Published in final edited form as:

Aphasiology. 2014 ; 28(7): 823–839. doi:10.1080/02687038.2014.913769.

What matters in semantic feature processing for persons with stroke-aphasia: Evidence from an auditory concept-feature verification task

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Abstract

Background—The relationship between object concept domains (living vs. nonliving) and their underlying feature structures is a frequent area of investigation regarding semantic processing in healthy individuals and some individuals with neuropsychological impairment resulting from herpes simplex encephalitis, semantic dementia and Alzheimer's disease. However, this relationship has been less well-investigated in persons with stroke-aphasia (PWA), even though many treatments for anomia following stroke are predicated on the use of semantic feature cues.

Aims—As part of a larger investigation into the influence of semantic feature processing on naming for PWA, this study examined the ability of PWA to confirm the relations between object concepts and associated semantic features.

Methods & Procedures—15 native English-speaking, right handed individuals with post-stroke-aphasia responded yes or no via button press to feature-verification questions designed to probe the relationships between concept domain and feature type and distinctiveness.

Outcomes & Results—PWA were more accurate and quicker to confirm concept-feature relationships when features contained function/action, rather than visual-perceptual, information about concepts and when features were distinctive to concepts rather than shared. The truthfulness (i.e., veracity) of concept-feature pairings was demonstrated to differentially affect living versus nonliving concepts. Within domain, only nonliving concepts were verified more accurately and more quickly when pairings were true (rather than false). Between domains, true nonliving concept-feature pairings were more accurately and more quickly verified than true living concept-feature pairings. Also with respect to veracity, correlations were observed between aphasia severity and accuracy and speed of response to false concept-feature pairings.

Conclusions—Findings have implications for the way in which semantic processing is probed with PWA, as well as providing preliminary information regarding responsivity of PWA to differing types of semantic information for living versus nonliving concepts. The fact that PWA demonstrated disproportionate difficulty responding to certain types of semantic information also suggests preliminary implications for the utility of different types of semantic cues in semantically-based treatments for word retrieval impairment.

Keywords

semantic domain; feature type; feature distinctiveness; veracity

One of the more frequently observed findings in individuals who demonstrate impaired semantically-guided lexical retrieval is disproportionate impairment between concept domains. With respect to concrete objects, disproportionate impairment to processing of living concepts (e.g., animals) has been more frequently documented than that of nonliving concepts (e.g., tools), though both profiles have been observed (Capitani et al., 2003). Most theories of semantic organization contend that concepts' meanings are composed from their underlying feature structures (Cree & McRae, 2003), such that domain-based differences emerge as a result of interaction among factors related to their component features. Information type (e.g., function/action vs. visual-perceptual) has been one of the more frequently examined, with the interaction among feature-types and domains informing the development of sensory-motor-based hypotheses (e.g., Gainotti, 2006; Martin, Ungerleider, & Haxby, 2000). Feature distinctiveness (e.g., shared vs. distinctive) has also been examined, particularly with respect to how the relative strength of association among shared versus distinctive features for living and nonliving domains may render them more or less vulnerable to deficit in cases of neurogenic impairment (Tyler et al., 2000). As part of a larger study, we are examining these interactions in individuals with stroke-aphasia, a population that is less frequently investigated with respect to these questions; a surprising gap in the literature considering the prevalence of semantically-based treatments for naming impairment in these individuals. The purpose of the current paper is to examine theories of semantic processing that informed development of an assessment of semantic feature processing for individuals with stroke-aphasia and to determine how performance on this assessment may inform theory and clinical practice.

Feature-based theories of disproportionate impairments to living versus nonliving concepts: Information type and Distinctiveness

The influence of information Type: Behavioral findings

The seminal work of Warrington and Shallice (1984) was one of the earliest documentations of a feature-based account of disproportionate impairment for processing of living relative to nonliving concepts. The authors documented poorer performance for living concepts in both identification and naming tasks and posited a dichotomous relationship wherein impairment for processing of living concepts emerged from deficient processing of visual-perceptual semantic feature information, which was considered more salient for distinguishing among living concepts. In subsequent publications, Warrington and colleagues demonstrated the double-dissociation, documenting the reverse profile, i.e., disproportionate impairment to small, manipulable nonliving concepts (Warrington and McCarthy, 1987). They also proposed finer-grained associations among categories of living and nonliving concepts and the sensory/motor "information channels" that might be most salient for their differentiation (Warrington & McCarthy, 1987, pp. 1291-1292). For example, the authors propose that within the domain of living concepts, while visual-perceptual features are salient as a

general characteristic, fruits might be better distinguished by visual-color, whereas flowers might be better distinguished by visual-shape. Furthermore, within the domain of nonliving concepts, it is suggested that fine-motor movements associated with the hand might be particularly salient for small, manipulable object-concepts (e.g., pen), but less so for large, nonmanipulable nonliving object-concepts (e.g., vehicles) (Warrington & McCarthy, 1987, p. 1291). Since that time, the question of how sensory/motor feature processing influences naming ability has been extensively examined via behavioral and neuroimaging work with individuals with and without brain injury, providing evidence of associations among finer-grained categories (e.g., animals vs. fruit; manipulable vs. non-manipulable nonliving concepts) and feature information types (e.g., visual-color vs. visual-shape; action vs. function) (reviews e.g., Antonucci & Alt, 2011; Gainotti, 2006; Martin, 2007).

