HHS Public Access
Author manuscript
Aphasiology. Author manuscript; available in PMC 2017 January 01.

Published in final edited form as:
Aphasiology. 2016 ; 30(6): 719–749. doi:10.1080/02687038.2015.1081137.

Understanding semantic and phonological processing deficits in adults with aphasia: Effects of category and typicality

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Abstract

Background—Semantic and phonological processing deficits are often present in aphasia. The degree of interdependence between the deficits has been widely studied with variable findings. Semantic variables such as category and typicality have been found to influence semantic processing in healthy individuals and persons with aphasia but their influence on phonological processing is unknown.

Aims—This study examined the nature of semantic and phonological access in aphasia by comparing adults with aphasia to healthy control participants. Semantic and phonological tasks were used to assess the difference in processing requirements between and within each group as well as examine the effects of category and typicality on different stages of semantic and phonological processing.

Methods & Procedures—Thirty-two persons with aphasia and ten neurologically healthy adults were administered nine tasks: Category Superordinate, Category Coordinate, Semantic Feature, Rhyme Judgment (No-Name), Syllable Judgment (No-Name), Phoneme Verification (No-Name), Rhyme Judgment (Name-Provided), Syllable Judgment (Name-Provided), and Phoneme Verification (Name-Provided). Accuracy and reaction time data were collected for each of these tasks and between-group and within-group differences were analyzed via MANOVA/MANCOVA and hierarchical clustering analyses.

Outcomes & Results—Persons with aphasia performed with significantly lower accuracy than controls on phonological tasks but performed comparably on semantic tasks. Participants with aphasia were significantly slower than controls on all semantic and phonological tasks. Clustering of the nine tasks by accuracy revealed different processing requirements in the participants with aphasia compared to the control group while clustering by reaction time revealed similar trends in

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both groups in that phonological (no-name) items required the most processing time. Significant effects of category and typicality were noted in the semantic tasks but not in any of the phonological tasks.

Conclusions—Individuals with aphasia demonstrated overall impaired phonological processing with relatively preserved semantic processing as compared to controls. Per accuracy and reaction time measures, distinct trends in processing load for semantic tasks versus phonological tasks were seen in the individuals with aphasia whereas only speed of processing and not accuracy was impacted by phonological processing load in the control group. The results align most closely with discrete serial processing models of lexical processing as category and typicality effects were robust in the semantic tasks but not in any of the phonological tasks. Alternative explanations for these results also are discussed.

Keywords

category; typicality; aphasia; semantic; phonological; impairment

Introduction

Many two-step models of lexical access propose that semantic and phonological processes are distinct and are activated at different levels during single-word comprehension or production. During picture naming, for example, word production begins at a conceptual level (e.g., recognition of visual features of a pictured object, *turkey*). Conceptual knowledge of the target then activates semantic attributes of the target word from the lexical-semantic system (e.g., 'has wings', 'is food for humans'). Phonological codes of the target word form are then selected from long-term storage within the phonological lexicon (e.g., /t/, /ɝ/, /k/, /i/). Finally, short-term maintenance and sequencing of phonological segments occurs in the phonological buffer (e.g., *tur-key*) prior to articulation (e.g., "turkey"). During spoken word comprehension, comparable stages of processing occur but in the reverse order (i.e., translation of the acoustic signal into phonological codes, retrieval of word form, etc.). In these models, semantic processing is often represented by a single stage that does not separate input from output processes, while some researchers (e.g., Besner, 1987; Besner & Davelaar, 1982; Martin, Lesch, & Bartha, 1999b; Monsell, 1987; Nickels, Howard, & Best, 1997) argue that the systems mediating input phonology for spoken word comprehension (i.e., phonological input buffer and phonological input lexicon) and the systems mediating output phonology for spoken word production (i.e., phonological output lexicon and phonological output buffer) are separate.

While many researchers agree that the aforementioned processes are necessary for lexical processing (with some modifications to certain stages), considerable debate exists regarding the level of interaction between semantic and phonological stages during lexical access. On one end of the spectrum, there exists a set of models wherein lexical access proceeds in a discrete, serial fashion, and each stage of processing occurs sequentially in one direction (Indefrey & Levelt, 2004; Levelt, Roelofs, & Meyer, 1999; Levelt et al., 1991). Alternatively, interactive activation models (Dell, 1986; Dell & O'Seaghdha, 1992; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Foygel & Dell, 2000; Humphreys, Riddoch, & Quinlan, 1988; McClelland & Elman, 1986; Schwartz, Dell, Martin, Gahl, & Sobel, 2006) argue that the stages of semantic and phonological access interact and affect each other resulting in processing occurring in a parallel fashion; connections between semantic, lexical, and phonological nodes are bidirectional and several types of interactivity between nodes (i.e., forward-backward interactivity, lateral interactivity, integration between nodes) may occur to maintain stability between semantics, word form and phonemes.

Support has been found for each type of model within the literature on impaired language processing in persons with aphasia (PWA). For example, evidence that phonological and semantic processing deficits are discrete and independent has been demonstrated through speech error studies showing a distinction between semantic (e.g., *plane* for *helicopter*) and phonological errors (e.g., *pain* for *plane*) as well as reaction time studies demonstrating the effect of a semantic distractor before that of a phonological distractor on naming (Cuetos, Aguado, & Caramazza, 2000; Ellis, Kay, & Franklin, 1992; Howard & Gatehouse, 2006; Jefferies, Sage, & Ralph, 2007; Levelt, et al., 1991; Schriefers, 1990). Conversely, other studies with PWA have found that phonological and semantic deficits are interdependent as phonological representations are supported by their corresponding lexical and semantic representations (Kittredge, Dell, Verkuilen, & Schwartz, 2008; Martin & Saffran, 1997; Martin, Schwartz, & Kohen, 2006; Schwartz, et al., 2006). Therefore, within any theoretical model of lexical access, it can be presumed that breakdown can occur at any stage of processing yet the extent to which systems subsequent to the level of impairment are impacted depends on whether these systems are interactive.

Additionally, certain psycholinguistic factors have been found to differentially impact semantic and phonological stages of lexical processing in both neurologically-intact adults and PWA. For example, previous studies have shown that semantic access is influenced by a variety of factors, including lexical frequency (e.g., Kittredge, Dell, Verkuilen, & Schwartz, 2008), familiarity (e.g., Gernsbacher, 1984; Funnell & Sheridan, 1992), and word length (Ellis, Miller, & Sin, 1983; Howard, Patterson, Franklin, Morton, & Orchard-Lisle, 1984; Nickels, 1995; Nickels & Howard, 2004; Pate, Saffran, & Martin, 1987). Within the phonological system, frequency, familiarity, and possibly age of acquisition have been shown to impact access to the phonological output lexicon (POL) in PWA (Howard & Gatehouse, 2006), and it has been proposed that word length and phoneme position impacts processing at the level of the phonological output buffer (Romani, Galluzzi, & Olson, 2011).

Moreover, select psycholinguistic factors are inherently either semantic (e.g., category) or phonological (e.g., phonological neighborhood density) in nature. Pertinent to the present study, there is extensive evidence that the lexical-semantic factor of category impacts semantic processing in both healthy individuals (e.g., Ahn, 1998; Barsalou, 1983; Barsalou, 1985; Barton & Komatsu, 1989; Devlin et al., 2002; Diesendruck & Gelman, 1999; Estes, 2003; Hampton, 1998; Keil, Carter Smith, Simons, & Levin, 1998; Silveri et al., 1997; Vanoverberghe & Storms, 2003) and PWA (e.g., Forde & Humphreys, 1999; Hart, Berndt, & Caramazza, 1985; Laiacona & Capitani, 2001; Lambon Ralph, Lowe, & Rogers, 2007; Sacchett & Humphreys, 1992; Samson, Pillon, & De Wilde, 1998). Similarly, item typicality (i.e., the semantic distance from the category prototype) is also a lexical-semantic variable and has been found to influence both accuracy and reaction times in healthy participants (Hampton, 1979; Rosch, 1975; Rosch & Mervis, 1975; Rosch, Simpson, & Miller, 1976;

Vigliocco, Vinson, Damian, & Levelt, 2002) and can explain differences in semantic processing between PWA with different deficit profiles and healthy controls (Kiran, Ntourou, Eubanks, & Shamapant, 2005; Kiran & Thompson, 2003; Sandberg, Sebastian, & Kiran, 2012). Within the context of interactive models, it is reasonable to hypothesize that such semantic factors would impact phonological processing to a certain degree whereas this expectation would not hold within the framework of discrete serial models.

Ultimately, the discussion of whether lexical access is discrete or interactive is important because it facilitates understanding deficit profiles in PWA, and it is well-established that PWA can demonstrate impairments of semantics, phonology or both. One method for testing the interactivity between systems is to examine the differential effects certain psycholinguistic factors (especially inherently semantic/phonological factors) have on different stages of semantic and phonological processing.

Aims

Therefore, the current study aimed to further our understanding of the nature of lexical processing in PWA and healthy controls by examining general differences in semantic and phonological processing between groups as well as the effects of semantic factors (i.e., category and typicality) on processing within each system within each group. All participants were administered the following three sets of experimental tasks: (1) three semantic (SEM) tasks designed to primarily target semantic processing, (2) three phonological no-name (PhN-N) tasks designed to highly tax processing at the level of the POL, and (3) three phonological name-provided (PhN-P) tasks designed to target processing within the phonological buffer system. Holistic language processes (e.g., overt word production) were not explicitly probed in the experimental tasks. Rather, the component processes underlying such language tasks were isolated in order to systematically examine different stages of semantic and phonological processing in healthy individuals versus a large sample of PWA. To do so, we addressed the following questions:

1. What are the differences between healthy controls and PWA in processing on the nine semantic and phonological tasks according to accuracy and reaction times?

   We predicted that healthy controls would be significantly faster and more accurate on all tasks than PWA. We also predicted that the difference between groups would be greatest for the PhN-N tasks as one of hallmark deficits of PWA is anomia, and these tasks primarily taxed retrieval at the POL. We hypothesized that the differences between tasks would be the smallest for the SEM tasks but the magnitude of the difference between groups would depend on the amount of semantic impairment in the group of PWA.

2. How do task demands influence processing according to accuracy and reaction times within groups?

   We predicted that PWA would demonstrate a clear delineation in processing requirements according to task type (i.e., SEM versus PhN-N versus PhN-P). Unlike the PWA, we believed that processing demands across tasks would be similar for controls as they were expected to do well on all tasks.

3. What are the effects of category and typicality on processing according to accuracy and reaction times within the semantic and phonological tasks in each participant group?

