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

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UNDERSTANDING SEMANTIC AND PHONOLOGICAL PROCESSING DEFICITS IN ADULTS WITH APHASIA: EFFECTS OF CATEGORY AND TYPICALITY

by

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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. Within semantic processing, category and typicality are proposed to influence accuracy and response time on semantic tasks in both healthy and aphasic subjects.

Aims: This study examines the nature of semantic-phonological access in aphasia by comparing adults with aphasia to healthy control subjects. Three semantic tasks and three phonological tasks containing typical and atypical items of six semantic categories were used to assess the difference in category and typicality effects between persons with aphasia and healthy adults. Finally, we aim to identify demographic factors and formal language measures that correlate with semantic and phonological processing performance.

Methods: Twenty patients with aphasia and ten neurologically healthy adults were administered six tasks: category superordinate, category coordinate, semantic feature verification, syllable judgment, rhyme judgment, and phoneme verification. Accuracy and reaction time data were collected and analyzed as three conditions: 1) phonological no name, 2) phonological name provided, and 3) semantic.

Results: Patients with aphasia performed with significantly lower accuracy than controls, with greater between-group difference on phonological tasks than on semantic tasks. Patients were significantly slower than control on semantic and phonological no name conditions, but showed no difference on the name provided condition. Both patient and control groups showed category effect on semantic accuracy. The only category effect found on RT was controls on the phonological no name condition. Control showed an effect of typicality on the semantic condition for accuracy while patients showed it for RT. Correlations were found between language measures and education and task performance.

Conclusions: Patients demonstrated greater phonological than semantic deficits. Both patient and control groups showed effect of category, but patients showed a reduced effect of typicality. Category and typicality effects are robust in semantic tasks, but not in either phonological task conditions, providing support for discrete serial processing models of lexical processing. Education level was found to be a predictor for semantic boundary knowledge, but not for phonological processing skills.

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INTRODUCTION

Patients with aphasia often present with various degrees of semantic and phonological deficits. The separate and interactive natures between semantic and phonological processing have both been evidenced by numerous studies on speech errors in normal language processing as well as in aphasia. Within semantic processing, previous studies have found category specific deficits in some patients with aphasia and other studies on typicality have found faster and more accurate access to typical items within a category. However, few studies have addressed category and typicality access in both phonological and semantic tasks together. The current study explores whether patients' naming deficits arise from an impairment at the semantic level or the phonological level of processing, how category and typicality play a role in semantic processing in aphasia, and what demographic and impairment factors account for the nature of deficits seen in patients with aphasia.

Models of Lexical Processing

Several models have been proposed to account for word retrieval in normal language processing. Levelt's model of spreading activation (Levelt, Roelofs, & Meyer, 1999) proposed that word production begins at the conceptual level, such as seeing a picture. Conceptual knowledge of the target activates semantic features of the word. In the following stage, a word is selected from the lexicon. Speech errors may occur because neighboring nodes in the lexicon may be activated (e.g. *banana* for *apple)*. After the word form is retrieved, phonological encoding occurs at the third stage in which sounds of the word is retrieved and sequenced before articulation. This model is characterized by discrete serial processing, in which each stage of processing occurs sequentially in one direction.

On the other hand, while Dell's interactive activation model (Dell, 1986; Dell & Reich, 1981; Foygel & Dell, 2000; Schwartz, Dell, Martin, Gahl, & Sobel, 2006; Dell & O'Seaghdha, 1992) proposed similar stages of word retrieval, it argues that the stages interact and affect each other resulting in a parallel-processing model; activation not only spreads forward but also feeds back between stages to maintain stability between semantic, word form and phonemes. This is different than the Levelt model in that connections between semantic, lexical, and phonological nodes are bidirectional. Another model widely used is the Ellis & Young model of lexical processing (1988), when a picture is presented, the concept is accessed at the visual object recognition system, semantic information is then accessed at the semantic system. Semantic representation of the word activates the phonological structure of the word stored at the phonological output lexicon ("inner speech"), and finally phonological manipulation and articulation take place at the phonological output buffer. (See Figure 1.)

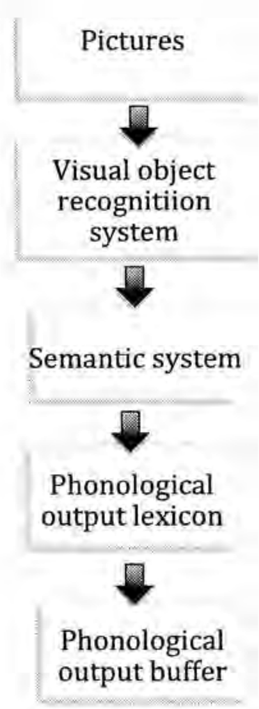


Figure 1. Stages of lexical processing based on the Ellis & Young model (1988).

In all of the above models of lexical processing, semantic access is proposed to be activated at a separate level than phonological processing, and the presence of these two stages are supported by speech errors studies showing distinction between semantic (e.g., *plane* for *helicopter*) and phonological errors (e.g., *pain* for *plane*) (Fromkin, 1971; Garrett, 1976; Levelt et al., 1991; Schriefers, Meyer, & Levelt, 1990), reaction time studies showing effect of semantic distractor before that of phonological distractor on naming (Schriefers et al., 1990; Levelt et al., 1991), as well as brain imaging studies that suggest sequential activation of semantic to phonological information (Heim, Opitiz, & Friederici, 2002; Indefrey & Levelt, 2000; Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1998).

While the two-stage model accounts for lexical processing, Dell, Schwartz, Martin, Saffran, & Gagnon (1997) suggests bidirectional interaction between the stages, and is supported by speech error phenomena such as the mixed semantic and phonological speech error of retrieving *rat* for *cat*. This view provides evidence for the overlap and interdependency between semantic and phonological processing.

Semantic and Phonological Deficits in Aphasia

Aphasia is characterized by anomia—deficit in naming. According to previous studies, such naming deficits result from incorrect or incomplete activation of semantic or phonological nodes (Butterworth, 1989; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Foygel & Dell, 2000). In the model of speech production discussed above, semantic information is accessed before phonological information in two stages (Butterworth, 1989, 1992; Dell, 1986, 1988; Garrett, 1976, 1992; Kempen & Huijbers, 1983; Levelt, 1989, 1992; Patterson & Shewell, 1987). This means if a patient has an underlying semantic deficit, his or her phonological processing will further be impaired. According to these models, breakdown can occur at any stage of processing: semantic deficit at the semantic system level results in impaired semantic information; deficit at phonological output lexicon results in intact semantic information, but impaired naming; deficit at the phonological output buffer results in impaired ability to store, manipulate, and process phonological information.

Whether semantic and phonological processing are interdependent or separate has been a topic of debate in the literature. Many claim that phonological and semantic deficits are interdependent as phonological representations are supported by their corresponding lexical and semantic representations (Martin, Schwartz, & Kohen, 2006; Schwartz, Dell, Martin, Gahl, Sobel, 2006; Martin & Saffran, 1997; Martin, Breedin, & Damian, 1999; Martin, Lesch, & Bartha, 1999). This claim is evidenced by studies such as nonword repetition (that nonwords are recalled less accurately than real words due to lack of semantic support), lexical bias, and short-term memory studies. Martin & Saffran (1997) studied fifteen stroke patients with semantic and phonological processing deficits and found that activation at both the phonological and semantic levels representation contributes to short-term memory performance. In a lexical bias study, Dell & Oppenheim (2007) found that when induced phoneme exchanges with priming, subjects produced more phoneme exchanges that were semantically related to the priming phrases than semantically unrelated phrases, showing that word forms are influenced by meaning, providing evidence for the interactive nature between semantic-lexical and phonological activations. Tyler, Voice, & Moss (2000) tested the interaction between semantics and phonology by examining how imageability, a semantic variable, affects phonological processing task performance, and concluded that lexical processing is a "highly interactive system in which semantics and phonology are in constant communication with each other" (p. 324).

On the other hand, some argue that phonological and semantic processing are discrete and independent (Cuetos, Aguado, & Caramazza, 2000; Howard & Gatehouse, 2006; Howard & Nickels, 2005; Caramazza & Hillis, 1990; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000; Howard & Franklin, 1990, 1993; Martin, Shelton, & Yaffee, 1994, etc.). Cuetos, Aguado, & Caramazza (2000) reported a case of dissociation between semantic and phonological errors in a fluent aphasic, whose semantic errors were much greater than phonological errors. The study challenged the proposal by Dell et al.'s (1997) that fluent aphasia is characterized by global damage to all levels of the lexical access system. Instead, brain damage can disrupt distinct subcomponents of the lexical processing system, resulting in varying levels of semantic and phonological deficits.

Howard & Nickels (2005) studied two patients with short-term memory impairments and found that both subjects had impaired phonological buffers yet intact lexical semantic buffer. They concluded that phonological and lexical-semantic buffers are separate and independent. Howard & Gatehouse (2006) outlined the difference between semantic impairment and impaired access to the phonological output lexicon (POL) in aphasia naming: semantic impairment is affected by semantic variables such as imageability and concreteness while POL impaired naming is not affected by semantic variables but by frequency, familiarity, and possibly age of acquisition. According to this view, impaired POL access results in naming deficits but comprehension of semantic information remains intact and semantic errors are not commonly observed.

To examine the relationship between phonological and semantic processing deficits in aphasia, the tasks used in the current study were based on tasks previously used to investigate phonological and semantic deficits. Phonological processing deficits in aphasia can be assessed with phonological tasks involving phonological judgment and manipulation including rhyme judgments, segmentation, and minimal pairs (Howard & Nickels, 2005). Inner speech (Geva, Bennett, Warburton, & Patterson, 2011) has been widely investigated in aphasia; Feinberg, Gonzales, Rothi, & Heilman (1986) used word length, rhyme judgment with picture stimuli to test inner speech while Marshall, Rappaport, and Gariabunuel (1985) also used rhyme, syllable number count tasks to test inner speech. Semantic processing deficits have been assessed with tasks such as category generation; category sorting, category superordinate verification, semantic feature verification, etc. (Hampton, 1979; Casey, 1992; Larochelle & Pineau, 1994; McCloskey & Glucksberg, 1978; Rips, Shoben, & Smith, 1973; Smith, Shoben, & Rips, 1974; Kiran & Thompson, 2003; Grober et al., 1980; Fujihara et al., 1998).

Semantic access is known to be influenced by numerous factors such as frequency (e.g., Jescheniak & Levelt, 1994; Kittredge, Dell, Verkuilen & Schwartz, 2008), familiarity (Gernsbacher, 1984; Funnell & Sheridan, 1992), word length (Ellis et al., 1983; Howard, Patterson, Franklin, Morton, & Orchard-Lisle, 1984; Kohn, 1988, 1989; Nickels, 1995; Nickels & Howard, 2004; Pate, Saffran, & Martin, 1987), etc. Among these factors, category-specific impairment has been documented and is one of the research questions in this current study. Previous studies on category and typicality effects within semantic processing will be further discussed in the following sections.

