each sentence, with a mean F0 and range (max-min

F0) computed for the entire phrase from these values. A peak F0 value for each content word was also computed by isolating three glottal pulses at the peak of the vocalic nucleus (generally near the midpoint) and computing the period, and from that, the F0.

Data analyses

To normalize for gender differences in speakers' F0 and for high within- and between-subject variability in sentence duration, noun/verb ratios (i.e. the two content words within the sentences) were computed. Within the sentences, the nouns were always sentence-final; they were therefore always longer than the verbs, yielding noun/verb duration ratios that were above one. Conversely, because of F0 declination across sentences, F0 was always higher for verbs than for nouns, resulting in noun/verb F0 ratios that were always below one. F0 range values were also analyzed but were first normalized by dividing the F0 range (maxF0 - minF0) by mean F0 for each sentence for each participant so that changes in mean F0 across participants would not influence the findings.

Separate repeated-measures ANOVAs (by subjects [F_1] and items [F_2]) were conducted for the duration ratios, the F0 ratios and for the F0 range values with Group (LHD, RHD, NC) as a between-subjects variable and Sentence Type (Literal, Idiomatic) and Decomposability (NH, VH, NVH, NVL) as within-subjects factors.

Results

Temporal Cue Analyses

As expected, the LHD participants took longer to produce the sentences than the RHD and NC participants (NC: M = 1158 ms, SD = 137 ms; RHD: M = 1095 ms, SD = 99 ms; LHD: M = 1837 ms, SD = 469 ms). Five out of six LHD participants showed this pattern.

For the noun/verb duration ratios, statistical analyses yielded significant main effects for Group ($F_1(2, 18) = 5.37$, p = .01; $F_2(2, 64) = 27.92$, p = .0001), and Decomposability ($F_1(3,54) = 35.95$, p =

.0001; $F_2(3, 32) = 39{,}90$, p = .0001). A Sentence Type effect was also found, ($F_1(1, 18) = 10.17$, p = .005; $F_2(1, 32) = 16.76$, p = .0003), indicating that participants were able to distinguish literal from idiomatic productions of idiomatic sentences using temporal cues. This effect is seen in Figure 1, where the noun/verb ratio for idiomatic productions is always higher than the ratio for literal productions.

[Insert Figure 1 about here]

This indicates that in the idiomatic condition, there is a greater length difference between nouns and verbs than in the literal condition. Figure 2 unpacks the noun/verb ratios and shows, for each group, the mean length of nouns and verbs when they were produced within an idiomatic or a literal sentence. As can be seen clearly in this figure, nouns were always longer than verbs whether produced within an idiomatic or literal sentence. However, what is also clearly shown is that nouns produced within the idiomatic sentences are always longer (by 26 ms) than when produced within a literal sentence. Verbs, on the other hand, barely differ in length when produced within an idiomatic sentence or a literal sentence (2 ms difference). This is true for all three groups of participants. The Group x Decomposability interaction was significant in the subjects analysis only ($F_1(6, 54) = 2.48$, p = .03; $F_2(6, 64) = 1.50$, p = .2). No other interactions reached significance.

Scheffe's *post hoc* test was used to investigate the significant main effects of Group and Decomposability. The *post hoc* test for Group revealed that the LHD patients differed significantly from the NC participants (p = .02), but not from the individuals with RHD (p = .63). The RHD and NC groups did not significantly differ from each other either (p = .19). The mean noun/verb duration ratios for the NC, RHD and LHD groups were 1.58, 1.43 and 1.35 respectively. A smaller difference between the lengths of nouns and verbs in the LHD patients was striking, although the difference between the RHD and LHD groups did not reach significance. The *post hoc* test for Decomposability showed that the noun/verb ratios for the NH condition (NH = 1.70) was significantly higher than that of the other

three conditions (NVH = 1.46, p = .0001; NVL = 1.46, p = .0001; VH = 1.31, p = .0001), indicating that in the NH condition the difference between the lengths of the verbs and nouns was much larger than in the other conditions. The ratio for the VH condition was also significantly lower than all other conditions (NVH – p = .0006; NVL – p = .0004; NH – p = .0001) indicating that in this condition, the difference between the lengths of the verbs and nouns was much smaller than in the other conditions.