We predicted that category and typicality effects would be more robust in semantic relative to phonological tasks since both psycholinguistic variables are lexical-semantic in nature. Additionally, if lexical processing is truly interactive, we hypothesized that category and typicality effects would be present in the SEM and PhN-N tasks (since the lexical system is activated in both tasks) but would be least likely in the PhN-P tasks. Conversely, if processing is discrete, effects of category and typicality were expected to be present in the SEM tasks only.

Method

Participants

Thirty-two participants with aphasia (20 males) as a result of middle cerebral artery stroke(s) were recruited from hospitals and group therapy settings in the Boston area. Two participants had two left-hemisphere CVAs, and one participant had a right hemisphere CVA and presented with crossed aphasia. Additionally, three PWA had some right-hemisphere involvement in addition to left-hemisphere CVAs; their primary presentation was aphasia. Thirty-one PWA were monolingual English speakers; one participant was bilingual but acquired English at an early age and primarily used English at home. Ten healthy monolingual English-speaking control participants (6 males) with no reported history of stroke, traumatic brain injury, or other neurological damage also participated in this study. It should be noted that a small sample of neurologically-intact controls was justified in the present study as these participants were expected to perform consistently and near ceiling across all tasks, unlike the heterogeneous group of PWA. All participants had normal or corrected-to-normal vision and hearing. PWA and control participant demographic information, including age, gender, handedness, years of education, monolingual status, neurological history, months post-onset and aphasia type (for PWA), was collected using self-report questionnaire. Welch two sample t-tests revealed that PWA and control participants did not significantly differ by age, $t(26.09) = -1.46$, $p = .16$, or by education, $t(13.69) = .91$, $p = .38$. See Tables 1a/1b for PWA/control demographic information.

In addition to the behavioural tasks described below, PWA were administered different language assessments, including the Boston Naming Test (BNT; Kaplan et al., 2001) to assess naming performance, the Pyramids and Palm Trees Test (PPT; Howard & Patterson, 1992) to assess semantic processing, and the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2007) to obtain Aphasia Quotient (AQ) which indicates overall severity of language deficits in aphasia (see Table 2 for report of individual scores). Of note, AQ was above the criterion cut score for mild aphasia for three PWA. However, we were interested in fully representing the heterogeneity seen in chronic aphasia, and these participants were included in the present study as they demonstrated impaired linguistic skills on other assessments (e.g., P20 scored 39/60 on BNT).

Materials

Several computer-based tasks were developed for this study. Color photographs of real-life objects were used for the visual stimuli. Visually confusing or ambiguous items were avoided. Audio clips of stimuli and tasks instructions were recorded by a native male American English speaker. In all tasks, stimuli were divided into six semantic categories, three of which were living: *vegetables*, *fruits*, and *birds* and three were nonliving: *furniture*, *transportation*, and *clothing*. Approximately 40 items for each category were submitted to Mturk (https://www.mturk.com/mturk/), where approximately 500 anonymous workers rated each item's typicality on a scale of 1 to 5. Each item received ratings from at least 20 workers. Foil items that did not belong to the category were used to identify outlier workers whose answers were discarded in the calculation of typicality. Using the Mturk ratings, the average rating for the category was calculated, and z-scores were calculated by taking the distance from the item's rating to the category average divided by the standard deviation. To avoid ambiguous typicality, mid-ranking items were not used in development of the tasks. See Appendix A for a list of sample stimuli and Table 3 for stimuli ratings by category.

Experimental Tasks

Nine experimental tasks were designed to capture abilities within three different systems involved in lexical access: the semantic system, the phonological output lexicon (POL), and the phonological buffer system. The semantic tasks were consistent with other examinations of semantic processing abilities in PWA such as category generation, category sorting, category superordinate verification, and semantic feature verification (Casey, 1992; Fujihara, Nageishi, Koyama, & Nakajima, 1998; Grober, Perecman, Kellar, & Brown, 1980; Hampton, 1979; Kiran, Ntourou, & Eubanks, 2007; Kiran & Thompson, 2003; Rips, Shoben, & Smith, 1973). Similarly, the phonological tasks were similar to tasks utilized in previous studies examining phonological processing deficits in PWA, including phonological judgment and manipulation involving rhyme judgments, segmentation, and minimal pairs (Howard & Nickels, 2005; Jefferies & Lambon Ralph, 2006).

Each task required participants to make either a semantic or phonological judgment regarding the target item(s). While certain tasks required both semantic and phonological processes (e.g., PhN-N), the onus for successful completion of the judgment was *primarily* on one of the aforementioned systems for each task type (i.e., SEM, PhN-N, PhN-P) (see Figures 1a–d). Each task consisted of 80 items split into two runs. Items/pairs were balanced across category, typicality, and yes/no conditions. Unless otherwise specified, the yes/no responses were given via a keyboard button press with "x" corresponding to a "yes" response and "z" corresponding to a "no" response. A fixation of 2000ms was displayed between presentations of stimuli across tasks. The specific tasks and the theoretical motivation for the design of each task type are described in further detail below.

Semantic (SEM) Tasks—Performance on these tasks was primarily indicative of semantic processing. In each task, the target word of the pictured item(s) was provided, and the semantic information required to make the judgment was presented in both spoken and written form to reduce the effect of reading or auditory comprehension deficits on performance.

Category Superordinate: Participants were presented with a picture of a basic-level item and its spoken name along with a written and spoken superordinate category name. Participants determined whether the item belonged to the given category (e.g., *chandelier: furniture*).

Category Coordinate: Participants were presented with the pictures and the spoken forms of two basic-level items, one item immediately followed by the next. Participants decided whether the items belonged to the same semantic category (e.g., *truck: canoe*). At the beginning of the task, the six categories were listed as part of the instructions to minimize category ambiguity.

Semantic Feature: Participants were provided with simultaneous visual and auditory presentation of a basic-level item immediately followed by a written and spoken semantic feature. Participants judged whether the feature applied to the item. Of the 80 trials, half were related items and features (e.g., *penguin: swims*) while the other half were unrelated items and features. Related features consisted of defining type (features shared by >80% of the items within the category), characteristic type (features shared by <80% of the items within the category), unrelated features (features that applied to some category members but not the target item) and non-category features.

Phonological No-Name (PhN-N) Tasks—In the PhN-N tasks, the target word of the pictured item was not presented, and covert lexical retrieval was required. Therefore, performance on these tasks *primarily* taxed the ability to access phonological forms of words at the level of the phonological output lexicon (POL). Even though no overt word production was required, processing in the PhN-N tasks can be attributed to the output system for two main reasons. First, according to the literature (see Levelt, 1999; Indefrey & Levelt, 2004), visual input of a pictured item causes the automatic activation of lexical-semantic information which in turn activates downstream phonological encoding processes if such processes are required; even in the absence of articulation, the lead-in processes required to retrieve the word form of the pictured item from long-term storage would likely be mediated by the POL. Secondly, the PhN-N tasks required whole-word *generation* of target items (even though targets were not articulated) rather than whole-word *recognition*. According to Martin, Lesch, and Bartha (1999b), the ability to internally produce and imagine the sound of a real word involves activating the input form of a word *from* its output form. Therefore, it is further likely that the primary system involved with initial retrieval of word form was the POL.

Following lexical retrieval, phonological segmentation was required to complete the judgment task. We make the case that the *primary* barrier for successful PhN-N task completion was retrieval of target word forms from the POL, not segmentation in the buffer system. Therefore, we suspected the PhN-N tasks would challenge PWA due to their anomia while controls would demonstrate similar accuracy on the PhN-N and PhN-P tasks as they were not anomic. Each task is described in further detail below.

Rhyme Judgment: A picture of a category item was presented, and 1000ms later a target word (either rhyming or non-rhyming) was presented auditorily (e.g., picture of *turkey* followed by audio of "*murky*"). Participants judged whether the name of the pictured item rhymed with the spoken word. All words were mono- or bi-syllabic. Non-rhyming pairs differed in a single phoneme, balanced across phoneme position (i.e., medial, final).

Syllable Judgment: Participants were presented with pictures whose corresponding lexical items contained one, two, or three syllables. Participants indicated whether the target word contained two syllables (e.g., "yes" response to an image of *cherry*)[1]. The 80 trials contained 40 two-syllable words, 20 one-syllable words and 20 three-syllable words in the list.

Phoneme Verification: In this task, participants were presented with a picture of a basic-level item and then decided whether the name of the item contained a particular phoneme that was presented auditorily (e.g., picture of *slippers* – audio of /g/). The image appeared on the screen for 2000ms before the audio began. Comparison phonemes were balanced across initial-, medial-, and final-word position. All words were mono- or bi-syllabic. Voiced-voiceless contrast was avoided to minimize errors due to audio presentation errors.

Phonological Name-Provided (PhN-P) Tasks—Immediately following the PhN-N task trial, the same visual stimulus was presented concurrently with its auditory name followed by comparison target sound or word. Participants were instructed that they could change the response they provided for the PhN-N trial if they believed they were previously incorrect. Since these tasks exactly mirrored the PhN-N tasks except the name of the target item was provided, performance was indicative of the ability to segment phonological information within the phonological buffer system. According to Howard and Nickels (2005), auditory rhyme judgments (and by extension, similar tasks requiring phonological segmentation of auditory information) are processed within the phonological input buffer. Similarly, in the present study, target and comparison stimuli in the PhN-P tasks were presented auditorily but unlike Howard and Nickels (2005), visual input via the pictured target item was also provided. Therefore, it is possible that some phonological manipulation or segmentation was mediated by the phonological output buffer and/or the by the connection between input and output buffers.

Procedure

All tasks were administered using E-Prime (Psychology Software Tools, Inc.) on a laptop. Participants entered their responses with their left hand using adjacent keys on the keyboard. At the beginning of each task, a tutorial was provided to familiarize the participants with the task instructions. Feedback was provided during the practice items only. Participants were asked to answer as accurately and as quickly as possible. The administration order of the nine tasks and the items within each task were randomized.

[1]Of note, due to changes in study protocols for a separate project, the last nine PWA included in this data set (i.e., P24–P32) responded with a button press of "1", "2" or "3" for items with one, two or three syllables, respectively. Performance with regards to accuracy and reaction times did not significantly differ between these participants and the participants who responded with a yes/no button press. Therefore, the responses for all PWA were included in final analyses.

Data Analysis

Accuracy and reaction times (RT) on correct trials were collected for each participant. Outliers in RT were replaced by the participant's mean RT within each task. All task trials were excluded for tasks in which RTs on over 50% of the trials exceeded 10000ms (i.e., four tasks excluded in PWA group, none for controls). Raw RTs were reported for between-group analyses. Since there was great variation in reaction time within the PWA group, raw RTs were converted into z-scores (hereafter known as zRTs) to normalize the data for within-group analyses.