The influence of information Type: Neuroanatomical findings

In addition to predictions regarding concept/feature interactions, it also has been proposed that brain regions serving as the neuroanatomical substrates for processing of sensory-motor-based semantic features are adjacent to regions responsible for processing the relevant sensory (e.g., visual-form, visual-color) information and motor movements (e.g., hand movements for associated with manipulating small objects). Again, evidence supporting these predictions has been documented via functional imaging with healthy controls (Keifer, 2001; Keifer, Sim, Liebich, Hauk, & Tanaka, 2007; Martin & Chao, 2001; Thompson-Schill, 2003) and in neuropsychological populations demonstrating disproportionate domain-and/or feature-based impairment following lesion to the implicated brain regions (e.g., CVA: Antonucci et al., 2008; Buxbaum, Veramonti, & Schwartz, 2000; Buxbaum & Saffran, 2002; Semantic dementia: Lambon Ralph et al., 1999; 2003; Herpes Simplex Encephalitis: Gainotti & Silveri, 1996; Warrington & Shallice, 1984).

The influence of distinctiveness (distinctiveness)—Another characteristic of semantic feature processing that has been investigated with respect to domain-based differential impairment is that of feature distinctiveness, which refers to the likelihood that a particular feature will differentiate members of the same category. For example, as stated above, visual-perceptual features may be considered particularly salient for distinguishing among living concepts. However, some features are more distinguishing (or distinctive) than others. The feature ‘has four legs’ is not particularly helpful in distinguishing between mammals, as most mammals share this feature. Conversely, the feature ‘has black and white stripes’ would likely serve to distinguish (i.e., be distinctive to) the zebra from most other mammals. In part as a response to the body of evidence contradicting the predictions of early formulations of sensory/motor-based theories, Tyler and her colleagues incorporated the influence of distinctiveness in their proposal the *Conceptual Structure Account*, in which domain-based differential impairments emerged due to differences in strengths of association among features for different concept domains (Tyler, Moss, Durrant-Peatfield, & Levy, 2000). Specifically, Tyler and colleagues proposed that living concepts have a stronger form-function correlation between features shared by many concept category members (e.g., has eyes-can see, has legs-can walk) whereas nonliving concepts’ form-function relationships are stronger for more distinctive or distinguishing features (e.g., fork: has tines, used for spearing) (Tyler et al, 2000, p. 201). Relative to the effect these differences have on

vulnerability of semantic categories, it was proposed that living concepts would be more vulnerable to deficit as lesion to their more distinguishing (visual-perceptual) features would not be offset by strong correlation with other feature types. Such deficits would have a particularly debilitating effect in tasks in which retrieval of distinguishing information is required (e.g., naming, which requires retrieval of a specific label), with less impact observed in tasks that do not have such requirements (e.g., category sorting, which may rely more on ability to group items based on shared features) (Tyler et al., 2000, pp. 204-205).

The combined influence of these theories of semantic organization has led to widespread cognitive neuropsychological investigation across populations of individuals with semantic deficits, in particular individuals with semantic dementia, herpes simplex encephalitis, and Alzheimer's disease (e.g., Rogers et al., 2004; Warrington & Shallice, 1984; Moss, Tyler, Durrant-Peatfield, & Bunn, 1998; Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997, for review see also Capitani et al., 2003). There has been less investigation of the effect of these relationships on semantically-guided lexical retrieval in individuals with stroke-aphasia. This may, in part, be due to the fact that the preponderance of evidence suggests that those with stroke-aphasia do not tend to exhibit the more severe loss of conceptual knowledge demonstrated within other neuropsychological populations (Jeffries and Lambon-Ralph, 2006). However, a recently growing body of evidence suggests there may be subtle semantic feature processing differences contributing to deficient semantically-guided lexical retrieval in individuals with stroke-aphasia (e.g., Antonucci, Beeson, Labiner, & Rapcsak, 2008; Mason-Baughman & Wallace, 2013; Wallace & Mason-Baughman, 2012). Understanding how these differences manifest and influence concept name retrieval in these individuals is particularly important considering the preponderance of word retrieval treatments that are predicated on processing of semantic information (Boyle, 2010; Kiran, 2007).

