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Research Article

Effect of Working Memory Load and Typicality on Semantic Processing in Aphasia

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Purpose: This study evaluated the effects of a linguistic characteristic, typicality, and a processing variable, working memory on the abilities of people with aphasia (PWA) and neurologically intact adults to process semantic representations. This was accomplished using a newly developed assessment task, the Category Typicality Test, which was created for the Temple Assessment of Language and Short-Term Memory in Aphasia.
Method: A post hoc quasi-experimental design was used. Participants included 27 PWA and 14 neurologically intact adults who completed the picture and word versions of the Category Typicality Test, which required them to determine if two items are in the same category. Memory load was altered by increasing the number of items to be compared, and the typicality of items was altered to increase linguistic complexity.
Results: A four-way mixed analysis of covariance was conducted. There was a significant interaction between working memory load and category typicality with performance accuracy decreasing as working memory load increased and category typicality decreased. There was also a significant interaction for typicality and stimuli with better performance in the picture condition and a significant interaction for working memory and group with lower performance accuracy for PWA. Post hoc pairwise comparisons revealed differences between memory load, typicality, stimuli conditions, and group. PWA also showed greater magnitude of change than neurologically intact adults when comparing high and low working memory load conditions, but not typicality conditions.
Discussion: Increasing working memory load had the most substantial impact on the accuracy of category judgments in PWA, but the interaction between increased working memory load and decreased category typicality of items to be compared resulted in reduced accuracy in both groups. These findings suggest that manipulation of processing and linguistic variables in assessment will provide insight into the nature of linguistic breakdown in aphasia.
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The ability to access and maintain activation of semantic representations of words in language tasks is a common target of assessment and intervention in aphasia. This ability is modulated by linguistic characteristics such as imageability (e.g., Hanley & Kay, 1997; Kiran et al., 2011; N. Martin et al., 2018, 1996), the related variable concreteness (e.g., Paivio et al., 1968), and cognitive processing variables such as short-term memory capacity (e.g., N. Martin et al., 2018; N. Martin & Saffran, 1997; R. C. Martin, Shelton, et al., 1994) and working memory load (N. Martin et al., 2012). Effects of such variables on word processing are well documented in research literature (Baddeley, 2003; James, 1975; Kroll & Merves, 1986; Paivio et al., 1968); however, there are few clinical assessments that provide insight into how these variables may impact performance on semantic tasks. In this study, we examined the effects of two variables, category typicality (a linguistic characteristic) and working memory load (a processing variable), on accuracy of judgments of category membership in people with aphasia (PWA) and neurologically intact adults using a newly developed subtest for the Temple Assessment of Language and Short-Term Memory in Aphasia (TALSA; N. Martin et al., 2018).

A concept's typicality is determined by evaluating whether it is a good representative of its category (Collins

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& Loftus, 1975; Rosch, 1975; Rosch & Mervis, 1975). The importance of this variable relates to its differential effects on word processing efficiency: Generally, atypical exemplars of a category are processed more slowly and with less accuracy compared to typical exemplars in speakers with aphasia and neurologically intact speakers (Kiran et al., 2007; Kiran & Thompson, 2003a; Meier et al., 2015). However, Kiran and Thompson (2003a) reported a different pattern for people with Wernicke's aphasia who did not demonstrate a significant difference between processing time of typical and atypical exemplars and required significantly more time to process typical exemplars than people with Broca's aphasia and neurologically intact adults. The typicality effect is observed in numerous language tasks (Patterson, 2007), such as naming (Rossiter & Best, 2013), category verification (Fujihara et al., 1998), lexical decision (Rogers et al., 2004), and memory tasks (e.g., Greenberg & Bjorklund, 1981; Schmidt, 1985). Although atypical members of a category are more difficult to process, the inclusion of atypical exemplars in learning and relearning paradigms boosts learning in all category members (e.g., Kiran & Thompson, 2003a; Plaut, 1996) and improves response to treatment in aphasia (Kiran & Thompson, 2003b). Despite this benefit to learning and its impact on semantic processing, the effect of this variable is not often evaluated during aphasia assessment. Sensitivity to this semantic variable should provide information about the status of semantic and phonological processing abilities in aphasia. If a person with aphasia shows better performance on categorization tasks for typical than atypical exemplars, this mirrors the typicality effect observed in neurologically intact speakers, though the effect may be more exaggerated in PWA.