To address the first aim of the study, one-way MANOVAs were used to examine the differences in accuracy and RT between groups on the nine tasks. In order to demonstrate processing trends for each task within each group per the study's second aim, hierarchical cluster analyses on group accuracy and zRT scores were performed. Lastly, to target the final aim of the study, MANOVAs and MANCOVAs (with WAB-AQ entered as the covariate) were used to test within-group effects of category and typicality on accuracy and zRTs across the nine tasks. For each set of analyses involving MANOVAs/MANCOVAs, task accuracy or zRT on each of the tasks within each task type were the dependent measures. Specifically, the first MANOVA/MANCOVA always included task accuracy/zRT for the three SEM tasks; the second analysis included task accuracy/RT for the three PhN-N tasks; and the third analysis included task accuracy/RT for the three PhN-P tasks.

Results

To ensure the ecological validity of the experimental tasks, Pearson correlations were conducted between experimental task performance and participant demographic and testing information. To account for multiple comparisons, p-values were adjusted according to the false discovery rate method of Benjamini and Hochberg (1995). After correction, no significant correlations between control demographic information and task performance were found. For PWA, the results were consistent with our expectations: all of the experimental tasks correlated with scores on WAB-R AQ (excluding Category Coordinate) and BNT (excluding PhN-P Syllable Judgement), indicating that semantic and phonological abilities as captured by the experimental tasks were significantly related to individual differences in aphasia severity and naming skills. Additionally, the SEM tasks correlated with the PPT scores, indicating that the SEM tasks indeed captured underlying semantic impairments. See Table 4 for breakdown of these correlations.

Additionally, in order to quantify the possibility of at-chance or below-chance performance within each participant group, chance values on accuracy scores were calculated for each task. The chance values indicate that as a group, not only did PWA perform better on semantic versus phonological tasks but that for a great number of PWA, any level of phonological processing rendered their task performance at- or below-chance. Conversely, all controls performed all tasks above chance accuracy. See Table 5 for further breakdown of chance performance in the PWA group.

Between-Group Differences in Task Processing

To determine the difference in accuracy and processing time between control participants and PWA on the nine tasks, one-way MANOVAs were conducted with a between-subject independent factor of group and dependent variables of task accuracy/RT. A significant main effect of group on SEM task accuracy was not found, *Pillai's trace* = .145, $F(3,37) = 2.09$, *ns*. Controls were significantly more accurate than PWA for the PhN-N tasks, *Pillai's trace* = .636, $F(3,36) = 20.94$, $p < .001$ for each task, Rhyme Judgment: $F(1,38) = 35.99$, $p < .001$; Syllable Judgment: $F(1,38) = 25.38$, $p < .001$; Phoneme Verification No-Name: $F(1,38) = 66.14$, $p < .001$. Similarly, a significant main effect of group on accuracy was noted for the PhN-P tasks, *Pillai's trace* = .548, $F(3,36) = 14.56$, $p < .001$, with the univariate analyses revealing that PWA had significantly lower accuracy on each of these tasks, Rhyme Judgment: $F(1,39) = 25.92$, $p < .001$; Syllable Judgment: $F(1,39) = 10.12$, $p < .01$; Phoneme Verification: $F(1,39) = 43.23$, $p < .001$.

For processing time, a significant main effect of group on RT was seen for the SEM tasks, *Pillai's trace* = .564, $F(3,37) = 15.92$, $p < .001$, with significant univariate between-group differences for each task, Category Coordinate: $F(1,39) = 34.24$, $p < .001$; Category Superordinate: $F(1,39) = 40.43$, $p < .001$; Semantic Feature: $F(1,39) = 44.14$, $p < .001$. Controls were significantly faster for the PhN-N tasks, *Pillai's trace* = .542, $F(3,33) = 13.02$, $p < .001$, and the univariate effects were also significant for each task, all at the $p < .001$ level. Similar to the other two task types, a significant between-group difference was found for the PhN-P tasks, *Pillai's trace* = .506, $F(3,36) = 12.30$, $p < .001$, and once again, the univariate analyses revealed between-group differences for each task, all significant at $p < .001$. Overall, these results demonstrate that PWA were significantly slower to respond than controls across all tasks but had significantly lower accuracy for phonological tasks only (see Figures 2a–2b).

Clustering within Groups

Interestingly, visual inspection of the between-group results revealed that despite group differences in processing accuracy and speed, there appeared to be similar trends in task performance across groups. Therefore, for each group, task accuracy and zRT[2] were entered into hierarchical joining tree cluster analyses to further elucidate these trends and characterize task performance. Euclidean distances were computed with all clusters weighted equally using the single linkage distance. Based on the amalgamation schedule and plots of single linkage distance, a linkage distance cutoff at 75 points was chosen.

Hierarchical Cluster Analyses by Accuracy—For the PWA, three distinct clusters emerged after the cutoff. Cluster 1 contained all phonological tasks excluding Syllable-Judgment N-P; cluster 2 contained Syllable Judgment N-P alone; and cluster 3 was comprised of the three SEM tasks. In the control group, three clusters also emerged after the cutoff: cluster 1 was the largest, containing all SEM tasks, all PhN-P tasks, and Rhyme Judgment N-N; cluster 2 contained Syllable Judgment N-N alone and cluster 3 contained

[2]As the hierarchical cluster analyses were within-group analyses, zRT, not raw RT, was used so that the great variability within the group of PWA could be accounted for and comparisons could be made without mistakenly inflating or deflating the results.

Phoneme Verification N-N alone. For the PWA, the separate clusters of semantic and phonological tasks verified the discrepancy in their semantic and phonological processing abilities. Accuracy also was highest on the semantic tasks for the controls, but their performance on the phonological tasks was comparable to their semantic task performance except for two PhN-N tasks (see Figure 3).

Hierarchical Cluster Analyses by zRT—For zRT, two distinct clusters emerged in the PWA reaction time data. Cluster 1 contained the three PhN-N tasks and cluster 2 contained all PhN-P and SEM tasks. Three clusters resulted from the control reaction time data. Similar to the PWA data, cluster 1 contained the three PhN-N tasks, and cluster 2 contained Rhyme Judgment N-P, Phoneme Verification N-P, and all SEM tasks while Syllable Judgment N-P stood alone in cluster 3. Overall, these results demonstrate that both groups needed significantly longer time to make judgments when lexical access, phonological processing and phonological segmentation were required, as demonstrated by the PhN-N tasks existing in separate clusters for each group (see Figure 4).

Category and Typicality Effects within Groups

For each of these analyses, the independent measure was the lexical-semantic variable (i.e., either category or typicality). The dependent measures were accuracy/zRT values for each task within each of the three task types.

Category—For PWA, the main effect of category on accuracy was significant for the SEM tasks, *Pillai's trace* = .267, $F(15,540) = 3.52$, $p < .001$, and univariate analysis revealed a significant category effect for each task, Category Coordinate: $F(5,180) = 2.34$, $p < .05$; Category Superordinate: $F(5,180) = 4.50$, $p < .001$; Semantic Feature: $F(5,180) = 2.89$, $p < .05$. Pairwise comparisons between categories revealed a general trend of significantly higher accuracy for living categories (i.e., *birds* and *vegetables*) versus nonliving categories (i.e., *clothing*, *furniture* and *transportation*) for Category Coordinate, the opposite trend in Semantic Feature accuracy, and no apparent trend for living/nonliving things in Category Superordinate. A significant category effect on accuracy was not found for the PhN-N, *Pillai's trace* = .080, $F(15,522) = .95$, *ns*, or PhN-P tasks, *Pillai's trace* = .035, $F(15,522) = .42$, *ns*.

Similar to PWA, the effect of category on accuracy in the SEM tasks was significant for the control participants, *Pillai's trace* = 1.00, $F(15,162) = 5.40$, $p < .001$, specifically for Category Coordinate, $F(5, 54) = 10.79$, $p < .001$, and Semantic Feature, $F(5, 54) = 10.32$, $p < .001$. Unlike PWA, controls were most accurate on *clothing* relative to other categories in Category Coordinate although accuracy on *birds* and *fruits* was significantly higher than *furniture* and *transportation*. Similar to the PWA, controls' accuracy was highest for *clothing* and *furniture* in Semantic Feature. A significant effect of category on accuracy was not observed in the PhN-N tasks, *Pillai's trace* = .397, $F(15,162) = 1.65$, *ns*. In the PhN-P tasks, a main effect of category on accuracy was significant for the overall model, *Pillai's trace* = .531, $F(15,162) = 2.32$, $p < .01$, but the univariate analyses revealed no significant effects of category on any of the individual tasks, Rhyme Judgment: $F(5, 54) = 2.08$, *ns*; Syllable Judgment: $F(5, 54) = 1.77$, *ns*; Phoneme Verification: $F(5, 54) = .31$, *ns*.

No significant main effects of category on PWA zRT were found for the SEM, *Pillai's trace* = .115, $F(15,540) = 1.44$, *ns*, PhN-N, *Pillai's trace* = .114, $F(15,468) = 1.23$, *ns*, or PhN-P tasks, *Pillai's trace* = .134, $F(15,522) = 1.63$, *ns*. Category did not have a significant main effect on zRT across tasks within the three task types for controls either, SEM: *Pillai's trace* = .192, $F(15,162) = .74$, *ns*; PhN-N: *Pillai's trace* = .400, $F(15,162) = 1.66$, *ns*; PhN-P: *Pillai's trace* = .221, $F(15,162) = .86$, *ns*. Overall, item category did not significantly impact accuracy in the six phonological tasks or reaction times on any task for either group, but both groups showed a category effect on accuracy for tasks specifically targeting semantic processing (see Figure 5a–b).

Typicality—A significant effect of typicality on SEM task accuracy was found for the PWA, *Pillai's trace* = .184, $F(3,58) = 4.37$, $p < .01$. Specifically, PWA were significantly more accurate for typical relative to atypical items in Category Coordinate, $F(1,60) = 5.11$, $p < .05$, and Category Superordinate, $F(1,60) = 8.17$, $p < .01$, but not in Semantic Feature, $F(1,60) = .14$, *ns*. The effects of typicality on accuracy were not significant in the PhN-N, *Pillai's trace* = .065, $F(3,56) = 1.30$, *ns*, or the PhN-P tasks, *Pillai's trace* = .051, $F(3,56) = 1.00$, *ns*. For controls, the multivariate main effect of typicality on accuracy approached significance for the SEM tasks, *Pillai's trace* = .374, $F(3,16) = 3.18$, $p = .052$. Similar to PWA, controls demonstrated a significant typicality effect only for Category Coordinate, $F(1,20) = 8.61$, $p < .01$, and Category Superordinate, $F(1,20) = 6.62$, $p < .05$. Significant effects of typicality on accuracy were not observed in the PhN-N, *Pillai's trace* = .220, $F(3,16) = 1.51$, *ns*, or PhN-P tasks, *Pillai's trace* = .045, $F(3,16) = .25$, *ns*.