Category effect

Category effect in semantic processing has been documented in numerous studies, in particular the difference between animate and inanimate categories (Barton & Komatsu, 1989; Devlin et al., 2002; Keil, 1989; Vanoverberghe & Storms, 2003; Caramazza & Shelton, 1998; Cardebrat, Demonet, Celsis, & Fuel, 1996; Silveri et al., 1997); between animals and artifacts (Diesendruck & Gelman, 1999; Ahn, 1998; Estes, 2003, 2004); and between well-defined (Hampton, 1998; Keil, Smith, Simons, & Levin, 1998) and ad-hoc, or goal-derived categories (Barsalou, 1983, 1985). Diesendruck & Gelman (1999) studied the category boundaries for animals and artifacts and proposed that category membership for animals is absolute and that for artifacts is relatively graded. The stimuli in the current study contain animate and inanimate categories; animate categories have been found to have more perceptual features whereas inanimate categories are characterized by more functional features.

Category-specific deficits in aphasia have been widely studied (Berndt, 1988; Kurbat & Farah, 1998; Sacchett & Humphreys, 2004; Goodglass & Budin, 1988; Laws, Adlington, Gale, Moreno-Martinez, & Sartori, 2007; Lambon Ralph, Lowe, & Rogers, 2007; Howard, 1995; Forde & Humphreys, 1999, etc.). Inherit familiarity of a category has been proposed to influence category knowledge (Malt & Smith, 1982): in a familiar category such as *clothing*, even the atypical items (e.g. scarf, tie) are familiar and recognizable to most, while in a less familiar category such as fruit, not many have knowledge of the atypical items (e.g. currant).

Typicality effect

Typicality is determined by the semantic distance from the category prototype, i.e., the amount of feature overlap within a semantic category (Vigliocco, Vinson, Damian, & Levelt, 2002) and has been found to predict category organization and lexical access. The typicality effect has been documented in studies on normal individuals in which typical examples receive preferential processing compared with atypical examples within a category (McCloskey & Glucksberg, 1978; Hampton, 1979; Posner & Kelle, 1968; Rosch, 1973, 1975). Reaction time to typical stimuli was found to be faster than to atypical in category verification tasks (Hampton, 1979; Casey, 1992; Larochelle & Pineau, 1994; McCloskey & Glucksberg,. 1978; Rips, Shoben, & Smith, 1973; Smith, Shoben, & Rips, 1974).

Three major models of normal typicality processing have been proposed: the feature comparison model, the prototype/family resemblance models, and the exemplar models. The feature comparison model proposes that categorization is processed in two stages, in which typical examples and nonmembers pass through the first stage of judging characteristic features because the number of matched features of category membership is either exceeding high or low; while atypical examples have to proceed to the second stage and rely on defining feature matching for membership to be determined (Rips et al., 1973; Smith et al., 1974; Smith &

Medin, 1981). The prototype/family resemblance models propose that a category has set of features that are shared with most members of the category, and typical members have a higher number of shared features with other members than atypical members do. Thus, category membership is determined by the degree of similarity to a prototype of the category. The prototype of a category is an idealized concept that is not previously encountered (Rosch & Mervis, 1975; Hampton, 1979, 1993, 1995; Kalish, 2002). In the exemplar models, memory plays a role in categorization; a newly encountered item is judged to be an example of the category based on its degree of similarity to previously stored examples of the category (Heit & Barsalou, 1996; Komatsu, 1992; Smith & Medin, 1981; Storms, De Boek, & Ruts, 2000).

To investigate the effects of typicality within a category, category coordinate judgment and category superordinate tasks have been used in previous studies. Rosch & Mervis (1975) reported faster reaction time in participants when the pair contains typical members than when the pair contains atypical members in a category coordinate judgment task. Moreover, several studies reported faster reaction time when identifying typical items as members of a category than atypical items in category superordinate identification tasks (Hampton, 1995; Kiran & Thompson, 2003; Rosch, 1975; Storms, De Doeck, & Ruts, 2000).

However, it has been shown in semantic priming studies that category and typicality boundaries are less robust in individuals with aphasia. In Kiran, Ntourou, & Eubank (2007), nonfluent patients and controls showed effect of typicality but patients with fluent aphasia did not. Sandberg, Sebastian, Kiran (2012) studied the effects of category and typicality comparing patient with more semantic impairment and less semantic impairment; typicality effect was found in the group with more semantic impairment but not in the less semantic impairment group. This study will examine whether the difference in category and typicality effect between patients and healthy control subjects hold true in a wider range of semantic and phonological processing tasks.

Aims

The current study aims to understand the nature of semantic and phonological processing deficits in aphasia. Six semantic (category superordinate, category coordinate, semantic feature) and phonological (syllable judgment, rhyme judgment, phoneme verification) tasks containing typical and atypical items of six semantic categories were administered to twenty adult patients with aphasia and ten healthy control subjects. In each of the three phonological tasks described below, there were two conditions, the first where no spoken word is provided and a second condition, followed by the first where the spoken word is provided (i.e., cued condition). The main difference between the two conditions is that it allows the comparison between phonological access at the phonological output lexicon (Ellis & Young, 1988) when the spoken word is not provided, and phonological processing at the phonological output buffer when the spoken word is provided. Research questions include:

1) *What is the nature of semantic and phonological deficits in patients with aphasia relative to controls?*

We hypothesized that patients would exhibit more impaired phonological processing than semantic processing in our six tasks since the semantic system must be accessed before the phonological lexicon (Ellis & Young, 1988; Levelt, 1999), and according to the serial processing model, semantic impairment will automatically result in phonological impairment, while phonological impairment can exist in isolation if semantic system is intact, giving phonological processing twice the probability to be impaired in aphasia. Although we were uncertain about whether lexical processing is interactive or serial in nature, the results would indicate one way or another based on whether semantic and phonological processing deficits always coexist or may exist in isolation. Our three task conditions were designed to assess three levels of lexical processing: semantic condition to test the semantic system; phonological condition with no name provided to test the POL; phonological with name cue condition to test the phonological output buffer. We hypothesized that patients would perform with the highest accuracy and shortest reaction time on semantic tasks, followed by phonological tasks when name of item is provided, and with the lowest accuracy and longest reaction time on the phonological tasks when naming is required since aphasia is characterized by a deficit in naming and increased latency of naming (Goodglass & Baker, 1976; Marshal, Neuburger, & Sakellaris, 1982).

2) Do category and typicality have an effect on semantic and phonological processing?

We hypothesized that category effect would be present in both subject groups, with lower accuracy and longer RT on inanimate and less familiar categories than animate categories. Similarly, both patient and control groups were expected to show effects of typicality on accuracy and reaction time based on previous findings with typical examples more accurate than atypical examples (McCloskey & Glucksberg, 1978; Hampton, 1979, 1995; Posner & Kelle, 1968; Rosch, 1973, 1975; Storms, De Doeck, & Ruts, 2000; Kiran &Thompson, 2003).

3) What is the relationship between severity and semantic and phonological processing impairments? How do measures of semantic and phonological processing correlate with other measures of impairment in patients with aphasia?

Since the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) measures naming ability, we hypothesized our phonological task scores when naming is required to correlate with BNT scores. The Western Aphasia Battery-Revised (WAB-R; Kertesz, 2007) Aphasia Quotient (AQ) measures overall aphasia severity testing a wider range of language abilities, and was expected to exhibit moderate correlation with our task scores on all conditions. Education has been found to correlate with aphasia severity after stroke (González-Fernández, Davis, Molitoris, Newhart, Leigh, & Hillis, 2011; Connor, Obler, Tocco, Fitzpatrick, & Albert, 2003) and was expected to correlate with our task scores on all conditions.

METHOD

Participants

Twenty patients with aphasia as a result of MCA stroke(s) were recruited from hospitals and group therapy settings in the Boston area and participated in the current study. The group contained 13 males and 7 females, ages 37 to 89 years (mean = 62.35 ± 12.89 years), and 22 to 168 months post onset (mean = 52.47 ± 39.88 months). Three patients were left-handed and the remaining seventeen patients were right-handed. Years of education ranged from 12 to 18 years. All patients reported to be monolingual English speakers.

Healthy control subjects were ten adults between 44 to 68 years of age (mean age= 57 ± 8.24 years; N=10; 4 females and 6 males). All subjects reported no history of stroke, traumatic brain injury, or other neurological damage. Control subjects all reported to be monolingual English speakers with normal hearing and normal or corrected-to-normal vision.

Patient and control subject demographic information, including age, gender, handedness, years of education, monolingual status, neurological history, months post-onset (for patients), was collected using self-report questionnaire. See Table 1 for demographic information for both patient and control groups.

In addition to the behavioral tasks described below, patients were administered the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) to assess naming performance and the Western Aphasia Battery-Revised (WAB-R;

Kertesz, 2007) to obtain Aphasia Quotient (AQ) which indicates overall severity of spoken language deficits in aphasia. (See Table 2 for report of individual scores.)

Table 1. Demographic information for all participants. P10 education information unavailable because subject dropped out of study before data were obtained.

Participant	Group	Age	Years of Education	Handedness	Gender
P1	Patient	56	16	R	F
P2	Patient	51	16	R	M
P3	Patient	65	15	R	M
P4	Patient	54	16	R	M
P5	Patient	48	16	R	M
P6	Patient	66	18	R	F
P7	Patient	70	12	R	M
P8	Patient	49	12	R	M
P9	Patient	67	18	R	M
P10	Patient	83	N/A	R	F
P11	Patient	59	12	L	M
P12	Patient	70	12	R	M
P13	Patient	63	18	R	F
P14	Patient	86	12	L	M
P15	Patient	50	18	R	F
P16	Patient	72	18	R	M
P17	Patient	53	16	R	M
P18	Patient	37	16	L	F
P19	Patient	82	16	R	F
P20	Patient	66	12	R	M
AVERAGE		*62.35*	*15.21*	17R 3L	13M 7F
Stdev		12.89	2.42		
C1	Control	54	18	R	F
C2	Control	45	18	R	F
C3	Control	54	18	R	F
C4	Control	44	16	R	M
C5	Control	55	12	R	M
C6	Control	58	12	L	M
C7	Control	66	18	R	F
C8	Control	60	16	R	M
C9	Control	65	14	R	M
C10	Control	68	20	R	M
AVERAGE		*56.90*	*16.20*	9 R 1L	6M 4F
Stdev		*8.24*	*2.74*		

The BNT consists of sixty line drawings of nouns of gradually increasing difficulty; reported scores reflect subjects' ability to verbally name these drawings without given any phonemic or semantic cues. The mean BNT score from the patient group was 29.89 with a standard deviation of 19.02. The WAB-R AQ is derived from portions of the test battery, including information content and fluency of a spontaneous speech sample, auditory comprehension, repetition, and naming. The maximum AQ is 100. In our sample, the mean AQ was 68.78 with a standard deviation of 22.43. Number of months post-onset (MPO) was also included as a potential correlate for individual performance on our tasks.