F0 and Pitch Range analyses

The analysis of noun/verb F0 ratios yielded few robust effects. A main effect of Decomposability was found, but only in the subjects analysis ($F_1(3, 54) = 3.84$, p = .01; $F_2(3, 32) = 0.89$, p = .4). There was a Group effect which was significant in the items analysis only ($F_1(2, 18) = 1.26$, p = .3; $F_2(2, 64) = 4.092$, p = .02). Finally, there was an effect of Sentence Type, which was, again, only significant in the items analysis ($F_1(1, 18) = .95$, p = .3; $F_2(1, 32) = 4.14$, p = .05). Noun/verb F0 ratios in literal sentences were somewhat lower than in idiomatic sentences, indicating that the F0 difference between nouns and verbs was larger (i.e.: a larger denominator yields a smaller ratio) in the literal versions of the sentences. No other significant effects emerged. The F0 range analyses yielded no significant effects.

Discussion

The findings of the present study show that all three groups are able to distinguish literal and idiomatic sentence interpretations using temporal prosodic cues. Left- and right-hemisphere-damaged patients were able to disambiguate semantically ambiguous sentences by modulating, in a relatively normal manner, the acoustic cues necessary to distinguish both types of sentences that were presented to them. Although sample sizes for the brain-damaged participant groups were small, this finding is consistent with previous production studies investigating the use of prosodic cues to distinguish ambiguities at the sentence level (linguistic versus emotional prosody, or syntactic ambiguities), where results have

shown that both left- and right-hemisphere-damaged participants had fairly normal control over their production of prosodic cues (Baum & Pell, 1997; Baum, Pell, Leonard & Gordon, 2001; Shah et al., 2006).

The robust idiomaticity effect in the present study was reflected differently in the lengths of nouns and verbs, with nouns in the idiomatic productions much longer than nouns in the literal productions, whereas verbs in both types of productions were of relatively equal length[1]. The effect, however, appears not to be due to the semantics of the noun per se, or rather the noun's semantic contribution to the idiomatic meaning, as there was no Sentence Type x Decomposability effect. The effect cannot be related to an uncontrolled factor (e.g., frequency or word length differences) as the final noun was always the same across idiomatic and literal productions of the same idiom. It may simply be that the effect is related to the position of the noun and that extended final word lengthening serves as a specific marker of idiomaticity.

Similar to Van Lancker et al.'s study, the present results suggest that "individual word durations may serve as cues for signalling literal/idiomatic meaning" (Van Lancker et al., 1981; p. 333). In the present study, the effect is actually the opposite of what Van Lancker et al. (1981) found (i.e., in their study, medial words were shorter in the idiomatic than the literal productions). However, there are marked differences between the studies which may explain the inconsistent patterns of results. First, the results of Van Lancker et al.'s (1981) study were based on the utterances of only two speakers. Second, and more important, in the present study, there was greater control of the structure of the idioms

[1] One reviewer suggested that the effect could be due to the fact that idiomatic sentences were always produced first. Although this cannot be ruled out completely, we believe that the idiomaticity effect is not likely due to order of presentation as the participants were presented with both versions before being specifically instructed to focus on the meaning of the sentences and asked to distinguish them according to their literal/idiomatic interpretations.

presented to the participants. Verbs and nouns were matched for number of segments and number of syllables across conditions. Furthermore, medial words were always verbs and final words, nouns. Finally, the semantic decomposability of nouns and verbs relative to the idiomatic meaning of the whole utterance was controlled.