Though unintuitive, the presence of a strong category typicality effect with orthographically or verbally presented words suggests good access to semantics and possible difficulties at earlier stages of word access (phonological or lexical). When those levels of representation do not stay active long enough to support access to both typical and atypical words, the speaker is more dependent on access to semantics, which is more difficult for atypical than typical category exemplars. The typicality effect with pictured stimuli could also be present and would be indicative of difficulty accessing conceptual semantic information for atypical items. This effect would be exaggerated further by a variable such as working memory load, which we include in this category typicality judgment task.

Working memory load has also been studied extensively for its effects on word processing in neurologically intact individuals (e.g., Hadar et al., 2016; N. Martin et al., 2012) and PWA (N. Martin et al., 2012). A related variable is short-term memory, which Cowan (2008) describes as an ability to temporarily maintain conscious access to a limited amount of information. He distinguishes it from working memory, which is supported by short-term memory capacity but also involves manipulation of information in short-term memory storage (see also Baddeley, 2003). For PWA, verbal short-term memory span is invariably reduced relative to the spans of neurologically intact adults, and the degree of span reduction is directly related to severity of aphasia. This diminished verbal short-term memory capacity adversely affects working memory ability. Consequently, for most individuals with aphasia, an increase in working memory load typically leads to a greater decrease in performance than what is observed in neurologically intact adults on the same task. This pattern can be seen in many different language abilities such as sentence comprehension (Friedmann & Gvion, 2003; Wright et al., 2007), reading comprehension (Caspari et al., 1998; Sung et al., 2009), naming ability (Mayer & Murray, 2012), verbal–spatial ability (Christensen et al., 2018), and phonological and semantic processing of words (N. Martin et al., 2012). N. Martin et al. (2012) explored a different perspective on this association: the detrimental effects of increased working memory load on language performance. Specifically, they showed that increased memory load adversely affected performance on judgments of semantic similarity (synonymy) and phonological similarity (rhyming). They also demonstrated that this detrimental effect of working memory load was predicted by two factors: semantic short-term memory span and the executive ability of inhibition (N. Martin et al., 2012).

Although the effect of stimulus and processing variables are well documented in the literature for neurologically intact populations and in PWA, these variables are rarely included or manipulated in clinical aphasia assessments. Current theories posit that language breakdown in aphasia is a processing impairment affecting access to and retrieval of language representations, not a loss or degradation of those representations. One of the primary pieces of evidence for access impairments in aphasia is the inconsistency in which language breakdown can present (McNeil & Pratt, 2001). Given these patterns, it is of clinical and theoretical importance to evaluate language abilities while manipulating variables that are known to impact processing. Doing this provides a more detailed picture of language processing ability. Our study of the relationships among typicality, working memory, and category judgments is set in the context of a language-based model of verbal short-term memory (Craik & Lockhart, 1972; Martin & Saffran, 1990; Saffran, 1990). Short-term maintenance of activated linguistic representations of words is the process whereby short-term memory and linguistic knowledge converge. In this view, the short-term memory component of access and retrieval of words is viewed as part of the aphasia, an account that has been applied to diagnosis and treatment protocols for improvement of word and sentence processing (Francis et al., 2003; Kalinyak-Fliszar et al., 2011; N. Martin et al., 2018, 2020; Salis, 2012).

The Current Study

The primary goal of the current study was to obtain evidence that increased working memory load and a typicality of category members would reduce accuracy of judgments made about two object names or two depicted objects that are members of the same semantic category (e.g., birds, fruit, and clothing). We report data from the Category Typicality subtest of the TALSA battery (Kamen et al., 2009; N. Martin et al., 2018). The Category Typicality Test involves determining whether two pictured objects or their spoken/written word counterparts were members of the same semantic category. These judgments are made in three context conditions, which varied working memory load by increasing the number of pictures or words in the cohort of possible choices: (a) with only the two items present, (b) the two items plus two distractors, and (c) the two items plus four distractors. By increasing working memory load, the temporary storage demands inherent to working memory manipulations (short-term memory) are also increased. Additionally, pictured and written items were varied for typicality. This task allowed us to investigate two aspects of semantic processing involved in word comprehension: (a) access to the semantic concepts from words and from pictures and (b) short-term maintenance of activated words and their associated concepts. Furthermore, we investigated how each of these components is modulated by the typicality of the semantic concept and working memory load of the task. If someone can accurately determine whether two items in the array belong to the same category but fail to make that same judgment accurately when additional items are added to the array, we can attribute those deficits to impairment of working memory ability.