Table 2. Patient performance on WAB-R (Kertesz, 2006), BNT (Kaplan et al., 2001), and individual months post onset. P10 information unavailable because subject dropped out of study before data were obtained.

Participant	WAB AQ	BNT score	MPO
P1	80.2	34	75
P2	48	4	115
P3	49.6	9	50
P4	44.9	24	94
P5	72.5	49	86
P6	70.1	37	70
P7	10.2	0	168
P8	55.5	35	156
P9	58.6	18	22
P10	N/A	N/A	22
P11	85.8	49	36
P12	46.2	0	24
P13	67.7	8	26
P14	88.1	34	22
P15	93.9	59	33
P16	76.7	51	22
P17	91	28	27
P18	77.9	33	34
P19	92.7	57	47
P20	97.2	39	24
AVERAGE	*68.78*	*29.89*	*57.65*
Stdev	22.43	19.02	45.20

Materials

Six computer-based tasks were developed for this study. Six semantic categories were chosen to be used across these tasks; three of which were animate: *vegetable, fruit, birds*; while the other three were inanimate: *furniture, transportation, clothing*. Approximately forty items for each category were submitted to Mturk, where workers rated each item's typicality on a scale of 1 to 5. Each item received ratings from twenty workers. Foil items that did not belong to the category were used to identify outlier workers whose answers were discarded in calculation of typicality. Using the Mturk ratings, the average rating for the category was calculated and z-scores were calculated indicating the distance from the item's rating to the category average divided by the standard deviation. Z-scores of each item's ratings were used to provide typicality ranking. To avoid ambiguous typicality, mid-ranking items were not used in development of the tasks. See Table 3 for average typicality rating, z-scores for typical and atypical examples, familiarity, and word frequency for each category. See Table 7 in the appendix for a list of sample stimuli used in the six tasks.

Table 3. Average typicality rating by Mturk workers; z-scores for typical and atypical examples; Familiarity, spoken word frequency (Frequency CobSIM; CELEX, 1993), and written word frequency (Frequency FK; Frances & Kucera, 1982).

Category	Bird	Clothing	Fruit	Furniture	Transpor-tation	Vegetable
Avg typicality rating (1 to 5 scale)	1.86	2.55	2.42	4.06	2.73	2.59
Typical items z-score	-1.22 to -0.29	-1.4 to -0.03	-1.35 to -0.05	-1.63 to -0.21	-1.63 to -0.11	-1.25 to -0.02
AVERAGE	*-0.63*	*-0.85*	*-0.74*	*-0.91*	*-0.95*	*-0.66*
Atypical items z-score	-0.63 to -0.14	-0.85 to -1.43	-0.74 to 0.01	-0.91 to -0.06	-0.95 to 0.08	-0.66 to 0.07
AVERAGE	*0.32*	*0.89*	*0.51*	*0.87*	*0.8*	*0.97*
Familiarity	437.06	541.87	526.43	538.41	520.35	469.87
Frequency CobSIM	1.13	2.51	0.5	4.78	5.62	1.11
Frequency FK	5.81	18.07	14.53	34.31	40.76	7.45

As the first portion of the phonological tasks required visual naming, visually confusing or ambiguous items were also avoided. Color photographs of real-life objects were used for the visual stimuli. Audio clips of stimuli and tasks instructions were recorded by a male native American English speaker. The tasks are described in the following sections.

Experimental Tasks

The experimental tasks consisted of six language tasks designed to examine the impairment presented by subjects with aphasia at levels of semantic and phonological processing; each trial in the phonological tasks was further broken down into two conditions to examine the difference between naming and phonological manipulation.

Phonological tasks

Three phonological tasks were designed to test the ability to access phonological forms of words from semantics. All phonological tasks provided two opportunities for the participant to respond. In the first screen (the "no name" condition), the visual stimulus was presented but the auditory target name was not provided. The participant must name the image (silently or verbally) in order to perform the phonological processing required by the task. On the second screen ("name provided" condition), the same visual stimulus was presented along with its name as an auditory stimulus. The difference in accuracy and reaction time (RT) between these two conditions was interpreted as the difference between naming plus phonological processing and phonological processing only.

Each of the phonological tasks is described further below:

Syllable Judgment

Participants were presented with pictures whose corresponding lexical items contained one, two, or three syllables, then required to press "yes" or "no" on the keyboard to indicate whether the target word contains two syllables (e.g. image of carrot). After the first response, the target word was spoken along with the picture of the item (e.g. image of carrot – audio of "carrot"), and participants were required to decide again the number of syllables. Participants were instructed that they could change their answers on the second response input if necessary. A fixation of 2000ms was displayed between presentations of stimuli. The eighty trials contained forty two-syllable words, twenty one-syllable and twenty three-syllable words.

Phoneme verification

In this task, subjects were presented with a picture of a category item and then asked whether or not it contains a particular phoneme presented auditorily (e.g. picture of a robin – audio of /b/). The image appeared on the screen for 2000ms before the audio began. After the subjects entered the response, the target word ("robin") was presented auditorily in addition to the pictured item (also presented 2000ms before the audio began), followed immediately by a spoken repetition of the target phoneme (/b/). The subjects were then instructed to enter their second response. A fixation of 2000ms was displayed between presentations of stimuli. The phonemes were balanced across initial, medial, and final position in the words. All words were mono- or bi-syllabic words. This task consisted of eighty items, with an equal number of yes and no responses. Voiced-voiceless contrast was avoided to minimize errors due to audio presentation errors.

Rhyme judgment.

A target word (either rhyming or non-rhyming) was presented auditorily 1000ms after the picture. First, a picture of a category item was presented, followed by a spoken English word that did not appear in any tasks (e.g. picture of chicken – audio of "thicken"). The subject was asked to judge whether or not the word rhymed with the name of the picture. After a response was detected, the name of the item was spoken ("chicken") in addition to the picture, followed by a spoken repetition of the target word ("thicken"), and the subject was asked to answer again. All words were mono- or bi-syllabic. The task consisted of forty rhyming pairs and forty non-rhyming pairs. Non-rhyming pairs differed in a single phoneme, balanced across phoneme position (initial, medial, final) in the words.

Semantic Tasks

Three semantic tasks were designed to assess subjects' ability to access semantic information. Stimuli in the semantic tasks were presented as pictures and words. The target words were presented in both spoken and written form to reduce the effect of reading or auditory comprehension deficits on performance. Unlike the phonological tasks, subjects were only required to enter their response once to each stimulus since the second phonological input was unnecessary for the semantic tasks. In each task, the numbers of stimuli were balanced across category and typicality. Each of the three semantic tasks is described further below:

Superordinate category verification

Participants were presented with a picture of a category item and its spoken name, and a category name (written and spoken). They were asked to decide whether the item belonged to the given category (e.g. chandelier: furniture). Eighty items—forty typical and forty atypical— were presented with an equal number of yes and no responses.

Category coordinate judgment

Picture and the spoken form of two items were presented to the participants to decide whether or not the items belong to the same semantic category (e.g. carriage: canoe). At the beginning of the task, the six categories were listed as part of the instructions to minimize category ambiguity (e.g. Subjects were instructed to treat *vegetable* and *fruit* as separate categories rather than as one category of "food"). The task was consisted of eighty items. Stimulus pairs were balanced across category, typicality, and yes/no conditions.

Semantic Feature verification

Participants were presented with an item visually and auditorily along with a semantic feature in writing and in spoken form, and then asked to judge whether the feature applied to the item. Of eighty 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 (feature shared by >80% of the items within the category; e.g. "has feathers" for an item within the bird category), characteristic (feature shared by <80% of the items within the category; e.g. "eats fish" for an item within the bird category); unrelated features consisted of same category no (e.g. ostrich: flies) and noncategory features (e.g. robin: has wheels). These features were selected based on responses from an Mturk task with 20 workers. Feature types were balanced across category, typicality, and yes/no conditions.

Procedure

Participants were seated in front of a computer screen with either headphones or speakers for the duration of testing. They entered their responses with their left hand using two adjacent keys on the keyboard labeled "yes" and "no."

At the beginning of each task, a tutorial was provided to familiarize the participants with the task instructions. Feedback was provided on the participants' accuracy and thought logic during the practice items. However, during the test items, no feedback was provided. Participants were asked to answer as accurately and as fast as possible.

Responses to the six developed tasks were recorded using the program E-prime. Participants entered their answer using a keyboard; accuracy and reaction time data were recorded and further analyzed. Reaction time—the time between the stimulus was presented and the response was entered by the participant—was automatically logged by the testing program. No inter- or intra- rater reliability was conducted as the software minimized room for human error. The administration order of the six tasks was randomized in addition to the randomization of the items within each task. The tasks were administered over one to four sessions, depending on individual patient's cognitive linguistic level and fatigue.

Data Analysis

Accuracy and reaction time were analyzed to examine the correlation between task performance and individual aphasia severity (as determined by the

WAB-R AQ and BNT scores). Individual MANOVAs were used to test the effects of category and typicality and to examine difference between tasks. Within group and between group differences were calculated for both the patient group and the control group. To consolidate data from the tasks, average was calculated according to task type: average semantic score from the average of category superordinate, category coordinate, semantic feature tasks; average phonological (no name) drawn from average of syllable judgment, rhyme judgment, phoneme verification when no name cue was provided; average phonological (name provided) from average of the same three phonological tasks when the name cue was provided.

First, the accuracy and RT from semantic and phonological tasks were compared between patients and controls. Between task differences were examined using repeated measure and chance value count. Secondly, trials were separated according to category and typicality for analysis of the effects of these semantic variables on accuracy and RT in both subject groups. Finally, to examine how aphasia severity relates to task accuracy scores, correlations were calculated between task performance and subject demographic information including years of education, age, etc. as well as scores on standardized language measures.