For reaction times, a main effect of typicality on PWA zRT was found for the SEM tasks, *Pillai's trace* = .126, $F(3,58) = 2.78$, $p < .05$. Specifically, PWA's response times were significantly faster for typical relative to atypical items in Category Superordinate, $F(1,60) = 4.46$, $p < .05$. An effect of typicality on zRT was not found for the PhN-N, *Pillai's trace* = .090, $F(3,50) = 1.65$, *ns*, or PhN-P tasks, *Pillai's trace* = .021, $F(3,56) = .41$, *ns*. In the control group, no significant effects of typicality on zRT were found across tasks within the three task types, SEM: *Pillai's trace* = .255, $F(3,16) = 1.82$, *ns*; PhN-N: *Pillai's trace* = .062, $F(3,16) = .35$, *ns*; PhN-P: *Pillai's trace* = .079, $F(3,16) = .46$, *ns*.

Collectively, these results indicate that both PWA and controls were more accurate on typical examples compared to atypical examples within semantic tasks that specifically access category knowledge but typicality did not impact feature judgments or tasks involving any level of phonological processing (see Figure 6a). The effect of typicality on reaction times was significant only for one semantic task for the PWA; no other significant effects of typicality on reaction times were seen in either group (see Figure 6b).

Follow-Up Analyses: Category and Typicality Effects by Aphasia Severity

Lastly, we investigated whether effects of category and typicality on task accuracy and zRT co-varied by aphasia severity (i.e., WAB-AQ scores) within the group of PWA by performing MANCOVAs. For SEM task accuracy, WAB-AQ significantly contributed to the overall model, *Pillai's trace* = .288, $F(3, 165) = 22.21$, $p < .001$, with a significant main effect of category still observed, *Pillai's trace* = .479, $F(15, 501) = 6.35$, $p < .001$, and significant univariate effects seen for all three tasks, Category Coordinate: $F(5, 167) = 3.54$, $p < .01$; Category Superordinate: $F(5, 167) = 19.37$, $p < .001$; and Semantic Feature: $F(5, 167) = 3.07$, $p < .05$. When including WAB-AQ as a covariate, no significant effects of category on PhN-N and PhN-P accuracy or on zRT across tasks were found. WAB-AQ also significantly contributed to the model of typicality effects on SEM task accuracy, *Pillai's trace* = .671, $F(3, 53) = 35.97$, $p < .001$, and a significant main effect of typicality was observed, *Pillai's trace* = .348, $F(3, 53) = 9.43$, $p < .001$; significant univariate effects of typicality on accuracy were still seen in Category Coordinate, $F(1,55) = 7.29$, $p < .01$, and Category Superordinate, $F(1,55) = 27.13$, $p < .001$. However, WAB-AQ did not significantly contribute to the overall significant effect of typicality on SEM task zRT, *Pillai's trace* = .033, $F(3, 53) = .60$, *ns*. Typicality with the WAB-AQ covariate did not significantly impact accuracy or zRT on any of the PhN-N or PhN-P tasks. Overall, these results indicate that the effects of category and typicality on SEM task accuracy were influenced by aphasia severity whereas typicality effects on zRT were still found but aphasia severity was not a factor in this effect.

Discussion

Overall, the present study aimed to accomplish three main objectives: 1) to examine differences in semantic/phonological processing between healthy controls and PWA; 2) to investigate the differences in processing demands according to task within each group; and 3) to determine how the semantic variables of category and typicality affect different stages of semantic/phonological processing.

Based on a framework of lexical processing in which semantic processes flow into phonological processes, we expected PWA would exhibit greater phonological than semantic processing impairments. This hypothesis proved accurate; PWA had significantly lower accuracy on all phonological tasks than controls whereas accuracy differences in the semantic tasks did not reach significance. Only two PWA performed with at-chance accuracy on the semantic tasks, while up to 20 PWA performed at-chance on the phonological tasks. In light of relatively intact skills for correctly making semantic judgments, PWA's slowed reaction times on the semantic tasks may still align with slowed/impaired semantic processing as is expected in this population (Butterworth, Howard, & McLoughlin, 1984; Copland, Chenery, & Murdoch, 2000; Howard & Gatehouse, 2006; Jefferies & Lambon Ralph, 2006; Kiran, et al., 2007; Kiran & Thompson, 2003). These results were consistent with the view that the semantic system must be accessed before phonological information is processed and that there are more opportunities for impaired phonological than semantic access (Howard & Gatehouse, 2006).

The hierarchical cluster analyses further highlighted the distinction between processing within each group. For controls, similar processing demands were required for parsing semantic information (as in the SEM tasks) as was needed for manipulating phonological information without lexical access (as was required in the PhN-P tasks). Similar clustering was seen for PWA reaction times, yet a reaction time/accuracy tradeoff for this group was observed. Specifically, the PWA accuracy clusters revealed a very different trend in which task accuracy clustered closely for all three SEM tasks and the distance was pronounced between the semantic cluster and the cluster containing most of the phonological tasks. The combined results from the MANOVA and cluster analyses suggest PWA experienced the most ease with tasks requiring semantic processing but struggled to *successfully* complete tasks requiring any level of phonological processing and access, regardless of whether they were provided with the target word. Therefore, it can be concluded that the greatest impairments in the present group of PWA were observed at the level of the POL and the phonological buffer.

After establishing the differences in general semantic and phonological processing within each group, the main impetus of the present study was to examine the effects of category and typicality within each stage of processing. As expected, category significantly impacted accuracy in most of the SEM tasks for both groups, and PWA still showed differences in their accuracy for different categories even after accounting for aphasia severity. The results for both groups suggest that categories of living things receive preferential processing over nonliving categories when overt category knowledge is required (Barton & Komatsu, 1989; Devlin, et al., 2002; Diesendruck & Gelman, 1999; Vanoverberghe & Storms, 2003). The opposite effects seen in Semantic Feature (i.e., nonliving categories of *clothing* and *furniture* were more accurate) suggest that the inherent familiarity of these categories may have impacted feature decisions (Malt and Smith; 1982) yet category did not significantly affect processing time for Semantic Feature or any of the SEM tasks in either group.

With regards to typicality, both PWA and controls demonstrated higher accuracy for typical relative to atypical items for Category Coordinate and Category Superordinate but not Semantic Feature. Arguably, the former two tasks require overt access to category structure, including typicality, while Semantic Feature requires a different type of semantic processing. Furthermore, according to the MANCOVA results, typicality significantly and differentially impacted accuracy for PWA with different impairment levels but the effects of typicality on zRT in Category Superordinate were not influenced by aphasia severity. Otherwise, item typicality did not significantly impact reaction times in either group. It is possible that the null results are related to the fine-grained nature of typicality compared to the general, gross semantic processing demands of the experimental tasks. Generally, however, the results of the typicality effects on accuracy in the SEM tasks support previous findings in other semantic processing tasks in PWA (Kiran et al., 2007; Kiran & Thompson, 2003; Sandberg et al., 2012).

We predicted that the presence of the category and typicality effects on phonological processing would depend on the task type and the discrete or interactive nature of lexical processing. According to interactive processing models, semantic variables such as category and typicality should influence phonological processes, but such findings would not be expected according to discrete serial models. In the present study, the PhN-N tasks required lexical access and thereby required all stages of semantic and phonological processing, excluding articulation. The PhN-P tasks did not necessitate lexical retrieval and therefore were designed to capture processing *primarily* within the phonological buffer system. It is probable, though, that the pictured stimulus in each PhN-P task still triggered the flow of semantic information. Therefore, whether phonological processing in these tasks occurred within the input buffer, the output buffer, or in the flow of information between these two phonological buffers (see Howard & Nickels, 2005), it was likely that some amount of semantic processing in addition to processing within the buffer system still occurred. Ultimately, no effects of category or typicality were found in any of the PhN-N or PhN-P tasks. Taken together, the absence of semantic variable effects on any of the phonological tasks is suggestive of discrete versus interactive processing. However, alternative conclusions should also be considered.

First, it is probable that these results were influenced by the interaction of two major aspects of cognitive-linguistic processing: the integrity of the cognitive system(s) mediating lexical processing and the manner in which those systems were taxed by the different tasks. For control participants, who have intact language, the dearth of category and typicality effects in the PhN-N tasks may be partially explained by a lack of power (due to the small number of control participants and the few items within each category/typicality) and/or their overall high accuracy across tasks (i.e., a ceiling effect). For PWA, who clearly do not have intact language, their anomia likely rendered the PhN-N the most difficult of the three task types, but they also struggled with the PhN-P tasks which required segmentation, not word form retrieval. Segmentation is an inherently phonological task, and it is possible that the added challenge of segmenting targets in the PhN-N tasks overrode the effects of the inherently semantic variables of category and typicality. Furthermore, successful completion of these tasks relied on intact input processing of the comparison phoneme (as in Phoneme Verification N-N) or word (as in Rhyme Judgment N-N). Some researchers (e.g., Howard & Franklin, 1990; Monsell, 1987) posit that it is a necessary connection between input and output forms that mediates inner rehearsal of information. Therefore, it is possible that a subset of participants did poorly on these tasks due to impaired input processing or a damaged connection between input and output processes.

Secondly, while the large, representative sample of PWA in the current study lends itself to making general inferences about the semantic and phonological processing abilities in other PWA, some of the positive qualities of a case-series design are lost. Specifically, it was not feasible with such a large sample to perform lengthy assessments to characterize the exact locus of deficit in each participant, yet the literature in aphasia has demonstrated that there can be an interaction between level of deficit and the psycholinguistic variables that impact processing within a certain system (Howard & Gatehouse, 2006). One of the limitations of the current study is the lack of standardized testing of phonological skills and the inability to validate exact locus of breakdown within this sample. Beyond the MANCOVA analyses, we did not extensively examine possible intra-group differences in processing. In particular, we did not examine differences according to aphasia profile or type as we view aphasia profiles on a continuum and are attempting to move away from a dichotomous (and sometimes erroneous) way of grouping PWA. However, as experimental task performance did correlate with standardized test scores, the current results do reflect the individual differences seen in this large sample.