Semantic feature processing in stroke-aphasia—In an examination of the concept × feature (information type) relationship, Antonucci and colleagues (2008) worked with individuals with left inferior temporal lesions due to either left posterior cerebral artery infarct or left anterior temporal lobectomy. Results supported predictions of sensory-motor models, documenting that, across lexical retrieval tasks, individuals who had sustained left inferior temporal damage were disproportionately impaired in naming of living relative to nonliving concepts, and also had particular difficulty processing visual-perceptual semantic information for living concepts. In confrontation naming and naming-to-definition tasks, participants demonstrated less accurate naming of living compared to nonliving concepts. Furthermore, an interaction was observed in the naming-to-definition task between concept domain and information type, such that living concepts were named less accurately when definitions contained visual-perceptual information (Antonucci, Beeson, Labiner, & Rapcsak, 2008). The preponderance of evidence documenting the double dissociation, disproportionately deficient processing of nonliving concepts or deficient function/action feature processing, has been documented in reports of individuals with left dorsolateral stroke lesions (see Antonucci & Alt, 2011; Gainotti, 2000; 2006, for review), though to our knowledge there has not yet been a large-scale direct report of the interaction between domain and feature type in this population.

With respect to differential processing of shared (common) versus distinctive features in individuals with stroke-aphasia, Mason-Baughman and Wallace (2012; 2013) have recently examined how this factor interacts with the feature characteristics of relevance and importance. In consecutively published papers, these authors have demonstrated correlation between naming ability, ability to distinguish among semantically-related foils, and access to distinctive features during feature-concept matching tasks, reporting that persons with aphasia (PWA) who presented with more severe lexical retrieval deficits also demonstrated greater difficulty identifying distinctive relative to shared features.

Purpose—While the work cited above has provided important preliminary information, the interaction among domain, feature type, and distinctiveness has not yet been examined in combination in PWA. The data reported in the current study are part of a larger, ongoing investigation into these relationships, and their interaction with lesion location, in individuals with left hemisphere stroke-aphasia. The feature-verification task described herein was designed to elicit information about the interaction among concept type and feature information type and distinctiveness, using a task that could be completed by individuals with many types of aphasia, including those who might be unable to complete production tasks (e.g., confrontation naming, naming to definition, or verbal description) due to more severe language production deficits. This task provides information regarding how responsive PWA are to differing types of feature cues for two of the most commonly studied concept domains, which can have direct clinical implications for design of semantic feature-based treatment protocols, both those that provide for semantic feature review and those that require semantic feature generation (Boyle, 2010).

Method

Participants

Participants were fifteen right-handed, monolingual native English-speakers (6 female) with aphasia consequent to single left-hemisphere stroke. Average participant age was 58.3 (range: 42-82) years and participants attained an average of 13.8 (range: 12-20) years of education. Participants were required to be in the chronic phase post single, left hemisphere stroke (i.e., > 6 months post-onset) and to be without progressive neurological impairment. Time post-onset since participants' strokes averaged 79.9 (range: 30-167.5) months. Details of participants' demographic information and performance on standardized tests are presented in table 1. Following completion of informed consent and prior to beginning the experimental task, participants completed standardized tests, which included the *Western Aphasia Battery-Revised (WAB-R)* (Kertesz, 2006), the *Raven's Coloured Progressive Matrices (RCPM)* (Raven, 1938), as a measure of visual processing and nonlinguistic problem solving, and the picture version of the *Pyramids and Palm Trees Test (PPTT)* (Howard & Patterson, 1992), a test of semantic association. *WAB-R* AQs ranged from 32.6 to 95.2; *WAB-R*-based aphasia types were Broca's (n=3), Conduction (n=4), Anomic (n=6), and non-aphasic (n=2). A minimum subset score of 4/10 on the auditory comprehension subtests of the *WAB-R* was required for participation in the experimental task. Hearing was screened using a portable screening audiometer beginning at 40db at frequencies of 500Hz, 1000Hz, 2000Hz, 4000Hz, and 8000Hz. Responses to the pure tone hearing were somewhat

variable, with some participants requiring presentation of higher dB at the highest frequencies, either unilaterally or bilaterally and one participant responding unilaterally at the lowest frequencies. All participants were responsive to testing and discussion at conversational speech levels and loudness levels were confirmed as comfortable for participants during the practice task that preceded initiation of the experimental auditory feature-verification task.