Despite the ability of both groups of brain-damaged participants to distinguish the literal and idiomatic versions of idioms, there were differences among the groups. The LHD participants showed speech timing difficulties, as expected for this population (Baum, 1992; Danly & Shapiro, 1982; Gandour et al., 1994; Strand & McNeil, 1996) and produced longer sentences overall than the RHD and NC groups, who produced sentences with comparable overall lengths. Of course, given the small number of participants in each group, the absence of a difference must be interpreted with caution. For the LHD group, however, the group difference is also found in the noun/verb duration ratio analyses. Furthermore, there was more within-group variability in the individuals with LHD. In keeping with expectations based on the robustness of the phrase-final lengthening phenomenon in speech production (Oller, 1973), final nouns were always longer than phrase-internal verbs for all groups. However, the overall noun/verb ratio for the LHD patients was smaller than those of the NC and RHD groups, indicating that verbs and nouns did not differ in length as much for the LHD group compared to the other participant groups. These results are consistent with previous research suggesting that left-hemisphere damaged patients show a reduced sentence-final lengthening effect relative to other speakers (Baum & Boyczuk, 1999; Baum et al., 1997; Baum et al., 2001; Shapiro & Danly, 1985). Additionally, an inspection of individual patterns of results for the RHD participants showed that only 2/5 did not clearly contrast literal from idiomatic interpretations using temporal prosodic cues. These two RHD participants were two of the three RHD participants who performed at chance level in the *Figurative Language Comprehension Test* (RHD 3 and 4; Table 2 - *Supplementary Materials*). The

third participant (RHD 5) showed a large difference in the ratios between literal and idiomatic sentences produced, indicating that despite poor comprehension in the figurative language test, this participant was able to modulate temporal cues to distinguish both types of sentences. The noun/verb F0 ratio and the F0 range analyses yielded no robust findings.

With respect to the neural processing of idioms, the most accepted view about the hemispheric lateralization of idiom processing is that the RH is responsible for processing idiomatic language (see Van Lancker Sidtis, 2006 for a review). However, recent findings also underline the left-hemisphere's contribution to the processing of idioms (Papagno, Tabossi, Colombo & Zampetti, 2004; Papagno, Curti, Rizzo, Crippa & Colombo, 2006). In the present study, despite the fact that 3/5 RHD patients had low scores in the idiomatic language comprehension screening test (Table 2 - *Supplemental Materials*), they did not differ from the NC participants on any of the measures of prosodic realization, suggesting that RHD in these individuals did not disrupt the use of prosodic cues during idiom production. Recall, of course, that all the brain-damaged participants in the present study had fairly mild deficits. Although the LHD participants did exhibit some impairments, they were in keeping with a general deficit in temporal control, not necessarily specific to idiom processing. It should be borne in mind that the majority of data that have addressed idiom processing come from comprehension studies and not production analyses. Thus, although the present results are not entirely in keeping with either a RH or LH control of idiom processing, the nature of the task may not permit us to directly address these hypotheses.

With regard to the neural basis of prosody, previous studies investigating prosodic production have pointed to the recruitment of frontal brain regions (Mayer, Wildgruber, Riecker, Dogil, Ackermann & Dogil, 2002; Meyer, Steinhauer, Alter, Friederici, von Cramon, 2004). Mayer et al. (2002) showed that when neurologically intact participants produced reiterant syllables (*dadadada*)

with various superimposed prosodic contours (reflecting linguistic or emotional prosody), frontal regions (mainly the inferior frontal gyrus - IFG) were activated in the left hemisphere for linguistically-based prosody and in the right hemisphere for emotional prosody. Similarly, Meyer et al. (2004) found activation in the IFG, but also in the inferior precentral sulcus (IFPS) and in the central sulcus (CS) related to production of spectral prosodic cues (although the participants only performed silent rehearsal of prosodic patterns). These authors suggest that the production of prosodic information arises from the activation of a fronto-lateral neural network involving the IFG, IFPS and CS in the left hemisphere. In the present experiment, three LHD participants had frontal or frontal-parietal lesions (LHD 2, 4 and 5; Table 1 - *Supplemental Materials*). Although we cannot address in detail the proposed left hemisphere frontal neural network for prosodic production (Meyer et al, 2004) it is interesting to note that when it came to produce a distinction between literal and idiomatic sentences, only the three participants with frontal lesions were able use F0 cues to do so (the Meyer et al. study specifically refers to spectral cues). Although this does not make a strong case, the fact that these three participants were able to use the appropriate spectral cues to distinguish literal from idiomatic sentences is not in keeping with the frontal networks posited in these fMRI studies (Meyer et al., 2004; Mayer et al., 2002). Indeed, these three LHD participants should have been the ones having difficulty using prosodic cues to contrast literal from idiomatic sentences. Although one must, of course, be cautious about the interpretation of data from brain-damaged patients due to possible neural reorganization (Mayer et al., 2002) and our lesion data are limited, it is interesting to note the contrasting findings.