Lastly, the context of lexical processing in the current study is quite different than other studies with results that suggest that semantic variables can affect subsequent stages of phonological processing (e.g., treatment studies wherein generalization occurs from trained atypical to untrained typical items within a given category; see Kiran, 2007, 2008; Kiran &

Johnson, 2008; Kiran, Sandberg, & Sebastian, 2011; Kiran & Thompson, 2003). For example, within these treatment studies, PWA attempt to name pictured items following a semantic feature-based protocol over the course of several weeks; therefore, their phonological processing is embedded within the context of an entrenched semantically-rich environment. By comparison, the PhN-N tasks in the present study were relatively semantically-impoverished and were administered a single time. Furthermore, unlike treatment studies, overt word production was not required in the present study. While many PWA demonstrate similar levels of inner and overt speech abilities, some PWA have relatively better-preserved overt speech while other PWA demonstrate the reverse pattern (Geva et al., 2011). Therefore, different effects of category/typicality may have been seen if overt production was required.

While further study may be needed to further elucidate the discrete or interactive processes involved with lexical processing, the present results do have several important clinical implications. First, the findings show that PWA of varying aphasia severity levels overwhelmingly demonstrate relatively intact abilities to perform a variety of semantic tasks that can be used to scaffold semantic processing in a therapeutic setting. Furthermore, this study highlights the difficulty many PWA demonstrate with tasks requiring phonological segmentation and manipulation; in fact, many PWA performed at- or below-chance accuracy for these tasks. Therefore, it is important for clinicians to keep this fact in mind when administering therapies that require PWA to perform syllable, rhyme, or phoneme tasks (e.g., Phonological Components Analysis; Leonard, Rochon, & Laird, 2008). Lastly, this study presents some preliminary evidence that clinicians should carefully choose their stimuli according to category/typicality when addressing semantic processing deficits in PWA, but these variables may not need to be considered when targeting phonological processing.

Conclusions

In summary, the present study investigated the semantic and phonological processing skills in PWA versus healthy controls and the influence of semantic variables on these processes in each group. Overall, healthy controls and PWA demonstrated comparable ability to make semantic judgments while PWA were significantly less accurate and slower on all phonological tasks. The effects of category and typicality were present only in tasks requiring semantic processing in both participant groups. These results aligned best with the framework of discrete serial models of lexical processing but further considerations regarding the nature of lexical processing and other avenues to investigate these processes are warranted.

Acknowledgments

The authors thank Jeffrey Johnson, Sarah Villard, Carrie Des Roches, Elsa Ascenso, and Isabel Balachandran for their assistance in data collection. We also extend our gratitude to all the individuals who participated in the study.

This study was supported by the National Institutes of Health/National Institute on Deafness and Other Communication Disorders through grants NIH/NIDCD R33DC010461, 5K18DC011517-02 and 1P50DC012283.

APPENDIX A: Sample stimuli from six categories used in semantic and phonological tasks in the current study

Living Categories					
Vegetables		***Birds***		***Fruit***	
Typical	**Atypical**	**Typical**	**Atypical**	**Typical**	**Atypical**
broccoli	lima beans	sparrow	pelican	orange	kiwi
carrot	pumpkin	pigeon	swan	banana	fig
celery	okra	parakeet	goose	grape	raisin
cucumber	yam	lark	ostrich	strawberry	lime
green pepper	scallion	dove	flamingo	apple	guava
onion	kidney beans	woodpecker	vulture	cherry	prune
radish	rutabaga	robin	hummingbird	grapefruit	pomelo
cabbage	garlic	eagle	chicken	mango	huckleberry
asparagus	rhubarb	owl	duck	watermelon	currant
brussel sprouts	mushroom	bluejay	penguin	plum	kumquat
cauliflower	alfalfa	chickadee	turkey	peach	plantain
squash	olives	cardinal	peacock	pear	coconut

Nonliving Categories					
Furniture		***Transportation***		***Clothing***	
Typical	**Atypical**	**Typical**	**Atypical**	**Typical**	**Atypical**
bed	cot umbrella	truck	hot air balloon	pants	turban
sofa	stand	bus	raft	shirt	suspenders
dresser	carpet	van	submarine	jeans	veil
coffee table	wastebasket	taxi	sled	T-shirt	cape
desk	curtains	motorcycle	space ship	shorts	cummerbund
night stand	chandelier	plane	hang glider	sweater	apron
bookcase	blinds	subway	skis	skirt	bandana
recliner	hammock	jet	blimp	dress	ski mask
ottoman	pillow	train	stilts	suit	earmuffs
loveseat	stove	semi	carriage	underpants	helmet
cabinet	refrigerator	bicycle	tricycle	uniform	hat
toy box	sink	trolley	kayak	coat	shoe

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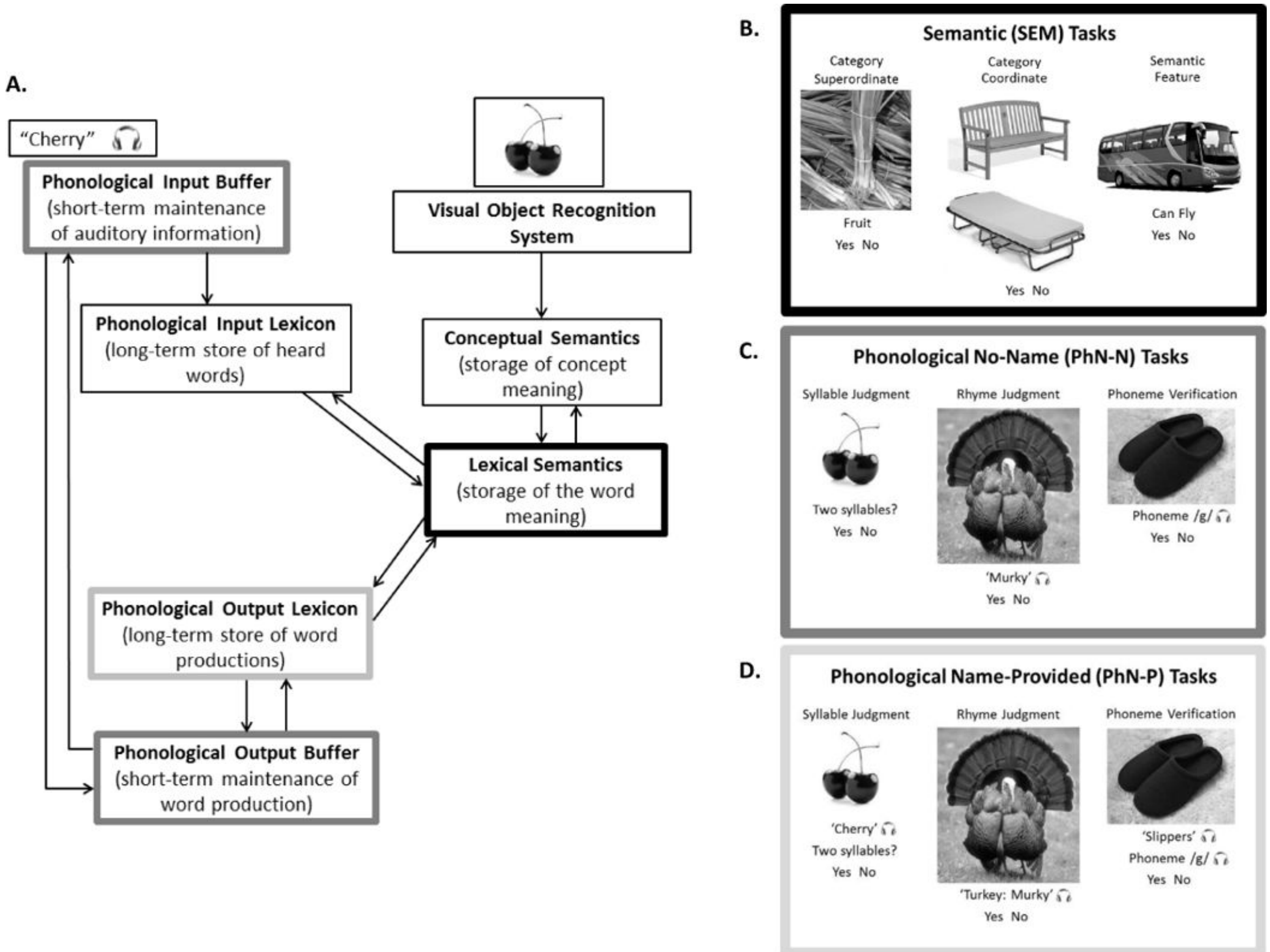

Figure 1.

Schematic representation of the tasks implemented in the current study and the stage of lexical processing each task primarily taxed, as indicated by matching outlines within stages of the model in (A) and the task outlines (B–D). A. Schematic of Lexical Processing, B. Semantic Tasks, C. Phonological No-Name tasks, D. Phonological Name-Provided tasks. See text for details.

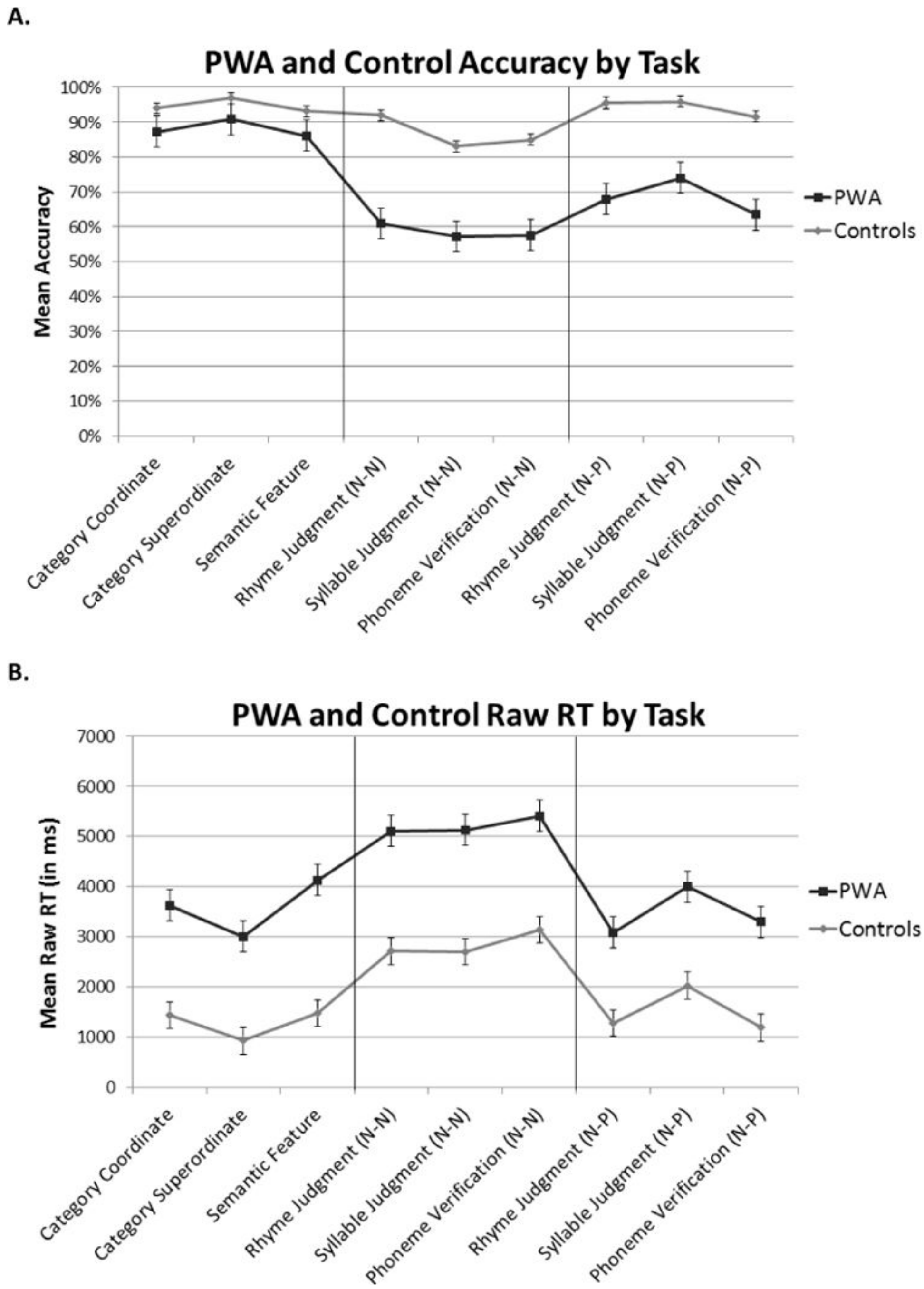

Figure 2.