Stimuli and Procedure: Response Time (RT) Feature-Concept Verification

Stimuli were drawn from a set of 60 concrete object concepts (30 living, 30 nonliving) balanced for age of acquisition (Morrison, Chappell, & Ellis, 1997) and familiarity, name agreement, and visual complexity (Rossion & Pourtois, 2004). Manipulability was balanced to the extent possible when factoring in other variables (Living concepts: 12 manipulable/18 non-manipulable, Nonliving concepts: 19 manipulable/11 non-manipulable; Arévalo et al., 2007). Concrete living and nonliving items were chosen that were judged by the author to be distinguishable by visual-perceptual and function/action information independently. Consider again the example of the zebra. Although a zebra can be clearly described and distinguished based on visual/perceptual features, such as having black and white stripes, it was not judged to be as easily distinguishable from similar category members (e.g., horse) based on function/action. Each participant responded to either set A or set B, each of which was comprised of half of the concept stimuli (i.e., 15 living and 15 nonliving). Administration of set A or B was counterbalanced among participants. Instructions were to verify (yes/no) whether true and false verbally-presented function/action and visual-perceptual features were associated with each concept. For each concept, two function/action and two visual-perceptual feature pairings were created, one in which the feature is shared by many object-concepts and one that is distinctive (information type and distinctiveness ratings for most object-concepts per McRae, Cree, Seidenberg, & McNorgan, 2005 database). In addition, false statements for each feature type were created for each concept. Thus, each participant responded to a total of 240 experimental items (15 living + 15 nonliving $\times$ 2 feature types $\times$ 2 levels of distinctiveness $\times$ 2 veracity). An example of each feature type for one living and one nonliving concept is provided in table 2.

Concept-feature pairings were presented for verification in the form of auditorally-presented yes/no questions. Stimuli were digitally voice-recorded by the author in a sound attenuated audiometric booth. The task was conducted on a laptop computer via *Empirisoft Direct RT* presentation software, which randomizes presentation of the auditory stimuli with each administration. Participants were instructed to verify via button-press that there was 'yes' or was not 'no' a relationship between the object-concept and the feature. All participants were instructed to use their left (non-dominant) hand to respond, as it was anticipated that some participants would be constrained to use of the left hand by right-sided hemiparesis or paralysis. Responses were collected via *Empirisoft DirectIn High Speed Button Box* with buttons labeled 'Y' for 'yes' and 'N' for 'no'. Participants received verbal and written instruction (presented via computer monitor) and participated in a practice set during which they responded to all concept-feature pairing types for one living and one nonliving concept not included in the experimental battery. Feedback on task procedures (e.g., reminder to use the left hand to respond, reminder that the next question would be presented as soon as a

button-press response was made) and loudness level adjustments were provided as necessary before proceeding with the experimental sets. Administration of the 240-item experimental task was divided among 2-3 sessions.

Planned Analyses

Concept/feature pairings were created to provide for analyses of the influence of information type (function/action vs. visual-perceptual), distinctiveness (shared vs. distinctive), and veracity (true vs. false) on accuracy and speed of verifying these feature types for living and nonliving concepts. Repeated measures ANOVAs were utilized to examine main effects and interactions, first among all four factors (domain, information type, distinctiveness, and veracity) and then to examine three factors (domain, information type, and distinctiveness) restricted to true concept-feature pairings.

Results

Mean group performance for each type of true and false concept-feature pairing is displayed in Figure 1. As a whole, the group performed relatively well on the task. While it is possible that the inclusion of two individuals who tested as non-aphasic on the *WAB-R* could have artificially inflated performance means, we note that neither participant achieved accuracy scores substantially above (i.e., 2 standard deviations) mean performance in either domain.

Examination across domain and feature type did demonstrate the influence of several factors on performance. Results from the RM ANOVA examining all four factors are displayed in Table 3.

Significant main effects for domain and veracity were not observed; however, a significant interaction between the two was demonstrated. Planned comparisons (Bonferroni corrected $\alpha=0.0125$) indicated that nonliving concepts were responded to more accurately, $t(14)=3.155$, $p=0.007$, and more quickly, $t(14)=-4.405$, $p=0.001$, when feature pairings were true rather than false, whereas no differences were observed for living concepts with respect to veracity of feature pairings. However, a domain-based difference was observed such that nonliving concept-true feature pairings were responded to more accurately, $t(14)=3.519$, $p=0.003$, and more quickly (though not at the corrected alpha level), $t(14)=-2.605$, $p=0.021$, than living concept-true feature pairings.

Significant main effects were demonstrated for information type, such that concept-feature pairings that contained function/action information were responded to more accurately and more quickly than those containing visual-perceptual information. (see table 3). Finally, a significant main effect of distinctiveness demonstrated that concept-feature pairings containing distinctive features were responded to more accurately than those containing shared features (see table 3).

Considering the greater clinical applications of understanding responsivity to true concept-feature pairings, accuracy and RT were also analyzed for these pairings only. Results from this RM ANOVA are displayed in table 4.