RESULTS

Accuracy Analysis

Patient vs. Control Accuracy

Individual MANOVAs shows significant difference between patient and control groups across semantic, phonological no name, and phonological name provided scores (*Pillai's trace*= .742, semantic: $p= .01$, $F(1,27) = 7.598$; phonological no name: $p<.001$, $F(1,27) =71.071$; phonological name provided: $p< .001$, $F(1,27)= 39.775$), (see Figure 2) indicating that patients achieved significantly lower accuracy than controls on all tasks. The greatest difference is observed in the phonological no name condition, suggesting that patients' accuracy suffered the most when they were required to name the target word without any cue provided. (See Figure 2)

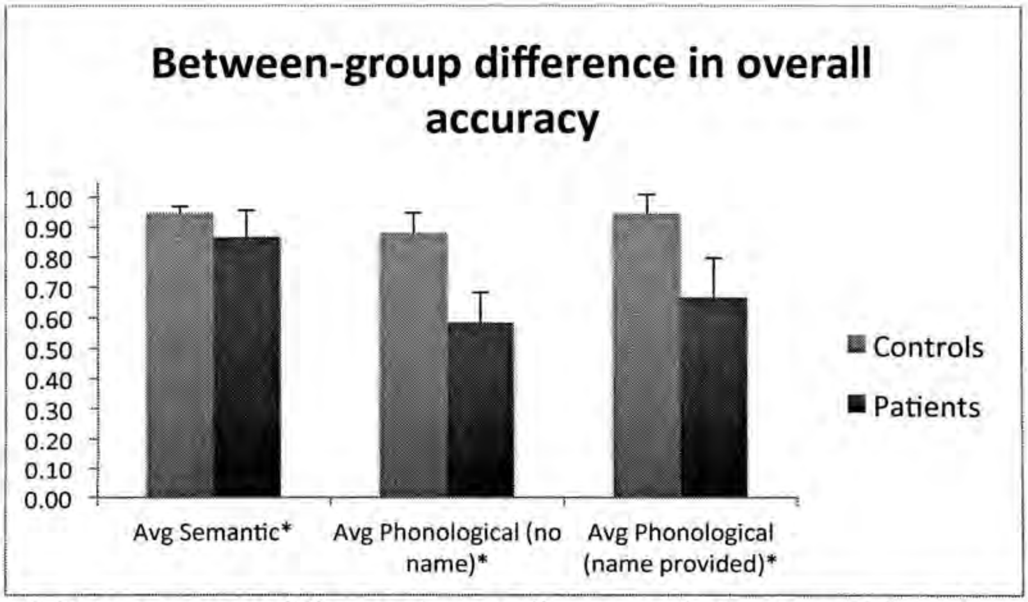
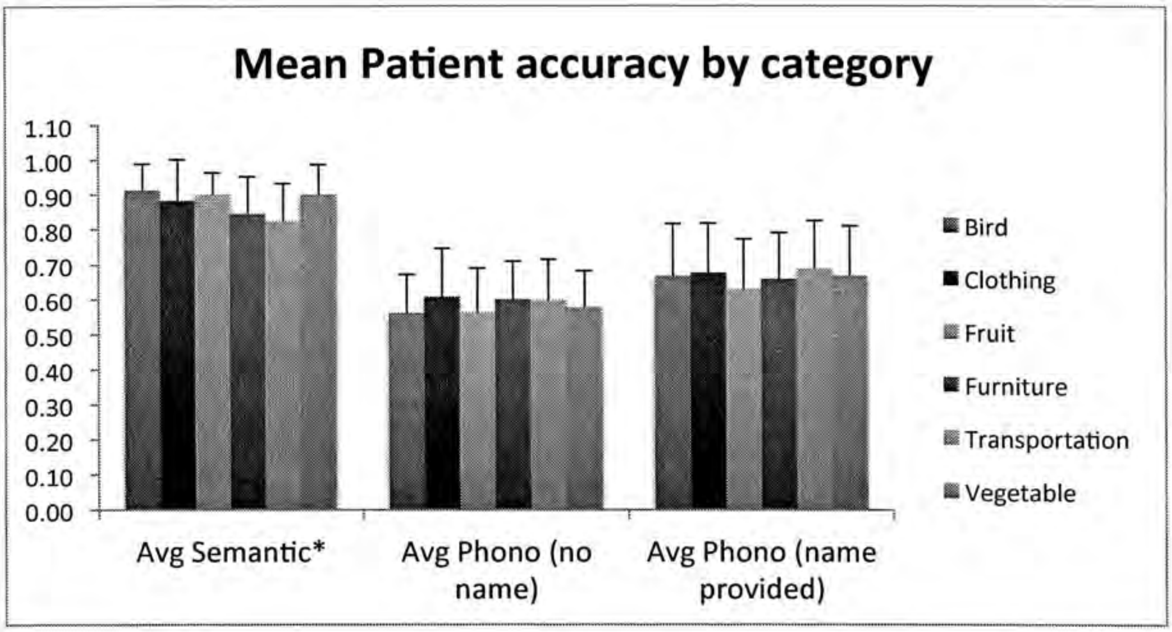


Figure 2. Between-group difference in overall accuracy in three conditions: Semantic, phonological no name, phonological name provided. Asterisk (*) denotes statistical significance. Avg sem score = average semantic scores, avg phon no name = average phonological (no name) scores, avg phon name provided = average phonological (name provided) scores.

Category Effect on Accuracy

Category effect was examined similarly using MANOVA of accuracy by category for each group. Significant effect of category was found in patient average semantic scores (*Pillai's trace* = .222, $F(5,108)=2.58$, $p<.05$) and not on phonological no name ($F(5,108)=.53$, $p=.75$) or phonological name provided ($F(5,108)=.41$, $p=.84$). In the control group, significant effect of category was found on average semantic scores (*Pillai's trace* =.731, $F(5,54)=6.00$, $p<.001$) and not on phonological no name ($F(5,54)=1.84$, $p=.12$) or phonological name provided ($F(5,54)=.57$, $p=.72$) . While there is no effect of category on either average phonological condition for both groups, both group showed the category effect on tasks requiring semantic processing, though controls showed a stronger effect, indicating that both patients and controls processed certain categories with greater ease, but the category difference is less apparent in patients. (See Figure 3)



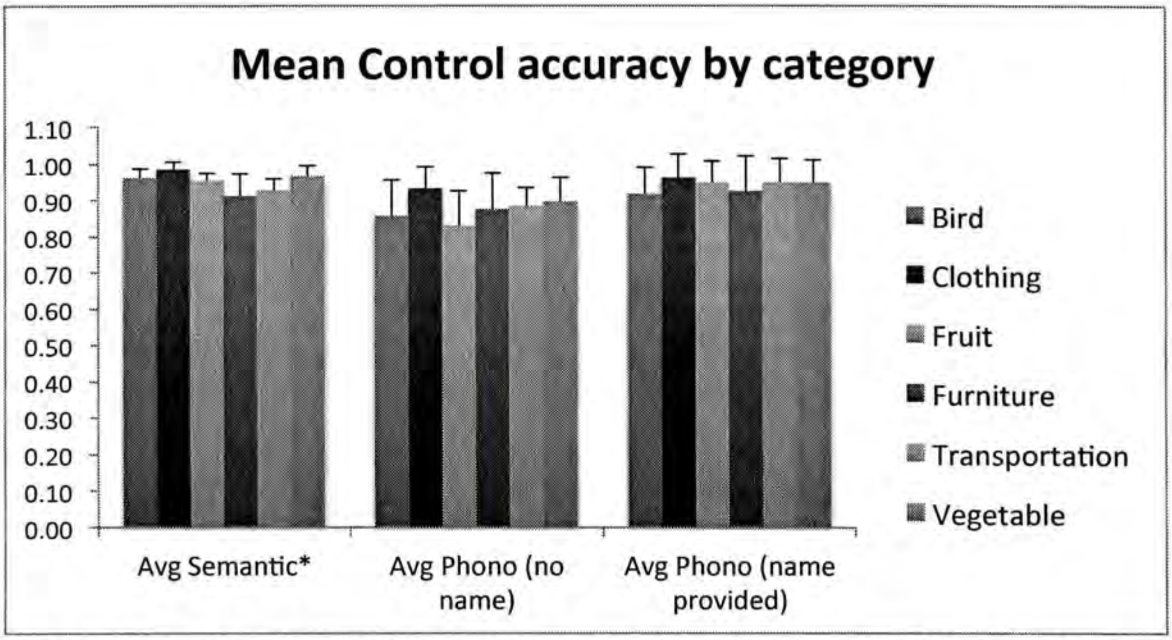


Figure 3. Mean patient and control accuracy by six categories: bird, clothing, fruit, furniture, vegetable, transportation on three task conditions: average semantic, average phonological (no name), average phonological (name provided). Asterisk (*) denotes statistical significance. Avg semantic = average semantic scores, avg phon no name = average phonological (no name) scores, avg phon name provided = average phonological (name provided) scores.

Typicality Effect on Accuracy

Difference between accuracy for typical items and atypical items was calculated using MANOVA for each group on the three conditions. No significant effect is found in patients (*Pillai's trace* = .072, semantic $F(1,36)$=.1.89, p=.18, phonological no name $F(1,36)$=.04, p=.85, phonological name provided $F(1,36)$=.03, p=.87. Controls show significant effect of typicality on average semantic score (*Pillai's trace* = .474, $F(1,18)$=10.407, $p<0.01$), but not for phonological no name ($F(1,18)$=.29, p=.60) or phonological name provided ($F(1,18)$=.27, p=.61). In the control group, subjects responded to typical stimuli with higher accuracy to atypical ones on tasks based on semantic decisions. The patient group did not exhibit such a difference in accuracy, indicating that controls were more accurate with typical examples in semantic processing, but typicality does not affect accuracy on phonological processing or patients' accuracy. (See Figure 4.)