Taken together, the present findings suggest that despite inconsistent patterns of results between Van Lancker et al.'s (1981) study and the present experiment, both demonstrate the use of temporal cues when emphasis on distinguishing literal from idiomatic interpretations is required. The results of

the present study, including a larger number participants and closely controlled stimuli, show that one of these cues - extended sentence final lengthening - stands out as a cue to signal the idiomaticity of sentences. Interestingly, both brain-damaged participant groups were able to distinguish idiomatic from literal sentences using temporal prosodic cues. However, the LHD patients were still found to have more difficulty than both other participant groups in the control of temporal prosodic cues at the word and sentence levels. The results are in keeping with the claim that the LH preferentially processes temporal cues (e.g., Van Lancker & Sidtis, 1992).

Acknowledgements

We are grateful to Ms. Erin Vensel for assistance with testing and analysis. This study was funded by a grant to S.R. Baum from the Canadian Institutes of Health Research (CIHR - MT11290).

References

Baum, S. R. (1992). The influence of word length on syllable duration in aphasia: Acoustic analyses. *Aphasiology, 6*(5), 501–513.

Baum, S. R., & Boyczuk, J. (1999). Speech timing subsequent to brain damage: Effects of utterance length and complexity. *Brain and Language, 67*, 30–45.

Baum, S. R., & Dwivedi, V. (2003). Sensitivity to prosodic structure in left and right-hemisphere-damaged individuals. *Brain and Language, 87*, 278–289.

Baum, S. R., & Pell, M. D. (1997). Production of affective and linguistic prosody by brain-damaged patients. *Aphasiology, 11*, 177–198.

Baum, S. R., & Pell, M. D. (1999). The neural bases of prosody: Insights from lesion studies and neuroimaging. *Aphasiology, 13*(8), 581–608.

Baum, S. R., Pell, M. D., Leonard, C. L., & Gordon, J. K. (1997). The ability of right- and left-hemisphere-damaged individuals to produce and interpret prosodic cues marking phrasal boundaries. *Language and Speech, 40*(4), 313–330.

Baum, S. R., Pell, M., Leonard, C., & Gordon, J. (2001). Using prosody to resolve temporary syntactic ambiguities in speech production: Acoustic data on brain-damaged speakers. *Clinical Linguistics and Phonetics, 15*, 441–456.

Brookshire, R. H., & Nicholas, L. E. (1993). *The Discourse Comprehension Test*. Tucson, AZ: Communication Skill Builders, A Division of The Psychological Corporation.

Cutting, J. C., & Bock, J. K. (1997). That's the way the cookie bounces: Syntactic and semantic components of experimentally elicited idiomatic blends. *Memory & Cognition, 25*, 57-71.

Danly, M., & Shapiro, B. (1982). Speech prosody in Broca's aphasia. *Brain and Language, 16*(2), 171–190.

Gandour, J., Dechongkit, S., Ponglorpisit, S., & Khunadorn, F. (1994). Speech timing at the sentence level in Thai after unilateral brain damage. *Brain and Language, 46*, 419–438.

Gandour, J., Dzemidzic, M., Wong, D., Lowe, M., Tong, Y., Hsieh, L., et al. (2003). Temporal integration of speech prosody is shaped by language experience: An fMRI study. *Brain and Language, 84*, 318– 336.

Goodglass, H., & Kaplan, E. (1983). The assessment of aphasia and related disorders, (2nd ed.). Philadelphia: Lea and Febiger.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). The Boston Naming Test. Philadelphia: Lea and Febiger.