A new main effect of domain was observed such that, irrespective of feature type, nonliving concepts were responded to more accurately and more quickly than living concepts (see table 4). The main effect of information type observed from analyses of true + false concept-feature pairings was maintained, such that pairings containing function/action information were more quickly responded to than those containing visual-perceptual information. However, the robustness of the previously observed accuracy advantage was weakened to the status of a trend. Also consistent was the finding that concept-feature pairings containing distinctive features were again responded to more accurately (but not more quickly) than those containing shared features.

Finally, as measures of the influence of severity of aphasia on task performance, *WAB-R* AQ and *WAB-R* auditory comprehension sub-score (*WAB-R* derived score used in calculating AQ, maximum of 10) were assessed for correlation with each concept-feature type pairing (please see tables 5 and 6). *WAB-R* AQ was considered a more global measure of aphasia severity, whereas the *WAB-R* auditory comprehension sub-score was used as a measure of severity that would not be confounded by motor speech impairment.

The only clear pattern to emerge suggests that severity of aphasia, as defined by both AQ and auditory comprehension sub-score, is correlated with accuracy and speed of responding to false concept-feature pairings, with a positive correlation being observed with accuracy and a negative correlation being observed with RT. This suggests that the more severe the aphasia (as defined by lower AQ/auditory comprehension sub-score), the more difficulty (i.e., lower accuracy and longer latency of response) an individual will demonstrate in responding to false/incorrect information.

Discussion

Fifteen individuals with aphasia participated in a response-timed auditory concept-feature verification task in which it was observed that several factors influenced both accuracy and speed of response. Performance was influenced by concept domain (i.e., living vs. nonliving), as well as by veracity of concept-feature pairing, and type and distinctiveness of information represented in the semantic features. While both accuracy and speed of response were variable, it is notable that group performance was relatively strong overall (e.g., mean accuracies as displayed in figure 1). This suggests that first, the task may be feasibly administered as a measure of semantic feature processing in individuals with stroke-aphasia, and that, consistent with previous reports of semantic deficiency in individuals with stroke-aphasia, overall impairment in concept-feature verification was relatively subtle.

Feature-based theories of disproportionate impairments to living versus nonliving concepts: The influence of information type

Main effects of domain and information type suggest that the current group of PWA demonstrated greater difficulty responding to semantic feature information when paired with living concepts, and greater difficulty responding to visual-perceptual features when paired with concepts from either domain. However, no interaction of domain with feature type was observed. These observations are inconsistent with broad predictions of sensory-motor-based hypotheses, which suggest that individuals demonstrating a profile consistent with

perisylvian language zone lesions should have greater difficulty processing semantic information related to nonliving concepts and/or function/action-based information. It is, of course, possible then that these predictions simply do not hold for individuals with stroke-aphasia and that to demonstrate such dissociations requires greater semantic impairment, as documented in individuals with more diffuse and bilateral tissue loss (e.g., Lambon-Ralph et al., 2003; Warrington & Shallice, 1984). It is also possible that sensory-motor-based theories are inadequate or even ill-suited to explain semantic processing of concrete objects (e.g., Capitani et al., 2003). However, with the current participants, there are additional factors influencing performance, particularly with respect to the interactions of veracity (and distinctiveness) with domain. As such, and in light of the neuropsychological evidence with respect to category/feature type relationships documented by others (Buxbaum et al., 2000; Buxbaum & Saffran, 2002; Gainotti, 2000; 2006) as well as in our work (Antonucci et al., 2008), conclusion on this point will be reserved pending additional evidence. As data from additional participants with stroke-aphasia, as well as from age- and education-matched controls, is analyzed across tasks, we will be better able to observe whether the predicted interactions emerge within the group of PWA based upon differing lesion profiles and as compared to the performance of individuals without brain lesion.

Feature-based theories of disproportionate impairments to living versus nonliving concepts: The influence of distinctiveness

There was a robust finding that participants demonstrated greater difficulty verifying concept-feature relationships when concepts were paired with shared features, than when paired with distinctive features. Distinctive features may have a more ‘privileged’ relationship with concepts than do shared features, in that they tend to be more exclusively associated with the concept being evaluated, hence requiring less semantic sifting through numerous other concepts to confirm the relationship (e.g., Tyler et al., 2000). An implication of this regarding the responsivity of PWA to semantic feature cues is that distinctive features may provide more support in selecting the appropriate, specific label during semantically-guided lexical retrieval (Wallace & Mason-Baughman, 2012; Mason-Baughman & Wallace, 2013). The current data provide additional support for the notion that semantic feature-based treatments may best be geared toward reinforcement of PWAs’ responsivity to distinctive (versus shared) feature training. Distinctive features may provide better support for lexical activation (Boyle, 2004; Kiran, 2007; Wallace & Mason-Baughman, 2012; Mason-Baughman & Wallace, 2013), potentially allowing SFA protocols to be streamlined toward a smaller, more select pool of feature cues (e.g., Hashimoto & Frome, 2011). In addition, with respect to the proposal that SFA may have the secondary goal of increasing effectiveness of communication even when specific lexical retrieval fails (Antonucci, 2009; Falconer & Antonucci, 2012), reinforcing PWA to provide more distinctive feature information may provide more explicit information to communication partners.