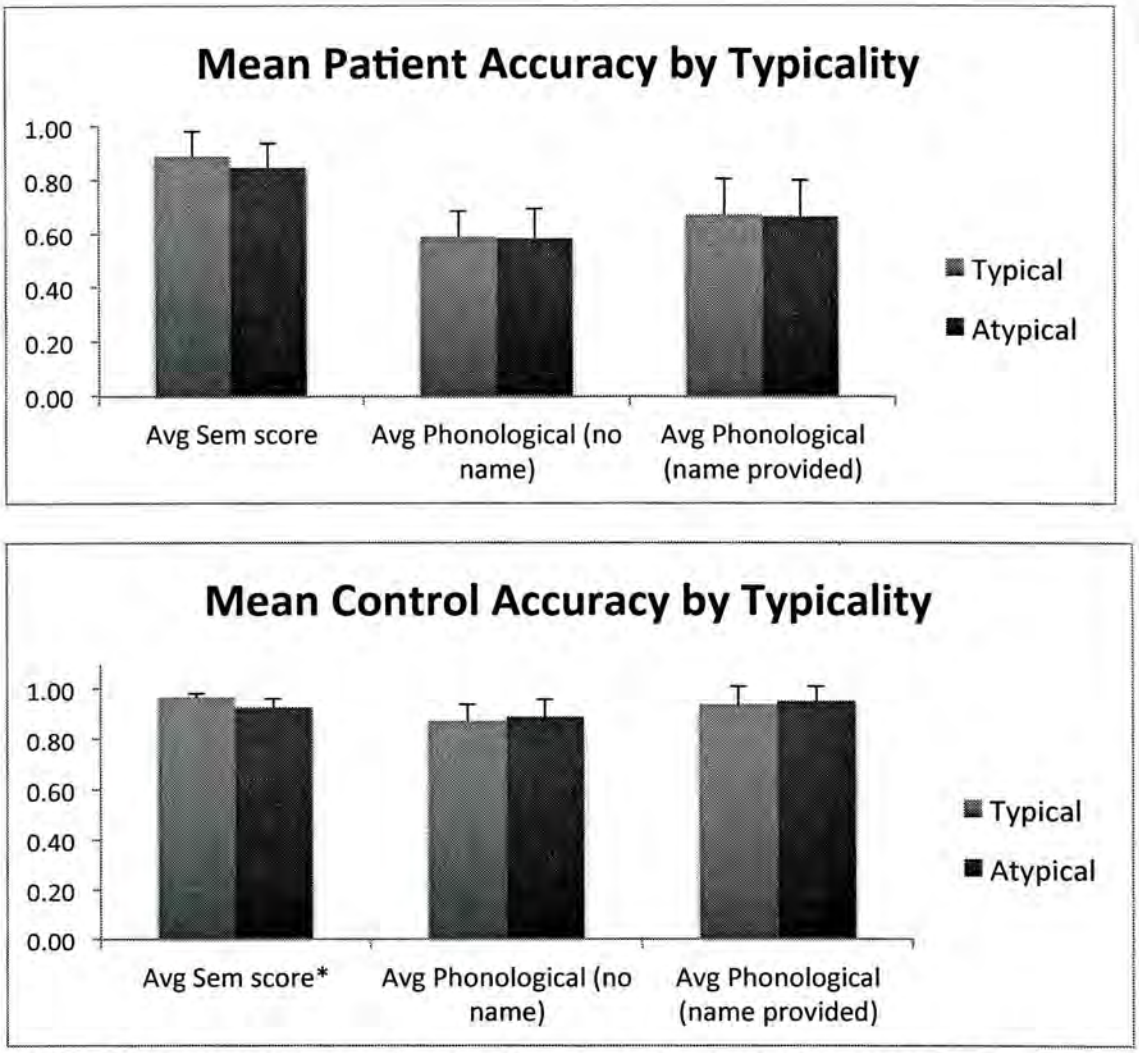


Figure 4. Mean patient and control accuracy by typicality: typical, atypical, on three task conditions: average semantic, average phonological (no name), average phonological (name provided). Asterisk (*) denotes statistical significance. Avg sem = average semantic scores, avg phon no name = average phonological (no name) scores, avg phon name provided = average phonological (name provided) scores.

Task Differences

To further explore the difference in accuracy pattern between subtasks within the three conditions (e.g. Category Coordinate, Category Superordinate, and Semantic Feature within "Average Semantic") in patients compared to controls, the subtasks were separated and analyzed relative to the other subtasks under the same condition. Difference between task scores on the nine task conditions was examined using MANOVA with subject group and task as variables. Between group difference is found among the three tasks on the semantic tasks (*Pillai's trace* =.42, $F(2,56)=7.00$, $p<.01$), phonological no name condition (*Pillai's trace* = .38, $F(2,54)=5.39$, $p<.01$), and the phonological name provided condition (*Pillai's trace* = .43, $F(2,54)=8.73$, $p=.001$). Similar score patterns exist between groups, suggesting that both patients and controls achieved similar accuracy in relation to task differences (e.g., both groups had the highest accuracy in Superordinate Category task among the three semantic tasks). No interaction is observed between group and task, indicating that subject group factor does not affect task differences. (See Figure 5.)

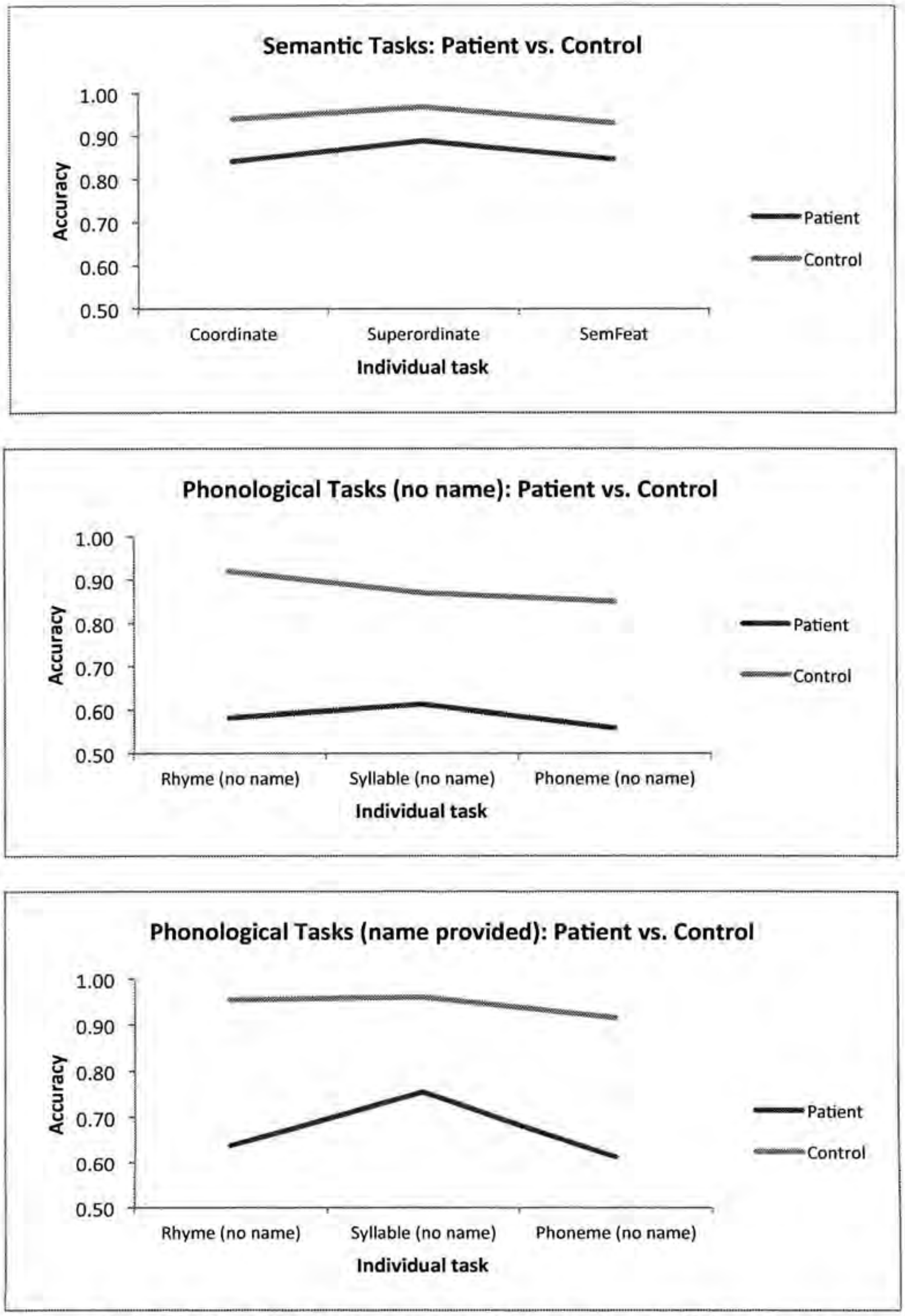


Figure 5: Individual task accuracy within each condition (average semantic: coordinate judgment, superordinate judgment, semantic feature verification; average phonological (no name): rhyme judgment, syllable judgment, phoneme verification; average phonological (name provided): rhyme

judgment, syllable judgment, phoneme verification) in both patient (red) and control (blue) groups.

Chance Values of Accuracy Scores

While accuracy is scaled from 0 to 100%, accuracy scores should be interpreted with caution since 50% indicates close to at chance performance. To further qualify the difference in performance between tasks and between subject groups, chance values were calculated. Since each response has two choices, yielding a 50% chance of accuracy, binomial distribution was used (number of trials=80; probability =.5). Accuracy score with chance value smaller than 0.05 is considered below chance (<33 out of 80); between .05 and .95 is considered at chance (33-47 out of 80); larger than .95 is considered above chance (>47 out of 80). All controls performed all tasks above chance accuracy. 19 of the patients achieve above chance accuracy on all semantic tasks. When no name is provided, 13 patients performed at chance on rhyme judgment, while 14 performed at chance on phoneme verification. No subjects performed below chance on any of the tasks. See Table 4 for individual breakdown of chance value.

Table 4: Accuracy (in number correct out of 80) showing chance value.
P=patient; C=control
Above chance (green): 48-80 correct
At chance (yellow): 33-47 correct
Below chance (red): 0-32 correct

	No Name			Name Provided			Semantic		
Subject	Rhyme	Syllable	Phoneme	Rhyme	Syllable	Phoneme	Coordinate	Super-ordinate	SemFeat
P1	46	48	44	44	46	44	67	75	72
P2	41	50	38	50	72	50	65	66	70
P3	36	42	44	57	64	46	78	72	71
P4	36	51	42	39	55	43	76	76	75
P5	42	52	39	45	60	40	76	73	73
P6	40	46	37	40	75	42	70	69	70
P7	40	44	41	44	35	40	61	58	60
P8	44	42	37	39	42	37	50	64	64
P9	36	49	40	45	61	42	68	70	61
P10	38	42	41	44	42	41	45	59	46
P11	44	48	47	43	62	51	67	73	64
P12	DNT	DNT	DNT	DNT	DNT	DNT	58	61	52
P13	35	48	39	34	69	45	69	70	65
P14	49	40	40	52	43	40	56	71	73
P15	74	68	73	76	75	79	79	80	78
P16	59	52	54	67	62	60	74	77	76
P17	57	46	48	58	70	68	66	77	70
P18	46	53	48	52	76	51	75	76	75
P19	60	56	51	67	63	54	78	80	72
P20	62	55	46	74	76	58	70	76	69
C1	78	77	74	79	80	79	80	80	76
C2	75	74	74	79	79	79	80	80	76
C3	70	63	65	77	76	71	79	80	73
C4	72	63	56	78	72	62	71	74	74
C5	76	73	68	79	76	71	73	77	75
C6	74	71	75	76	80	76	72	76	75
C7	78	74	69	79	80	77	77	80	73
C8	76	68	70	77	79	78	73	77	76
C9	59	66	54	62	69	59	76	74	73
C10	78	67	74	79	78	80	76	78	75

Table 5. Count of at chance performance of patients on each task. Total number of patients= 19 for Phonological No Name and Name Provided tasks; 20 for Semantic tasks.

	No Name			Name Provided			Semantic		
Chance Value	Rhyme	Syllable	Phoneme	Rhyme	Syllable	Phoneme	Coordi-nate	Super-ordinate	SemFeat
Above Chance	6	12	5	9	14	8	19	20	19
At Chance	13	7	14	10	5	11	1	0	1

Table 5 shows the count of patients by chance value. A gradation of performance is apparent based on the count of at chance performance in patients. Patients performed with the highest accuracy on semantic tasks with the most above chance performance, followed by the phonological name provided tasks, and with the lowest above chance rate in the phonological no name condition. This shows that manipulating semantic information was the easiest task, followed by manipulating phonological information when name cue provided, and the most difficult task condition was when both naming and phonological manipulation are required.