Between-group difference in overall accuracy (A) and mean RT (B) in the nine tasks. Task types are separated by a vertical line with SEM task scores listed first, followed by PhN-N task scores and then PhN-P scores.

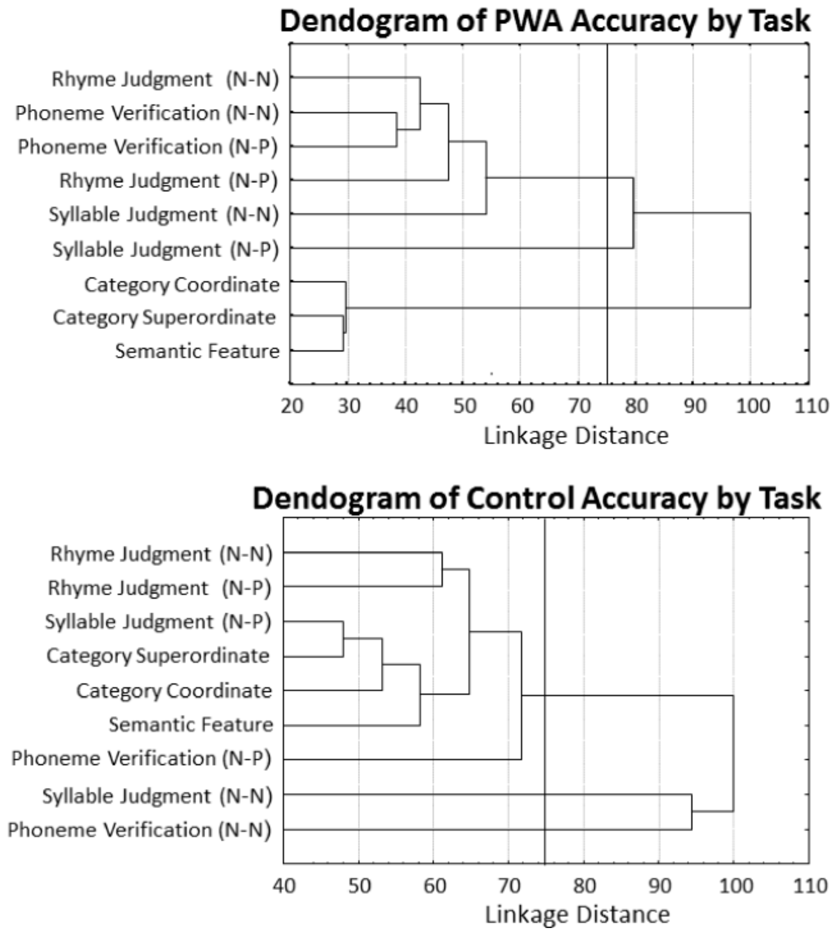

Figure 3.

Dendograms of the hierarchical cluster analyses of accuracy within each group. Tasks are clustered along the vertical axis. Standardized linkage distance is plotted along the horizontal axis with the cutoff linkage distance of 75 denoted by a vertical line.

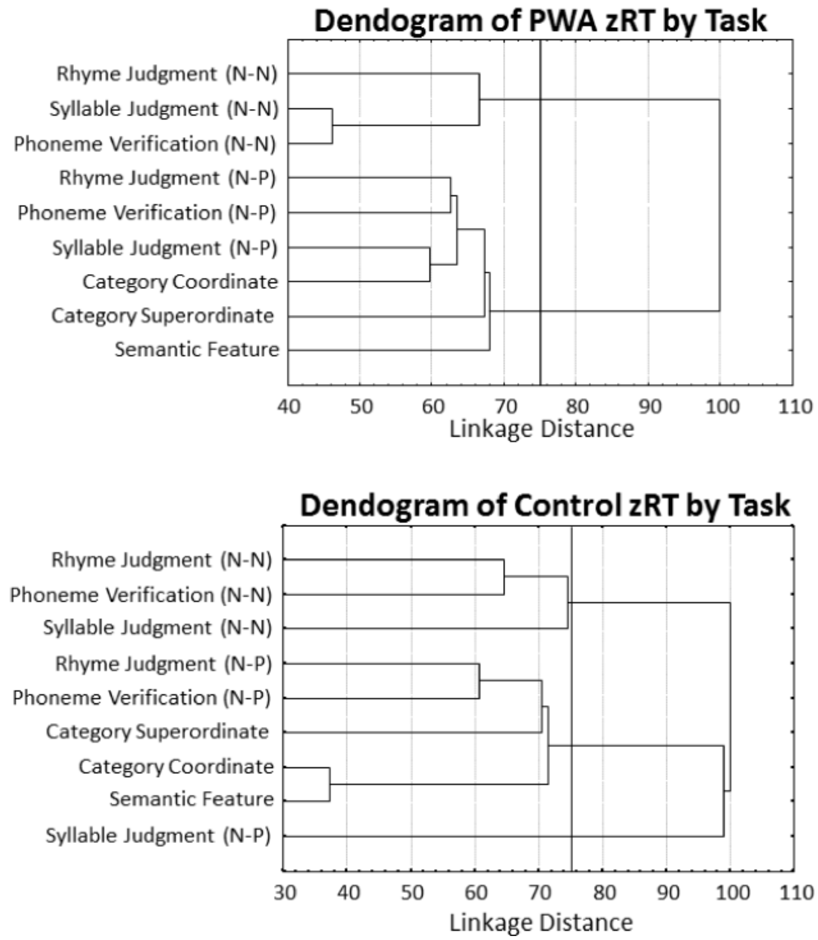

Figure 4.

Dendograms of the hierarchical cluster analyses of zRT within each group. Tasks are clustered along the vertical axis. Standardized linkage distance is plotted along the horizontal axis with the cutoff linkage distance of 75 denoted by a vertical line.

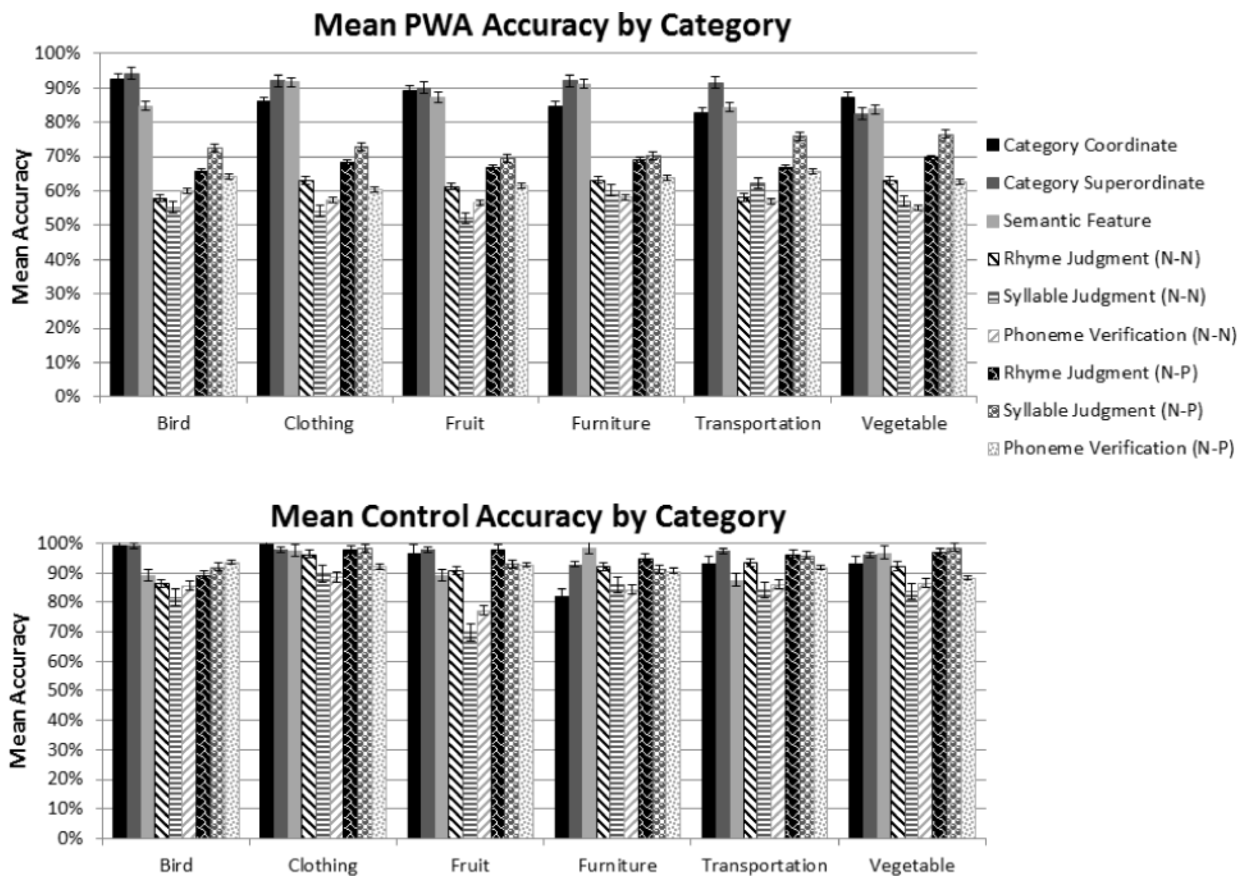

Figure 5a.