Per the above discussion of the interaction of distinctiveness with domain, it remains to be seen whether disparate processing of distinctive versus shared features in PWA may influence processing of different concept types. Prior work suggests that shared features may present a particular challenge for processing of living concepts during tasks requiring more fine-grained lexical-semantic processing (e.g., concept-feature verification, confrontation

naming) as they tend to have more shared features through which to sift and these features tend to be more highly correlated with each other (Antonucci & Falconer, 2012; Garrard et al., 2001; McRae et al., 1997; McRae et al., 2005; Moss & Tyler, 1997; Moss et al., 1998; Tyler et al., 2000; Zannino et al., 2006). While the domain $\times$ distinctiveness interaction only attained the level of a trend in the current study, participants demonstrated greater difficulty responding to shared versus distinctive features associated with living concepts, whereas no such difference was observed for nonliving concepts. As noted above, this interaction may also have influenced the unforeseen finding in the current group of PWA, who demonstrated greater difficulty responding to living concept feature pairings. It would stand to reason that greater difficulty processing share features that are more strongly correlated for living concepts would affect multiple category members simultaneously, whereas nonliving concepts would be less likely to be lesioned 'in bulk' except in cases of extreme semantic impairment (Tyler et al., 2000).

The influence of veracity: an unexpected finding

Finally, another finding, which was not previously predicted, concerns the influence of veracity of concept-feature pairings on performance. For the group as a whole, when effects of veracity were observed, true concept-feature pairings were responded to more accurately and/or more quickly than false pairings. This is noteworthy, particularly in light of the fact that the false pairings were blatant violations of the relationships, requiring less fine-grained semantic analysis than the true pairings. In addition, ability to respond to false pairings was correlated with severity of aphasia across most concept-feature types with a strength and consistency not observed for true pairings, such that participants with more severe aphasia had greater difficulty than those with less severe aphasia responding to false pairings. The most transparent implication of these findings is that, if performance is not equivalent with respect to evaluating true versus false semantic relationships, assessment of the ability of PWA to respond to semantic information must include assessment of both to be comprehensive.

With respect to implications for semantic feature-based treatments, the current findings seem more directly applicable to those described by Boyle (2010) as 'semantic feature review' treatments (e.g., Kiran & Thompson, 2003; Edmonds & Kiran, 2006; Kiran & Roberts, 2010) (Boyle, 2010, p. 414), in which PWA participate in review of concept-relevant semantic features chosen a priori by the clinician. While concept-feature verification is only one of several tasks undertaken in these protocols, making it impossible to assess the individual effects of this single step of the treatment hierarchy on treatment outcomes, the current findings suggest that it may be of interest to examine in future studies how ability to respond to true versus false pairings may influence an individual's ability to benefit from a treatment of this type. That is, does presentation of false pairings distract participants with misleading information that primes them toward lexical retrieval errors they are then unable to resolve? Regarding 'semantic feature generation' protocols (Boyle, 2010) (e.g., Boyle & Coelho, 1995; Boyle, 2004; Antonucci, 2009; Falconer & Antonucci, 2012) the question arises, if persons with more severe aphasia have difficulty responding when provided with inaccurate (i.e., false) semantic information by another, may they also have difficulty self-

monitoring when they produce inaccurate semantic information in the form of semantic errors?

Evidence suggests that during word retrieval PWA, including those with more severe impairment, *are* able to self-monitor (i.e., acknowledge errors) and subsequently self-correct, though those with more severe aphasia are less frequently successful in these attempts than persons with less severe impairments (Marshall & Tompkins, 1982). Only anecdotal evidence is available from the current data. Some participants did demonstrate evidence of having recognized an error immediately after a button press (e.g., commenting or hesitating after responding). However, the nature of the response-timed task precludes self-correction *per se*, as the button press response triggers presentation of the subsequent item. A useful modification for future use of this task might be to track error responses off-line to allow for post hoc analysis of response times to examine whether, for example, error-recognition might be associated with longer response times for items subsequent to an error response. Such data could also be compared via item analysis with participants' error profiles for the same concepts in production tasks, such as naming-to-definition and providing verbal descriptions, which are more closely aligned with procedures used during semantic cueing treatments.