Reaction time analysis

Patient vs. Control RT

Reaction times on correct trials are used to measure processing time. Since there is great variation of reaction time in the patient group, outliers (RT longer than 10000ms) were replaced by the subject's mean RT in each task. For patients whose RTs are longer than 10000ms in more than 50% of the trials, RTs above 5 standard deviations from the mean were considered outliers and such *RTs* were replaced by the mean. To standardize RT among patients and controls, RTs were converted into z-scores using each subject's RT mean and standard deviation. MANOVAs were used to test for group differences.

Between-group differences were found in average semantic RT ($p<.005$; $F(1, 27)=12.070$) and average phonological no name RT ($p<.05$; $F(1, 27)=5.765$). The patient group showed significantly longer RT semantic tasks compared to the control group, but showed faster RT than controls on phonological no name condition. No significant between-group difference in average phonological name provided RT was found, indicating that when only phonological manipulation but not naming is required, patients were as fast as controls in responding.

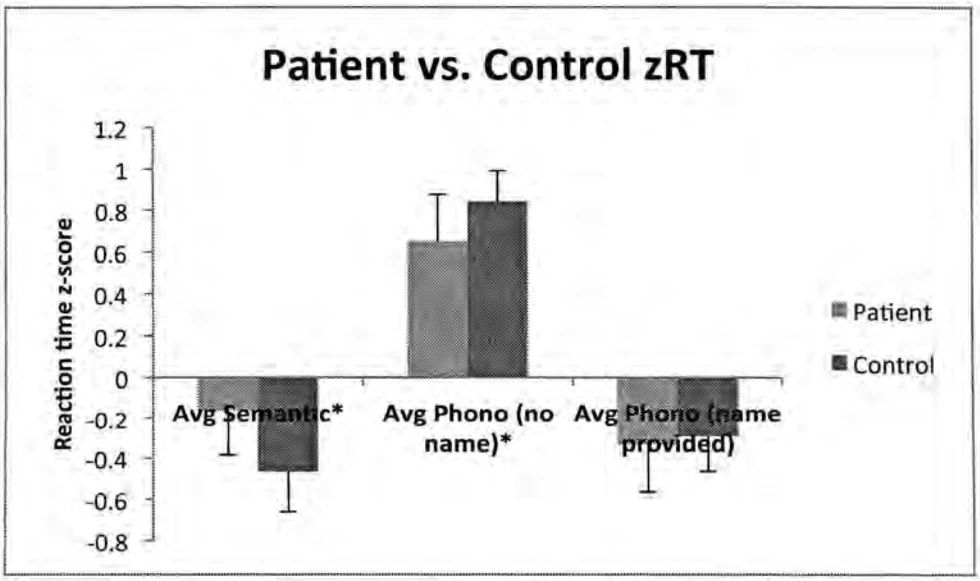
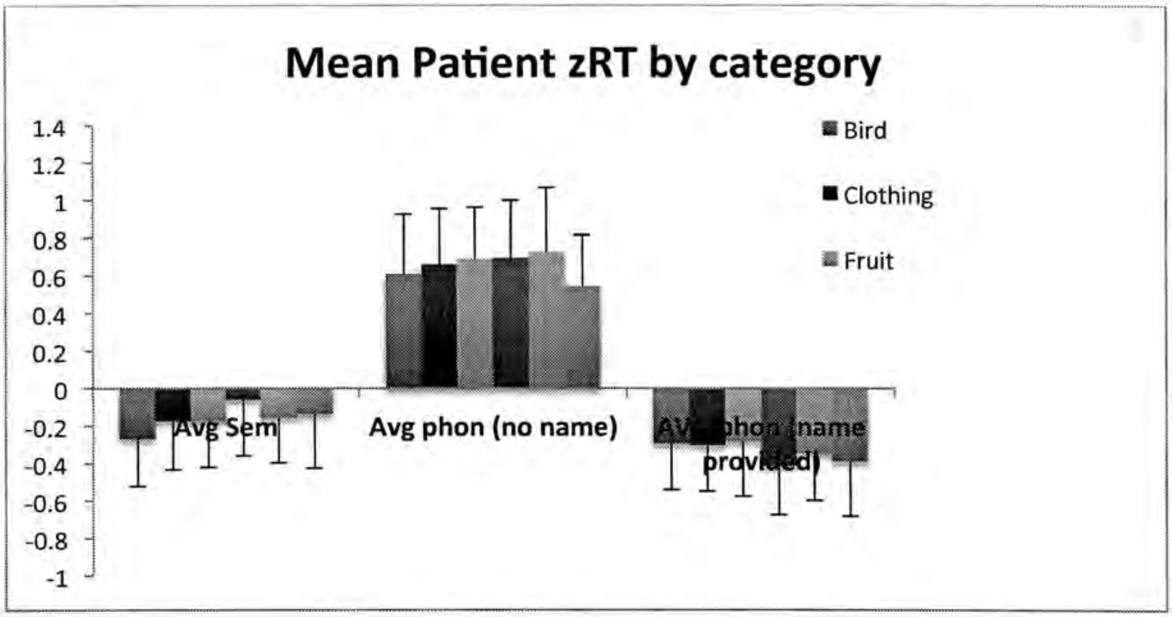


Figure 6. Average z-score of reaction time in patient and control groups.

Effect of Category on RT

No significant category effect was found in the patient group's zRT (*Pillai's trace* =.145; semantic $F(5,108)=1.09$, p=.370; phonological no name $F(5,108)=.795$, p=.556; phonological name provided $F(5,108)=.933$, p=.462). Category effect was found in the control group for the average phonological no name condition ($F(5,54)=2.954$, $p<.05$) but not for semantic (p=.787) or phonological name provided conditions ($p<.05$), indicating that controls named items in certain categories more easily than other categories. In the phonological no name condition, controls required the longest RT for *vegetables*, showing that it took control subjects the longest to name items from the *vegetable* category. (See Figure 6)



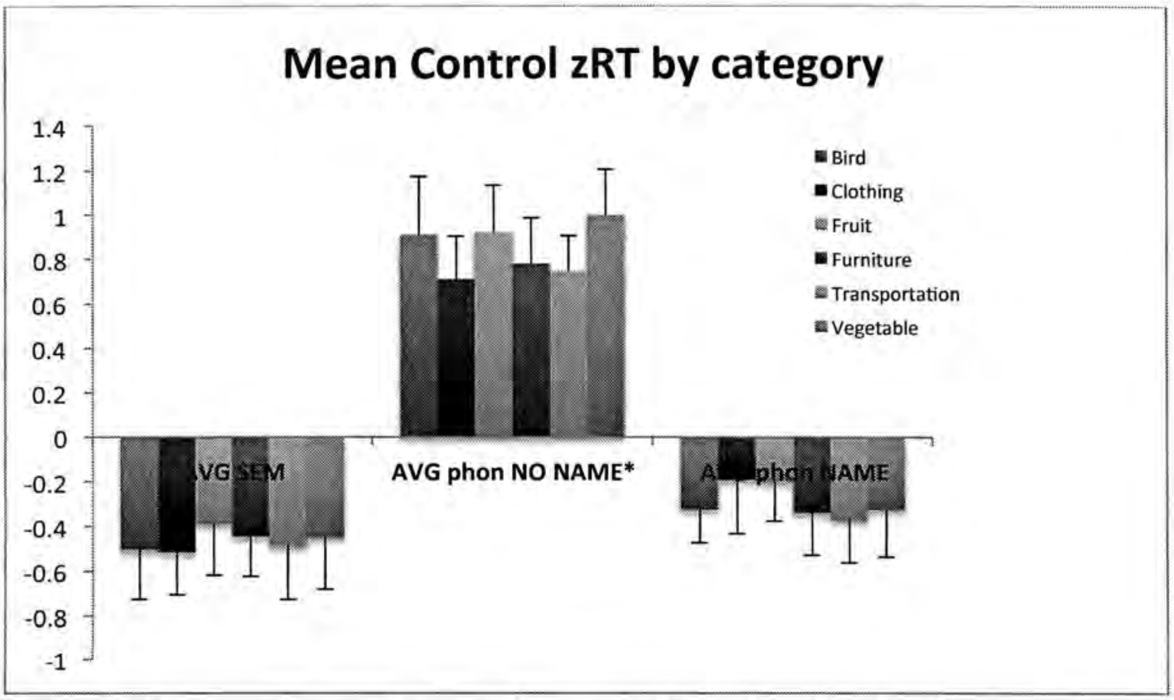
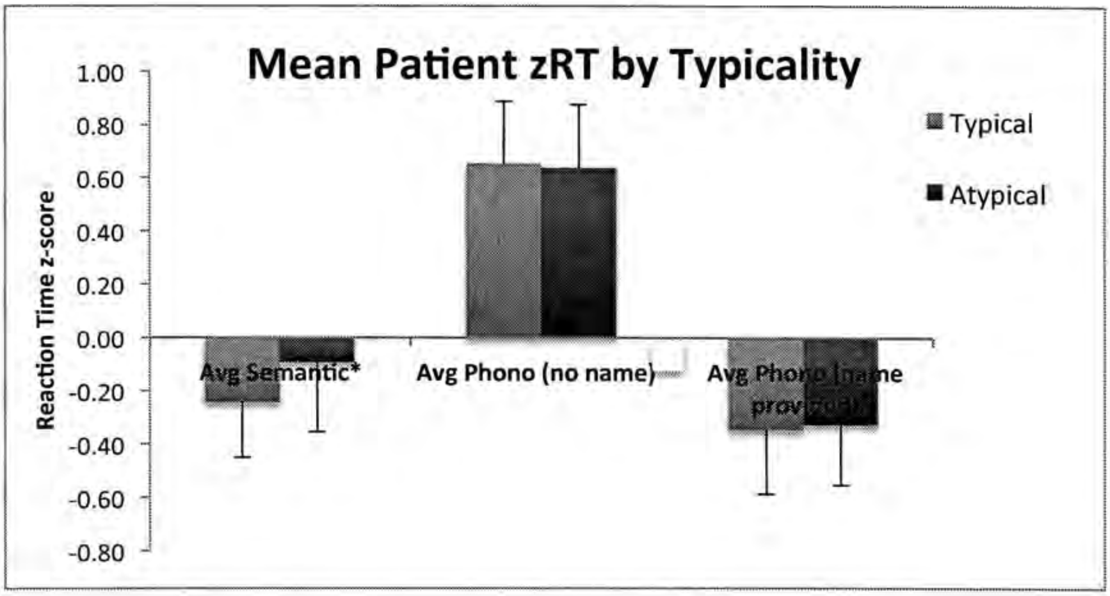


Figure 7. Mean patient and control z-score of reaction time by six categories: *bird, clothing, fruit, furniture, vegetable, transportation* on three task conditions: average semantic, average phonological (no name), average phonological (name provided). Asterisk (*) denotes statistical significance. Avg sem = average semantic scores, avg phon no name = average phonological (no name) scores, avg phon name = average phonological (name provided) scores.