Mean PWA and control accuracy by category (*bird*, *clothing*, *fruit*, *furniture*, *vegetable*, and *transportation*)

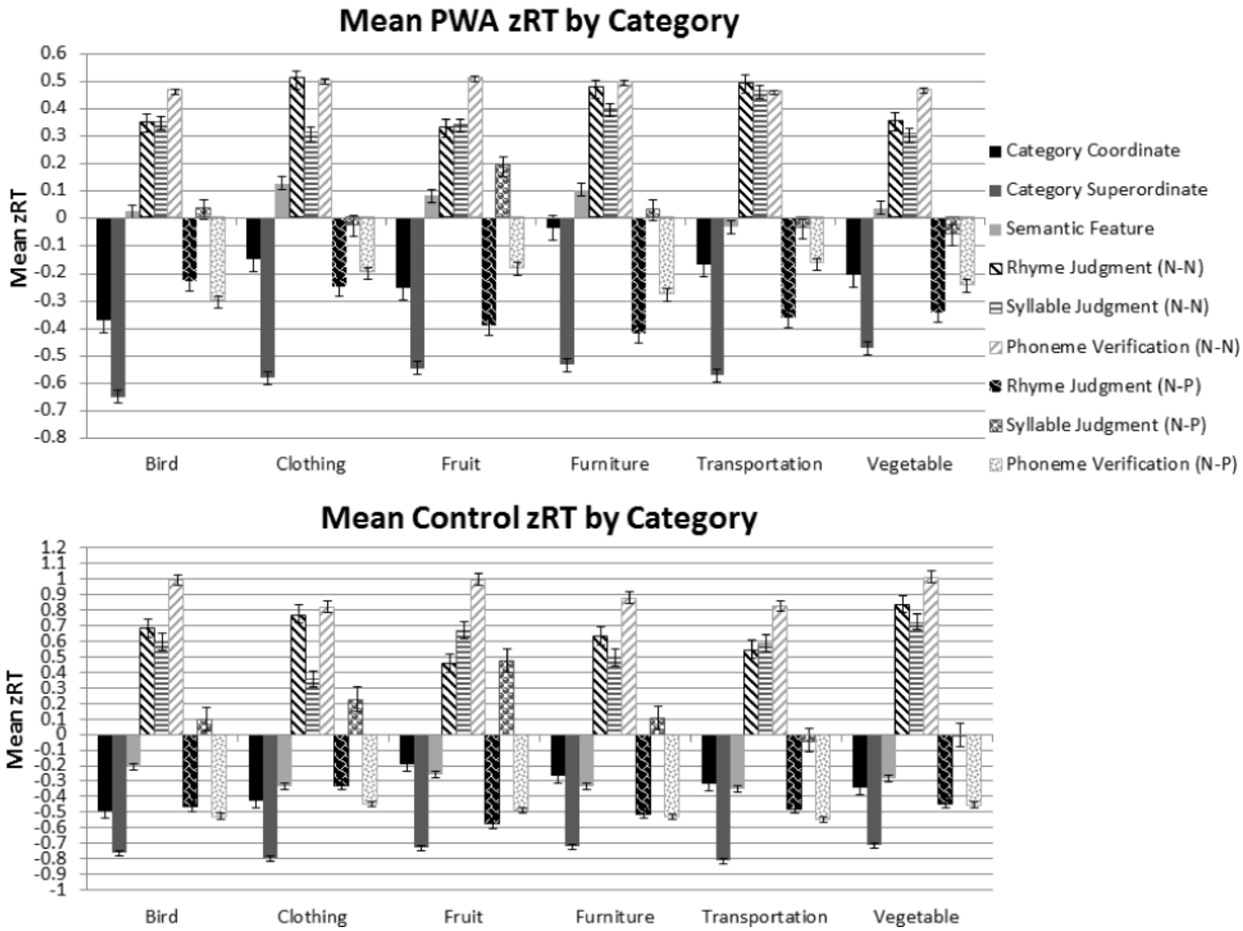

Figure 5b.

Mean PWA and control zRT by category (*bird*, *clothing*, *fruit*, *furniture*, *vegetable*, and *transportation*) across the nine tasks.

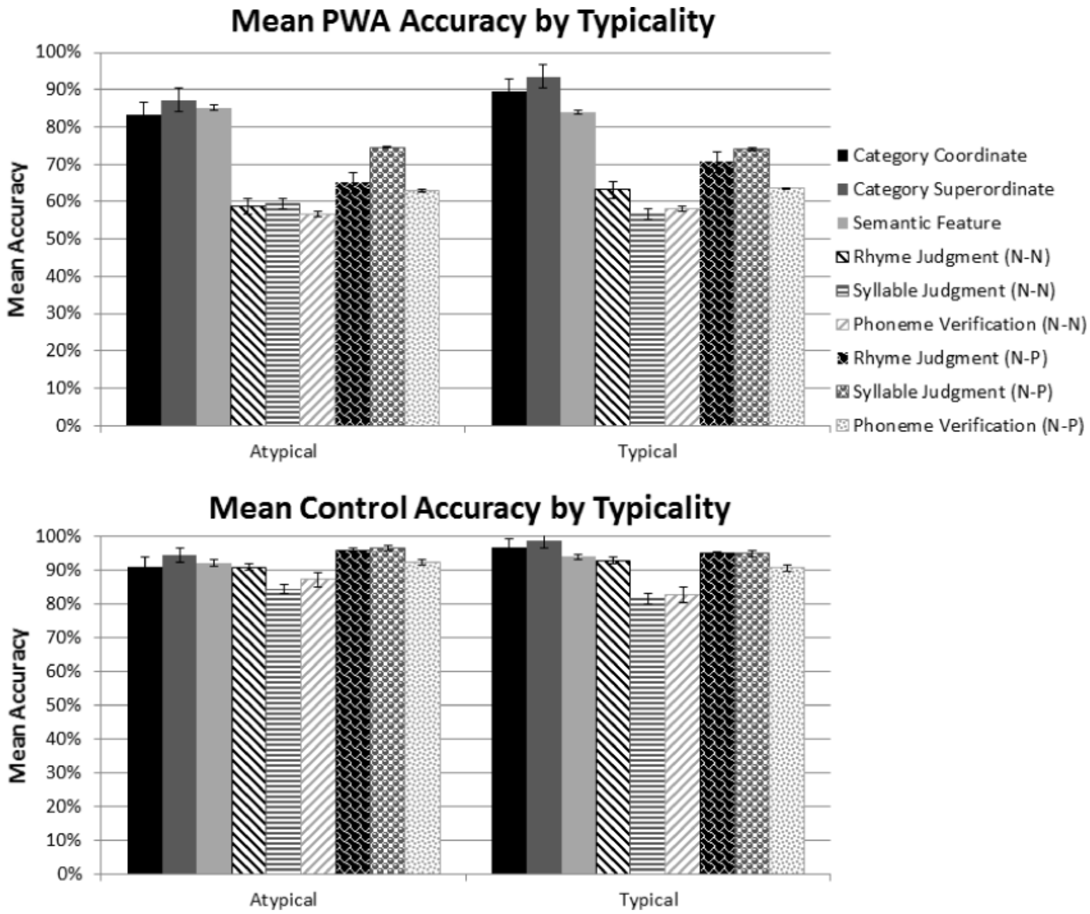

Figure 6a.
Mean PWA and control accuracy by typicality across the nine tasks.

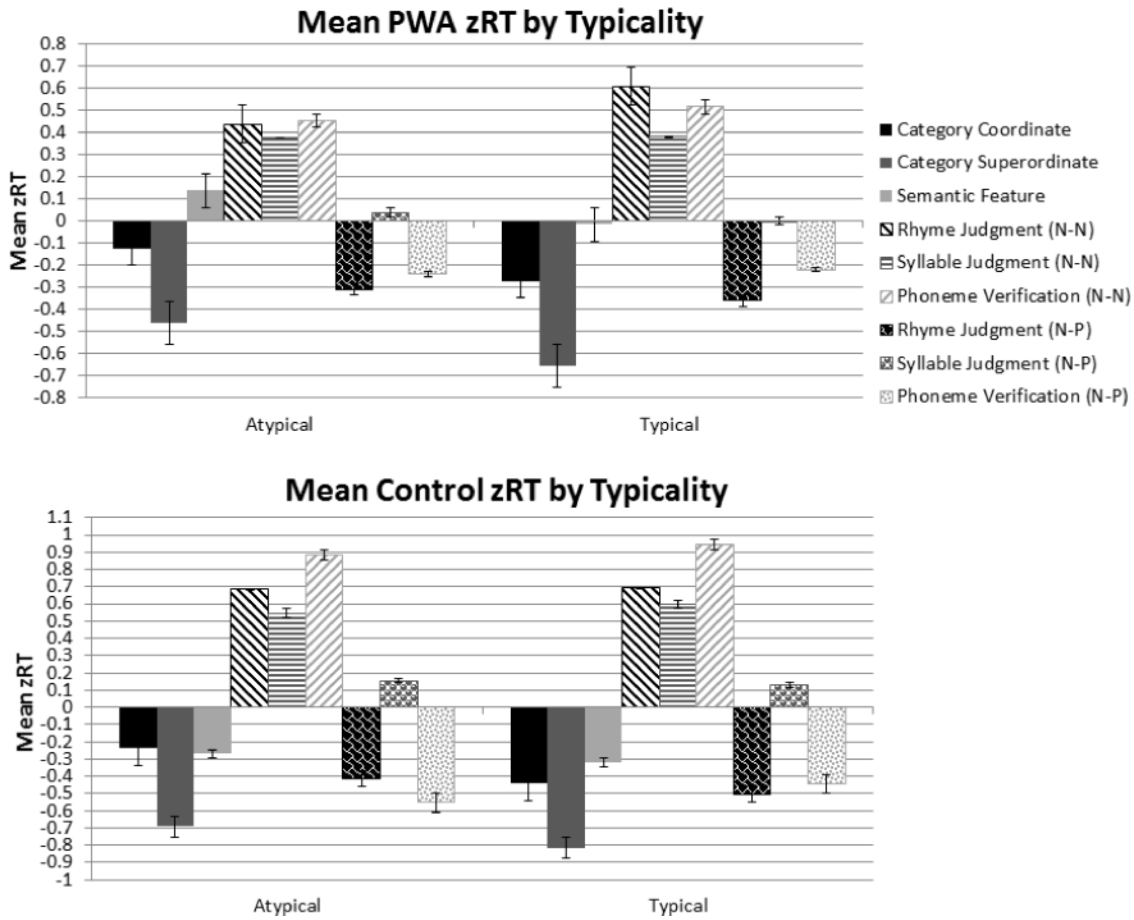

Figure 6b.