Studies of semantic feature generation treatment for PWA have documented error type profiles (e.g., proportion of phonemic paraphasias vs. semantic paraphasia vs. empty circumlocutions), as well as frequency of self-correction or reformulation of word retrieval errors (e.g., Boyle, 2004; Antonucci, 2009). However, it remains to be determined what types of errors PWA are most likely to self-monitor or self-correct. Specifically, if a PWA produces semantically inaccurate information, in what circumstances are they able to monitor and revise versus those instances in which an erroneous semantic self-cue leads to further confusion? In addition to this question, future investigations may also be usefully directed to addressing how clinicians can reduce and redirect provision of inaccurate semantic information during semantic feature generation treatment. Finally, it should be noted that the current data are uninformative with respect to PWA with more severe auditory comprehension deficits (i.e., below 4/10 *WAB-R* auditory comprehension sub-score), and, as such, do not provide for conjecture as to how suitable semantic cueing of this type may (or may not) be for these individuals.

Conclusions and Future Directions

The current work contributes to ongoing debate in the cognitive neuropsychological and clinical treatment literature, providing information about semantic organization in a less investigated patient population and supporting the growing literature on potential best practice for development of semantically-based treatment for word retrieval impairment. This work represents one component of our broader investigation of semantic processing in individuals with stroke-aphasia. As this work proceeds, we will be better situated to follow-up on predictions related to the interaction of domain and information type across a wider variety of individuals with aphasia, with respect both to behavioral and lesion analyses. In the current study, within group trends were of interest with respect to task feasibility and less frequently considered parameters such as influence of veracity. We are limited to within

group analyses due to the relatively small sample of participants within different aphasia profiles. Inclusion of additional participants will also allow for examination of between group differences within PWA, based, for example, on aphasia severity, aphasia type, and lesion profile. We will also be able to compare performance on the current task with production tasks in which participants are required to produce, rather than comprehend, semantic feature information. It is intended that the culmination of the current and future work will be application of these findings to development of theoretically-motivated semantically-guided lexical retrieval treatments for anomia in PWA.

Acknowledgements

Research reported in this publication was supported by the National Institute on Deafness and other Communication Disorders of the National Institutes of Health under grant number R03DC010262 awarded to Sharon M. Antonucci. The content is solely the responsibility of the author and does not necessarily represent the official views of the National Institutes of Health. Portions of this work were presented at the 2012 annual meeting of the Academy of Aphasia. The author thanks Carolyn Falconer for assistance with this project.

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Figure 1a-d.
Concept-Feature Verification Accuracy and Response Times for True versus False Pairings.

Table 1

Participants' demographic information and standardized test performance

	Gender	Age (years)	Education (years)	TPOI (months)	WAB-R2 AQ (/100)	Aphasia Type (per WAB-R)	RCPM3 (/36)	PPTT4 (/52)
P13	F	42	12	131	74.4	Conduction	27	47
P15	M	50	12	150	93.1	Anomic	30	49
P16	F	40	15	139	87.1	Anomic	35	46**
P19	M	56	12	45	76.8	Anomic	34	51
P20	M	59	16	29	50.3	Broca's	33	48
P23	F	50	13.5	72.5	73.6	Conduction	29	49
P30	M	60	12	45	91.6	Anomic	28	50
P39	M	59	20	36	32.6	Broca's	34	43**
P54	F	58	12	167.5	87.2	Anomic	23*	47
P62	F	82	11	60	94.4	Anomic	25	50
P65	M	56	13.5	96.5	88.1	Anomic	22*	43**
P69	M	45	14	35	51	Broca's	18*	45**
P73	F	75	12	55	95.2	NA	25	52
P81	M	63	16	106.5	79.3	Conduction	32*	50
P89	M	79	13	30	76	Conduction	36	51

Note:

* indicates > 2 standard deviations below normal performance based on age-, education-, gender-specific normative data reported by Measso and colleagues (1993).

*** indicates impaired performance on the *PPTT* (Howard & Patterson, 1992).¹ TPO (Time Post Onset)² WAB-R (Western Aphasia Battery-Revised)³ RCPM (Raven's Coloured Progressive Matrices)⁴ PPTT (Pyramids and Palm Trees Test)

Table 2

Feature type examples provided for living and nonliving concepts in the Feature-Verification Task

	True Function/Action Shared	True Function/Action Distinct	True Visual- Perceptual Shared	True Visual- Perceptual Distinct	False Function/Action Shared	False Function/Action Distinct	False Visual- Perceptual Shared	False Visual- Perceptual Distinct
Apple	Eaten by hand	Used in cider	Has seeds	Has a core	Worn by people	Chases mice	Has buttons	Has pointed ears
Crown	Worn on the head	Worn by royalty	Is circular	Has jewels	Is edible	Used to make jam	Has windows	Is fluffy

Table 3
Results from RM ANOVAs comparing True versus False Concept-Feature Pairings