Effect of Typicality on RT

Significant effect of typicality was found in the patient group on average zRT for semantic tasks (*Pillai's trace*=.35, p=.05; *F*(1,36)=3.96). No effect was found for the phonological no name zRT (*F*(1,36)=.05, p=.83) and phonological name provided zRT (*F*(1,36)=.07, p= 0.80). The control group showed no typicality effect (*Pillai's trace*=.32, semantic *F*(1,18)=1.973,p=.58, phonological no name *F*(1,18)=.00, p=.18, phonological name provided *F*(1,18)=1.00; p=.18). Patients spent longer time to process atypical items than typical items in the semantic tasks while controls showed no difference between processing typical and atypical items, suggesting that patients processed typical items faster than atypical items.



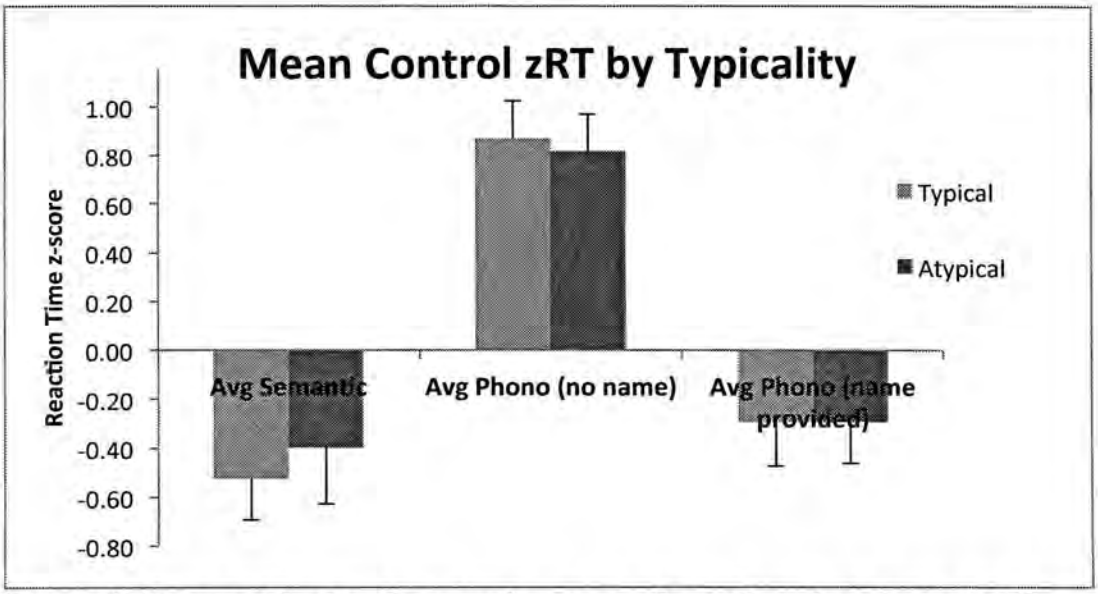


Figure 8. Mean patient and control z-score of reaction time by typicality: typical, atypical, on three task conditions: average semantic, average phonological (no name), average phonological (name provided). Asterisk (*) denotes statistical significance. Avg semantic = average semantic scores, avg phon no name = average phonological (no name) scores, avg phon name provided = average phonological (name provided) scores.

Correlation between task scores and other measures of impairment

Correlation was calculated between all subjects' individual task accuracy scores and demographic information, in addition to standardized naming and aphasia test scores in patients. High correlations ($p<.05$) are found between task accuracies and BNT scores and AQ in the patient group. Accuracy on the phonological no name condition is highly correlated with BNT scores ($r=.72$, $p<0.001$), indicating naming ability in our task is similarly measured by the BNT. Accuracy on the phonological name provided scores is correlated with their WAB-R AQ ($r=.63$, $p<.01$), suggesting that phonological processing at the buffer level is predicted by overall aphasia severity. In both the patient and control groups, there are significant positive correlations between years of education and average semantic scores (patient $r=.50$, $p<.05$; control $r=.64$, $p<.05$), showing that semantic processing ability is dependent on education in both aphasics and nonaphasics. See Table 7 for a breakdown of correlations.

Pearson Correlation with scores (Patient group)												
	Semantic			No Name			Name Provided			Average scores		
	Coordinate	Super-ordinate	SemFeat	Rhyme (no name)	Syllable (no name)	Phoneme (no name)	Rhyme (name provided)	Syllable (name provided)	Phoneme (name provided)	Avg Sem	Avg no name	Avg name provided
Age	-.485*	-.365	-.460*	-.009	-.423	-.170	.098	-.411	-.246	-.478*	-.215	-.241
Education	.576**	.352	.393	.016	.281	.204	.016	.506*	.248	.500*	.174	.323
WAB AQ	.276	.769***	.476*	.674**	.386	.465	.530*	.510*	.555*	.557*	.577*	.628**
BNT score	.504*	.791***	.636**	.696**	.639**	.599**	.500*	.267	.461	.716***	.721***	.472*
MPO	.030	-.229	.119	-.302	-.100	-.291	-.368	-.438	-.373	-.012	-.256	-.469*

Pearson Correlation with scores (Control group)												
	Semantic			No Name			Name Provided			Average scores		
	Coordinate	Super-ordinate	SemFeat	Rhyme (no name)	Syllable (no name)	Phoneme (no name)	Rhyme (name provided)	Syllable (name provided)	Phoneme (name provided)	Avg Sem	Avg no name	Avg name provided
Age	-.009	-.008	-.292	-.057	-.039	.091	-.332	.040	.149	-.074	.007	-.030
Education	.639*	.618	.026	.342	.065	.238	.366	.375	.435	.641*	.238	.432

*. 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 6.Correlations between demographic factors and standardized scores and individual task scores and average accuracy scores in each group. * = significance at the 0.05 level; **=0.01; *=0.001**

	Pearson Correlation with scores (Patient group)											
	Semantic			No Name			Name Provided			Average scores		
	Coordinate	Super-ordinate	SemFeat	Rhyme (no name)	Syllable (no name)	Phoneme (no name)	Rhyme (name provided)	Syllable (name provided)	Phoneme (name provided)	Avg Sem	Avg no name	Avg name provided
Age	-.485*	-.365	-.460*	-.009	-.423	-.170	.098	-.411	-.246	-.478*	-.215	-.241
Education	.576**	.352	.393	.016	.281	.204	.016	.506*	.248	.500*	.174	.323
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BNT score	.504*	.791***	.636**	.696**	.639**	.599**	.500*	.267	.461	.716***	.721***	.472*
MPO	.030	-.229	.119	-.302	-.100	-.291	-.368	-.438	-.373	-.012	-.256	-.469*

	Pearson Correlation with scores (Control group)											
	Semantic			No Name			Name Provided			Average scores		
	Coordinate	Super-ordinate	SemFeat	Rhyme (no name)	Syllable (no name)	Phoneme (no name)	Rhyme (name provided)	Syllable (name provided)	Phoneme (name provided)	Avg Sem	Avg no name	Avg name provided
Age	-.009	-.008	-.292	-.057	-.039	.091	-.332	.040	.149	-.074	.007	-.030
Education	.639*	.618	.026	.342	.065	.238	.366	.375	.435	.641*	.238	.432

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Table 6.Correlations between demographic factors and standardized scores and individual task scores and average accuracy scores in each group. * = significance at the 0.05 level; **=0.01; *=0.001**

DISCUSSION

The current study aimed to address the interactive nature between semantic and phonological processing in adults with aphasia, to investigate the effects category and typicality within semantic processing, and to explore the correlation between patient aphasia severity and demographic information and semantic and phonological impairments.

Table 6 summarizes the significant differences found (marked by "X") in the current study. In summary, patients performed with significantly lower accuracy than controls on all average task scores. Patients were slower than controls on semantic processing and phonological processing when naming was required, but no difference from the control group was found when the name cue was provided. In examination of the category and typicality effects on accuracy, both subject groups showed category effect on semantic tasks; only controls showed typicality effect on semantic tasks. For reaction time, controls showed the category effect on phonological tasks when naming is required; patients showed typicality effect on semantic tasks.

Table 7. Summary of significant differences found between patient and control groups and significant effects (indicated by "x") found in both subject groups on each task condition.

Patient vs. control		
Tasks	*ACC*	*RT*
Semantic	x	x
PhonNoName	x	x
PhonNamePro	x	

	Effect	Tasks	Patient	Control
Accuracy	Category	Semantic	x	x
		PhonNoName		
		PhonNamePro		
	Typicality	Semantic		x
		PhonNoName		
		PhonNamePro		
Reaction time	Category	Semantic		
		PhonNoName		x
		PhonNamePro		
	Typicality	Semantic	x	
		PhonNoName		
		PhonNamePro		

Our first hypothesis was that patients with aphasia would exhibit greater phonological processing impairment than semantic impairment. While the patient group was less accurate than the control group in all tasks as expected, the greatest difference was observed in the phonological no name condition and the smallest difference was observed in the semantic condition, showing that patients are more impaired in phonological processing than semantic processing. To discuss accuracy in terms of chance values, only one patient performed at chance on semantic tasks, while up to 14 patients performed at chance on the phonological tasks. This is consistent with the view that the semantic system is more likely to be spared in aphasia based on language processing models that the semantic system must be accessed before phonological information is processed (Ellis & Young, 1988; Levelt, 1999).

Regarding reaction time, as predicted, patients were significantly slower than the control group when responding to the phonological no name condition and semantic tasks. However, they showed no difference than the control group when processing phonological stimuli when the name is provided. Slower reaction time during the phonological (no name) tasks can be accounted for by patients' anomia; since the subject has to access the phonological form of the target word before being able to decide whether it rhymes with another word, whether it contains a certain phoneme, or how many syllables it has, and patients with aphasia require extra time compared to healthy controls during confrontational naming (Goodglass & Baker, 1976; Marshal, Neuburger, & Sakellaris, 1982), they were expected to demonstrate slower reaction time for phonological (no name) tasks. Nonetheless, no significant between-group difference was found in RT on the phonological name provided condition, indicating that patients with aphasia do not require extra time at the phonological output buffer (Ellis & Young, 1988) when their response is accurate.

When access to the semantic system is impaired (measured with semantic tasks), naming at the phonological output lexicon (measured with phonological no name tasks) is disabled. However, since phonological manipulation at the buffer (measured with phonological name provided tasks) can bypass the semantic system, aphasic subjects presented less severe impairment at the buffer than at the POL, resulting in the lack of RT difference from controls.

Our second hypothesis was that both patient and control groups would show effects of category and typicality on accuracy and reaction time, but with patients showing smaller effects. Atypical examples and inanimate and unfamiliar categories were predicted to be associated with lower accuracy and longer RT.