Libben, M., & Titone, D. (2008). The multidetermined nature of idiom processing. *Memory & Cognition*, *36*(6), 1103-1121.

Mayer, J., Wildgruber, D., Riecker, A., Dogil, G., Ackermann, H., & Grodd, W. (2002). Prosody production and perception: converging evidence from fMRI studies, In *SP-2002*, 487-490.

Mertus, J., 1989. *BLISS user's manual*. Providence, RI: Brown University.

Meyer, M., Steinhauer K., Alter, K., Friederici, A.D., & von Cramon, D.Y. (2004). Brain activity varies with modulation of dynamic pitch variance in sentence melody. *Brain and Language, 89*, 277–289.

Oller, D. (1973). The effect of position in utterance on speech segment duration in English. *Journal of the Acoustical Society of America, 54*, 1235–1247.

Papagno, C., Tabossi, P., Colombo, M., & Zampetti, P. (2004). Idiom comprehension in aphasia. *Brain and Language, 89*, 226–234.

Papagno C, Curti R, Rizzo S, Crippa F, Colombo MR. (2006). Is the right hemisphere involved in idiom comprehension? A neuropsychological study. *Neuropsychology*. *20*, 598--606.

Poeppel, D. (2003). The analysis of speech in different temporal integration windows: Cerebral lateralization as asymmetric sampling in time. *Speech Communication, 41*, 245–255.

Robin, D. A., Tranel, D. & Damasio, H. (1990). Auditory perception of temporal and spectral events in patients with focal left and right cerebral lesions. *Brain and Language*, 39, 539-555.

Ryalls, J. H. (1982). Intonation in Broca's aphasia. *Neuropsychologia, 20*(3), 355–360.

Shah, A., Baum, S.R. & Dwivedi, V.D. (2006). Neural substrates of linguistic prosody: Evidence from syntactic disambiguation in the productions of brain-damaged patients. *Brain and Language, 96*(1), 78-89.

Shapiro, B., & Danly, M. (1985). The role of the right hemisphere in the control of speech prosody in propositional and affective contexts. *Brain and Language, 25*(1), 19–36.

Strand, E., & McNeil, M. (1996). Effects of length and linguistic complexity on temporal acoustic measures in apraxia of speech. *Journal of Speech and Hearing Research, 39***,** 1018–1033.

Titone, D. A., & Connine, C. M. (1999). On the compositional and noncompositional nature of idiomatic expressions. *Journal of Pragmatics, 31*, 1655–1674.

Van Lancker Sidtis, D. (2006). Where in the brain is nonliteral language? *Metaphor and Symbol, 21*, 213–244.

Van Lancker, D., & Sidtis, J. J. (1992). The identification of affective-prosodic stimuli by left- and right-hemisphere-damaged subjects: all errors are not created equal. *Journal of Speech and Hearing Research, 35*, 963–970.

Van Lancker, D., Canter, G., & Terbeek, D. (1981). Disambiguation of ditropic sentences, *Journal of Speech and Hearing Research , 24,* 330-335.

Van Lancker Sidtis, D., Pachana, N., Cummings, J. L., & Sidtis, J. J. (2006). Dysprosodic speech following basal ganglia insult: Toward a conceptual framework for the study of the cerebral representation of prosody. *Brain and Language*, *97*, 135–153.

Wiig, E.H., & Secord, W. 1989: *Test of language competence – expanded edition*. San Antonio, TX: The Psychological Corporation.

Wilson, B. A., Cockburn, J., & Halligan, P. (1987). *Behavioural inattention test*. Titchfield, Fareham, Hants, England: Thames Valley Test Co.: National Rehabilitative Services.

Zatorre, R. J., & Belin, P. (2001). Spectral and temporal processing in human auditory cortex. *Cerebral Cortex, 11*, 946–953.

Figure Captions

Figure 1. Noun/verb duration ratios and standard error bars as a function of Group for each Sentence Type by Decomposability combination.

Figure 2. Mean raw noun and verb durations as a function of Group and Sentence Type (idiomatic or literal) in which they were produced.