	Accuracy		Response Time	
	<i>F</i> (degrees freedom)	<i>p</i>	<i>F</i> (degrees freedom)	<i>p</i>
MAIN EFFECTS				
Domain ^a	3.187 (1,14)	0.096	-	ns
Veracity ^b	-	ns	-	ns
Infotype ^c	7.454 (1,14)	.016*	7.719 (1,14)	0.015*
Distinctiveness ^d	5.185 (1,14)	.039*	-	ns
INTERACTIONS				
Domain × veracity	11.774 (1,14)	.004*	9.697 (1,14)	0.008*
Domain × infotype	-	ns	-	ns
Veracity × infotype	-	ns	-	ns
Domain × veracity × infotype	-	ns	-	ns
Domain × distinctiveness	3.653 (1,14)	0.077	-	ns
Veracity × distinctiveness	3.404 (1,14)	0.086	-	ns
Domain × veracity × distinctiveness	3.137 (1,14)	0.098	-	ns
Infotype × distinctiveness	-	ns	-	ns
Domain × infotype × distinctiveness	-	ns	-	ns
Veracity × infotype × distinctiveness	-	ns	-	ns
D × V × I × S	-	ns	5.12 (1,14)	0.04*

Note:

- ^aDomain (living vs. nonliving)
- ^bVeracity (true vs. false concept-feature pairing)
- ^cInfotype (function/action vs. visual-perceptual)
- ^dDistinctiveness (shared vs. distinct)

Table 4

Results from RM ANOVAs for True Concept-Feature Pairings

	Accuracy		Response Time	
	<i>F</i> (degrees freedom)	<i>p</i>	<i>F</i> (degrees freedom)	<i>p</i>
MAIN EFFECTS				
Domain ^a	17.469 (1,14)	.001*	3.114 (1,14)	.009*
Infotype ^b	3.449 (1,14)	0.084	5.818 (1,14)	.03*
Distinctiveness ^c	4.985 (1,14)	.042*	-	ns

Note:

- ^aDomain (living vs. nonliving)
- ^bInfotype (function/action vs. visual-perceptual)
- ^cDistinctiveness (shared vs. distinct)

Table 5

a: Feature Type Accuracy & W/AB-R Aphasia Quotient Correlations (<i>r</i>)										
	True Function/Action Shared	True Function/Action Distinct	True Visual- Perceptual Shared	True Visual- Perceptual Distinct	False Function/Action Shared	False Function/Action Distinct	False Visual- Perceptual Shared	False Visual- Perceptual Distinct		
Living	0.54 [*]	0.11	0.47	0.54 [*]	0.63 [†]	0.87 [†]	0.83 [†]	0.81 [†]		
Non-living	0.06	0.51	0.60 [*]	0.21	0.93 [†]	0.80 [†]	0.80 [†]	0.78 [†]		

b: Feature Type RT & W/AB-R Aphasia Quotient Correlations (<i>r</i>)										
	True Function/Action Shared	True Function/Action Distinct	True Visual- Perceptual Shared	True Visual- Perceptual Distinct	False Function/Action Shared	False Function/Action Distinct	False Visual- Perceptual Shared	False Visual- Perceptual Distinct		
Living	-0.61 [*]	-0.64 [†]	-0.42	-0.30	-0.58 [*]	-0.73 [†]	-0.72 [†]	-0.62 [*]		
Non-living	-0.59 [*]	-0.51	-0.57 [*]	-0.44	-0.74 [†]	-0.48	-0.66 [†]	-0.66 [†]		

Note:
^{*} *p* .05
[†] *p* .01
[‡] *p* .001

Table 6

a: Feature Type Accuracy & WAB-R Auditory Comprehension Correlations (<i>r</i>)									
	True Function/Action Shared	True Function/Action Distinct	True Visual- Perceptual Shared	True Visual- Perceptual Distinct	False Function/Action Shared	False Function/Action Distinct	False Visual- Perceptual Shared	False Visual- Perceptual Distinct	
Living	0.30	-0.04	0.43	0.58 [*]	0.78 [‡]	0.79 [‡]	0.63 [‡]	0.73 [‡]	
Non-living	0.11	0.59 [*]	0.68 [‡]	0.20	0.85 [‡]	0.80 [‡]	0.79 [‡]	0.71 [‡]	

b: Feature Type RT & WAB-R Auditory Comprehension Correlations (<i>r</i>)									
	True Function/Action Shared	True Function/Action Distinct	True Visual- Perceptual Shared	True Visual- Perceptual Distinct	False Function/Action Shared	False Function/Action Distinct	False Visual- Perceptual Shared	False Visual- Perceptual Distinct	
Living	-0.50	-0.48	-0.44	-0.20	-0.38	-0.63 [*]	-0.59 [*]	-0.53 [*]	
Non-living	-0.54 [*]	-0.44	-0.49	-0.39	-0.61 [*]	-0.27	-0.60 [*]	-0.52 [*]	

Note:
^{*} *p* .05
[‡] *p* .01
[#] *p* .001