Both groups showed an effect of category in accuracy on average semantic scores, suggesting that some categories are processed in a different manner than others, even in patients. Overall, both groups achieved higher accuracy on b*ird, vegetable, fruit*, suggesting that animate categories receive preferential processing than inanimate categories (Barton & Komatsu, 1989; Devlin et al., 2002; Diesendruck & Gelman, 1999; Keil, 1989; Vanoverberghe & Storms, 2003). Despite the overall higher accuracy with animate categories, the control group achieved the highest accuracy on *clothing*, an inanimate category, out of all categories, while patients had higher accuracy on *clothing* than on *furniture* or *transportation*. As proposed by Malt & Smith (1982), the inherent familiarity of the category may have an impact on category membership decision, which was required in Category Superordinate and Category Coordinate tasks of our semantic tasks (i.e., even atypical examples in *clothing* are familiar to subjects and thus category membership can be determined with greater ease.)

Unlike the category effect found in both patient and control groups on semantic processing accuracy, the only category effect found on RT was in the control group's phonological no name condition. Regardless of category familiarity or animacy, patients processed semantic and phonological information of stimuli at similar speed despite the difference in accuracy. When naming is required, controls processed animate and familiar categories faster. This is in partial agreement with the interactive model that phonological representations are supported by its semantic representation (Martin, Schwartz, & Kohen, 2006; Schwartz et al., 2006; Martin & Saffran, 1997; Martin, Breedin, & Damian, 1999; Martin et al., 1999). When the semantic representation of an item is weak due to unfamiliarity, the POL access is more difficult even in healthy subjects. On the other hand, the category effect in both subject groups may be explained by the relationship between lexical access and word frequency; the more frequently a word is heard or used, the easier it is to access (Newcombe, Oldfield, & Wingfield, 1965; Rochford & Williams, 1965; Wepman, Bock, Jones, & Van Pelt, 1956; Williams & Canter, 1982).

Examining typicality within category, controls show an effect of typicality on semantic tasks, while patients do not, suggesting that patients have impaired semantic information on typicality. While controls show preferential processing for typical items, patients appear to have decreased sensitivity for typicality and process both typical and atypical items with similar accuracy. However, since patients performed with low accuracy on both typical and atypical examples, typicality difference is not shown in accuracy, instead, the difference can be seen in

RT to typical and atypical items. In contrast to our accuracy results, patients showed a typicality effect on RT in semantic tasks while controls do not. This supports the findings of Kiran, Ntourou, & Eubank (2007) and Sandberg, Sebastian, & Kiran (2012) that category and typicality boundaries are less robust in aphasia patients with semantic impairments. This is inconsistent with the previous studies claiming typicality effect for patients with aphasia (McCloskey & Glucksberg, 1978; Hampton, 1979, 1995; Posner & Kelle, 1968; Rosch, 1973; 1975; Storms, De Doeck, & Ruts, 2000).

RT results in patients were consistent with previous findings that atypical items are processed more slowly than typical items (Hampton, 1995; Kiran & Thompson, 2003; Rosch, 1975; Storms, De Doeck, & Ruts, 2000). However, since controls showed no difference between processing typical and atypical items, it is not completely consistent with the previous studies. Patients processed typical items faster, but not with higher accuracy, while controls processed typical items with higher accuracy, but not faster speed. The difference in accuracy and RT from controls demonstrates patients' impaired sensitivity to typicality boundaries.

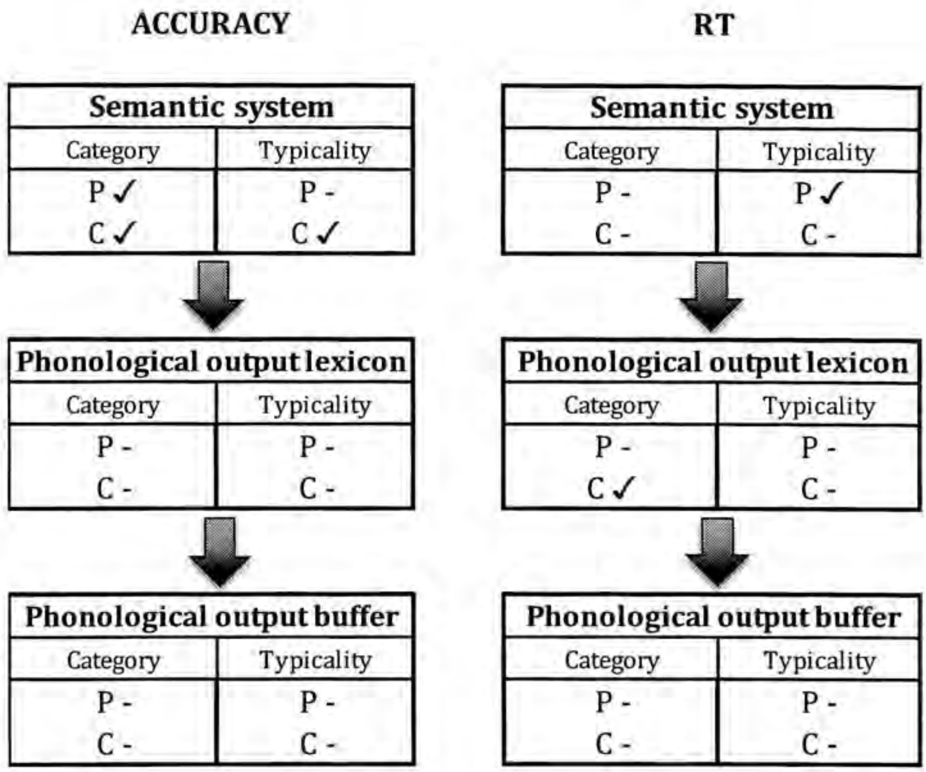

Figure 9. Category and typicality effects found in each stage of lexical processing model. Accuracy results shown on left and RT results on right. P=patient; C=control; ✓ = significant effect found; - = no effect found.

Revisiting the opposing views of the interactive processing models (Dell, 1986; Dell & Reich, 1981; Foygel & Dell, 2000; Schwartz, Dell, Martin, Gahl, & Sobel, 2006; Dell & O'Seaghdha 1992) and serial processing models (Levelt, Roelofs, & Meyer, 1999), we raised the question whether semantics and phonology maintain an interactive flow of communication during lexical processing. (Refer to Figure 8 for an illustration of category and typicality effects found in schematic representation of lexical processing.) According to the interactive processing model, semantic variables such as category and typicality should influence phonology. However, no effects of category and typicality were found at the POL or output buffer on accuracy, and only category effect was found in controls' RT at the POL. This indicates that semantic variables do not play a major role on phonological processing as suggested by previous studies (Martin & Saffran, 1997; Dell & Oppenheim, 2007; Tyler, Voice, & Moss, 2000). Instead, semantic variables category and typicality primarily influence category membership decision and feature judgment at the semantic system in both patients and controls, suggesting that semantic and phonological processing are discrete stages, consistent with previous findings that semantic deficits can be independent of phonological deficits (Cuetos, Aguado, & Caramazza, 2000; Howard & Gatehouse, 2006; Howard & Nickels, 2005; Caramazza & Hillis, 1990; Frost et al., 2000; Howard & Franklin, 1990, 1993; Martin, Shelton, & Yaffee, 1994).

Our last hypothesis was that individual accuracy on phonological no name tasks should reflect one's naming skills and other tasks reflects overall language impairment severity. Using the standardized test scores from each patient, patient BNT scores (naming skills) should show correlation with phonological (no name) scores while the WAB-R AQ (overall language severity) should show moderate correlation with all task scores. The results show strong correlations between BNT scores and all three phonological accuracy scores when naming is required, suggesting that our phonological no name tasks are sensitive to confrontational naming deficits as measured by the BNT. WAB-R AQ was found to correlate with phonological accuracy scores when name was provided—where phonological processing takes place at the phonological output buffer—suggesting that accuracy of phonological processing at the output buffer is dependent on overall severity of aphasia.

In addition, average semantic accuracy was found to correlate with years of education in both subject groups, consistent with studies that found education to be predictor of aphasia severity after stroke (González-Fernández et al., 2011; Connor, Obler, Tocco, Fitzpatrick, & Albert, 2003). The specific link to semantic abilities among other language tasks can be explained by the relationship between education and familiarity with semantic categories (i.e. The more education you receive, the more you learn about items within unfamiliar categories). This agrees with Le Dorze & Bédard (1998) that education level is correlated with the ability to transmit lexical-semantic information. Since both patients and control showed category effect on accuracy, familiarity/category knowledge appears to be a determining factor in accuracy regardless of semantic impairment (Gernsbacher, 1984; Funnell & Sheridan, 1992).

To conclude the major findings of the current study: first, patients with aphasia appear to have coexisting but varying degrees of semantic and phonological access deficits. The most apparent are the phonological access deficits (no name condition) at the phonological output buffer, but semantic processing is also impaired as evidenced by the less robust category and typicality effects on semantic tasks. Since category and typicality effects were found in the semantic condition, but not in phonological no name and name provided conditions, this suggests that phonological access is not dependent on typicality, but is somewhat dependent on category as category effect was observed in controls ability to name items. Second, the weak influence of semantic variables on phonological processing performance supports the discrete serial processing model over the interactive model. In addition, the robust effect of category on accuracy in both groups suggests frequency and familiarity effects are less affected by semantic impairments. Third, the separate correlations of BNT and WAB-R AQ to our task accuracy scores suggest naming and phonological manipulation without naming are separate stages in lexical processing (POL and buffer), and deficits are dissociable at each stage. The correlation between education and semantic scores suggest that though higher education is shown to preserve semantic knowledge, phonological abilities are unrelated to education level and are not spared after stroke despite education.

Some of the limitations of the current studies include variable motor control of stroke patients, lack of standardized measure to screen healthy control subjects, and variable cognitive linguistic abilities of patients. Some patients presented with more severe motor impairments in their hands and had trouble with physically pressing the response keys, which might have confounded accuracy and RT of answers. On the other hand, controls' healthy status was determined by self-report, while poorer performance by a couple of controls may be explained by very mild cognitive impairments that could have been screened out with standardized measures. Finally, given a larger sample size, patients could be divided into groups according to their aphasia profiles to further examine the relationship between semantic-phonological impairments and different aphasia profiles. Future research should include a larger sample size of patients with varying severity of semantic and phonological impairments to confirm the results of the current study.

APPENDIX

Table 8. Sample stimuli from six categories used in semantic and phonological tasks in the current study.

Animate 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
brussels sprouts	mushroom	bluejay	penguin	plum	kumquat
cauliflower	alfalfa	chickadee	turkey	peach	plantain
squash	olives	cardinal	peacock	pear	coconut

Inanimate Categories					
Furniture		***Transportation***		***Clothing***	
Typical	**Atypical**	**Typical**	**Atypical**	**Typical**	**Atypical**
bed	cot	truck	hot air balloon	pants	turban
sofa	umbrella stand	bus	raft	shirt	suspenders
dresser	carpet	van	submarine	jeans	veil
coffee table	wastebasket	taxi	sled	T-shirt	cape
desk	curtains	motorcycle	golf cart	shorts	cummerbund
night stand	chandelier	plane	hang glider	sweater	apron
bookcase	blinds	subway	rocket	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
toybox	sink	streetcar	kayak	coat	shoe

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