Mean PWA and control zRT by typicality across the nine tasks.

Table 1a

Demographic information for all PWA. P10 education information is unavailable because the participant dropped out of the study before data were obtained. W = White, B = Black, A = Asian; NR = No Response

Participant	Group	Age	Years of Education	Handedness	Gender	Race/Ethnicity	MPO	Aphasia Type
P1	PWA	56	16	R	F	W	75	Anomic
P2	PWA	51	16	R	M	W	115	Broca's
P3	PWA	65	15	R	M	NR	50	Broca's
P4	PWA	54	16	R	M	W	94	Wernicke's
P5	PWA	48	16	R	M	W	86	Broca's
P6	PWA	66	18	R	F	W	70	Conduction
P7	PWA	70	12	R	M	W	168	Global
P8	PWA	49	12	R	M	W	156	Broca's
P9	PWA	67	18	R	M	W	22	Broca's
P10	PWA	83	N/A	R	F	W	22	N/A
P11	PWA	59	12	L	M	W	36	Anomic
P12	PWA	70	12	R	M	W	24	Wernicke's
P13	PWA	63	18	R	F	B	26	Anomic
P14	PWA	86	12	L	M	W	22	Anomic
P15	PWA	50	18	R	F	W	33	Anomic
P16	PWA	72	18	R	M	B	22	Conduction
P17	PWA	53	16	R	M	W	27	Anomic
P18	PWA	37	16	L	F	W	34	Anomic
P19	PWA	82	16	R	F	W	47	Anomic
P20	PWA	66	12	R	M	W	24	Anomic
P21	PWA	61	18	R	M	W	51	Anomic
P22	PWA	89	17	R	F	W	126	N/A
P23	PWA	68	18	R	M	W	20	Anomic
P24	PWA	63	13	R	F	W	63	Conduction
P25	PWA	63	18	R	F	W	99	Conduction
P26	PWA	55	16	R	M	B	13	Anomic

Participant	Group	Age	Years of Education	Handedness	Gender	Race/Ethnicity	MPO	Aphasia Type
P27	PWA	50	13	L	F	W	31	Global
P28	PWA	26	15	R	M	W	39	Anomic
P29	PWA	49	12	R	M	B	50	Anomic
P30	PWA	79	16	R	M	W	14	Conduction
P31	PWA	68	18	R	M	A	10	Wernicke's
P32	PWA	70	12	R	F	W	63	Anomic
AVERAGE		*62.13*	*15.32*	28R, 4L	20M, 12F		*54.13*	
Stdev		13.87909	2.3858904				41.58	

Table 1b

Demographic information for all control participants. W = White, B = Black, A = Asian

Participant	Group	Age	Years of Education	Handedness	Gender	Race/Ethnicity
C1	Control	54	18	R	F	W
C2	Control	45	18	R	F	W
C3	Control	54	18	R	F	W
C4	Control	44	16	R	M	W
C5	Control	55	12	R	M	B
C6	Control	58	12	L	M	W
C7	Control	66	18	R	F	W
C8	Control	60	16	R	M	W
C9	Control	65	14	R	M	W
C10	Control	68	20	R	M	W
AVERAGE		*56.90*	*16.20*	9 R, 1L	6M, 4F	
Stdev		*8.24*	*2.74*			

Table 2

Patient performance on WAB-R (Kertesz, 2006), BNT (Kaplan et al., 2001), and PPT (Howard & Patterson, 1992). Selected information for P10, P13 and P22 is unavailable because the participants dropped out of the study before the data were obtained.

Participant	WAB AQ	BNT score	PPT score
P1	80.2	34	50
P2	48	4	46
P3	49.6	9	50
P4	44.9	24	48
P5	72.5	49	47
P6	70.1	37	47
P7	10.2	0	35
P8	55.5	35	50
P9	58.6	18	40
P10	N/A	N/A	N/A
P11	85.8	49	49
P12	46.2	0	34
P13	67.7	8	N/A
P14	88.1	34	42
P15	93.9	59	51
P16	76.7	51	48
P17	91	28	49
P18	77.9	33	50
P19	92.7	57	50
P20	97.2	39	48
P21	85	51	48
P22	N/A	N/A	N/A
P23	95	46	50
P24	52	10	47
P25	53.4	9	50
P26	87.2	50	50
P27	21.2	1	49
P28	77.6	43	49
P29	85.5	53	50
P30	90	52	49
P31	31.2	4	48
P32	86.6	42	38
AVERAGE	*69.05*	*30.97*	*46.97*
Stdev	23.24	19.71	4.59

Table 3

Familiarity and spoken word frequency (Frequency CobSIM; CELEX, 1993) written word frequency (Frequency FK; Frances & Kucera, 1982).

Category	Bird	Clothing	Fruit	Furniture	Transportation	Vegetable
Average typicality rating (1 to 5 scale)	1.86	2.55	2.42	4.06	2.73	2.59
Typical items z-score *AVERAGE*	−1.86 to −0.19 *−0.80*	−1.43 to −0.03 *−0.85*	−1.59 to 0.13 *−0.78*	−1.63 to −0.21 *−0.91*	−1.63 to −0.11 *−0.95*	−1.25 to −0.02 *−0.66*
Atypical items z-score *AVERAGE*	−0.19 to 2.16 *0.79*	0.05 to 1.96 *0.89*	0.22 to 2.51 *0.87*	−0.06 to 1.54 *0.87*	0.08 to 1.83 *0.82*	0.04 to 3.00 *0.97*
Familiarity (Avg ± stdev)	437.06 ± 76.08	541.87 ± 45.76	526.43 ± 58.06	538.41 ± 74.11	516.29 ± 67.09	469.87 ± 98.60
Frequency CobSIM (Avg ± stdev)	1.13 ± 2.25	2.51 ± 4.52	0.50 ± 1.00	4.78 ± 11.98	12.27 ± 44.14	1.11 ± 3.57
Frequency FK (Avg ± stdev)	5.81 ± 8.02	18.07 ± 19.30	14.53 ± 26.93	34.31 ± 47.14	27.52 ± 33.52	7.45 ± 9.97

Table 4

Correlations between demographic factors and standardized scores and individual task scores and average accuracy scores in each group. Strong correlations (>.6) indicated by three asterisks; moderate correlations (.5≥.6) indicated by two asterisks, and weak correlations (<.5) indicated by one asterisk.

Correlations between Novel Tasks, Demographical Information & Standardized Tests (PWA)

	SEM			PhN-N			PhN-P		
	Category Coordinate	**Category Super-ordinate**	**Semantic Feature**	**Rhyme Judgment (N-N)**	**Syllable Judgment (N-N)**	**Phoneme Verification (N-N)**	**Rhyme Judgment (N-P)**	**Syllable Judgment (N-P)**	**Phoneme Verification (N-P)**
Age	−0.390	−.255	−.324	−.158	−.307	−.012	−.048	−.266	−.142
Education	.448*	.231	.255	−.001	.195	.136	−.024	.294	.116
WAB AQ	0.336	.797***	.539**	.589**	.530**	.486*	.482*	.553**	.597**
BNT score	.555**	.812***	.618***	.668***	.639***	.620***	.497*	.406	.560**
PPT score	.633**	.640**	.676**	.369	.372	.370	.354	.330	.336
MPO	.013	−.006	.147	−.234	−.020	−.242	−.268	.042	−.219

Correlations between Novel Tasks & Demographic Information (Controls)

	SEM			PhN-N			PhN-P		
	Category Coordinate	Category Super-ordinate	Semantic Feature	Rhyme Judgment (N-N)	Syllable Judgment (N-N)	Phoneme Verification (N-N)	Rhyme Judgment (N-P)	Syllable Judgment (N-P)	Phoneme Verification (N-P)
Age	−.009	−.008	−.292	−.057	−.039	.091	−.332	.040	.149
Education	0.639	.618	.026	.342	.065	.238	.366	.375	.435

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

** Correlation is significant at the 0.01 level (2-tailed).

*** Correlation is significant at the 0.001 level (2-tailed).

Table 5

Chance performance of PWA on each task. Number of trials = 80; at-chance probability = .5 for all tasks (due to two-button press) excluding at-chance probability = .33 for Syllable Judgment for P24–32 (due to three-button response).

	SEM			PhN-N			PhN-P		
Participant	**Category Coordinate**	**Category Super-ordinate**	**Semantic Feature**	**Rhyme Judgment**	**Syllable Judgment**	**Phoneme Verification**	**Rhyme Judgment**	**Syllable Judgment**	**Phoneme Verification**
P1	67	75	72	46	48	44	44	46	44
P2	65	66	70	41	50	38	50	72	50
P3	78	72	71	36	42	44	57	64	46
P4	76	76	75	36	51	42	39	55	43
P5	76	73	73	42	52	39	45	60	40
P6	70	69	70	40	46	37	40	75	42
P7	61	58	60	40	44	41	44	35	40
P8	50	64	64	44	42	37	39	42	37
P9	68	70	61	36	49	40	45	61	42
P10	45	59	46	38	42	41	44	42	41
P11	67	73	64	44	48	47	43	62	51
P12	58	61	52	DNT	DNT	DNT	DNT	DNT	DNT
P13	69	70	65	35	48	39	34	69	45
P14	56	71	73	49	40	40	52	43	40
P15	79	80	78	74	68	73	76	75	79
P16	74	77	76	59	52	54	67	62	60
P17	66	77	70	57	46	48	58	70	68
P18	75	76	75	46	53	48	52	76	51
P19	78	80	72	60	56	51	67	63	54
P20	70	76	69	62	55	46	74	76	58
P21	79	78	71	63	63	52	60	77	59
P22	73	78	74	68	54	54	74	80	61
P23	67	75	74	46	48	44	44	46	44
P24	68	74	76	41	51	42	64	63	52
P25	DNT	DNT	68	43	53	DNT	57	75	DNT

Participant	SEM			PhN-N			PhN-P		
	Category Coordinate	Category Super-ordinate	Semantic Feature	Rhyme Judgment	Syllable Judgment	Phoneme Verification	Rhyme Judgment	Syllable Judgment	Phoneme Verification
P26	78	78	75	64	71	50	71	79	63
P27	67	65	61	40	19	43	40	22	40
P28	77	76	76	75	59	56	76	73	61
P29	75	76	70	41	46	53	62	51	55
P30	77	80	74	67	65	43	76	79	55
P31	70	62	61	38	27	42	41	27	39
P32	69	75	65	41	43	48	44	58	56
Total Above Chance	30	31	30	11	22	11	17	23	16
Total At Chance	1	0	1	20	8	19	14	8	14
Total Below Chance	0	0	0	0	1	0	0	0	0