The category matches are varied based on the typicality of the items; thus, there are typical–typical pairs (e.g., clarinet–guitar), typical–atypical pairs (e.g., flute–viola), and atypical–atypical pairs (e.g., cymbals–xylophone). The presence of a strong category typicality effect (i.e., lower accuracy when matching atypical items) in the word version would signal good access to semantics and possible difficulties at earlier stages of word access (phonological or lexical). When phonological or lexical levels of representation do not stay active long enough, they are unable to support access to both typical and atypical words. Alternatively, in the picture version of the task, we would expect less prominent effects of typicality. Picture stimuli should have more direct access to conceptual semantic representations, and thus, a typicality effect in the picture version of this task should represent reduced efficiency accessing conceptual representations with atypical exemplars to make a judgment on category membership. The working memory processing variable should impact the picture and word versions similarly. Although the picture version reduces lexical processing, it is not devoid of lexical processing, since participants are likely to access this information for the pictured items and the category when completing the task. Maintenance of semantic concepts and lexical information related to those concepts occurs via short-term memory (e.g., Dell et al., 1997; N. Martin et al., 2018; Potter, 2012). Therefore, the picture and word versions of the Category Typicality Test should be sensitive to the working memory processing variable.

The clinical importance of this task is that it can reveal how a person's ability to demonstrate semantic knowledge can be compromised by linguistic complexity (typicality) and working memory load in the context of a category judgment matching task. In keeping with current theories of aphasia, which reflect a difficulty in accessing and maintaining access to that linguistic knowledge in the context of language performance (e.g., Dell et al., 1997; N. Martin et al., 2018; N. Martin & Saffran, 1997; Schwartz et al., 2004), it is important to assess effects of variables that can compromise that access. If typicality and memory load are found to affect performance on tests of semantic knowledge, this information should guide clinicians' choices of tasks to use in assessment and treatment of word processing disorders in aphasia.

Research Questions and Hypotheses

1. How does working memory load and typicality of stimuli impact the accuracy of semantic category judgments completed by PWA and neurologically intact adults on the Category Typicality Test? *Hypothesis 1:* Both variables will significantly impact accuracy. Therefore, we expect a significant interaction between working memory load and category typicality reflecting decreased accuracy as working memory load increases and item typicality decreases (i.e., items become more atypical).
2. How does stimulus condition (picture and word) interact with working memory load and typicality effects to impact accuracy of semantic category judgments of the Category Typicality Test? *Hypothesis 2:* A significant interaction will be present between stimuli and typicality conditions. The effects of typicality should be less potent for pictures than words for both groups. Consistent with evidence that pictures have more direct access to the concepts they represent than words (Paivio & Csapo, 1973; Shepard, 1967; Taikh et al., 2015), judging category matches of pictures should be less affected by typicality of the category members than the word condition. Increasing working memory load should reduce accuracy in both stimuli conditions because working memory's efficiency is impacted by the reduced short-term memory capacity in aphasia.
3. How does group (PWA and neurologically intact adults) impact accuracy of category judgments on the Category Typicality Test?
    - 3a. How does group interact with working memory load and typicality effects to impact accuracy of a semantic category judgment task? *Hypothesis 3a:* We predict a significant interaction for group and expect PWA to perform less accurately in relation to neurologically intact adults.
    - 3b. Is there a significant difference between the magnitude of change in accuracy observed between (a) high and low typicality conditions and (b) high and low working memory conditions when comparing PWA to neurologically

intact adults? *Hypothesis 3b:* PWA will demonstrate a more exaggerated typicality effect. Since typicality is a linguistic variable, we expect a greater difference between the effects of typicality on the processing of names of an object compared to pictures of the objects because the deficit in aphasia is in accessing semantic concepts from words (lexical semantics). Picture stimuli mitigate that issue, with direct access to the concepts they represent. In contrast, as a processing variable, memory load should affect access to semantics via words or pictures. Thus, PWA would demonstrate a greater effect of increased working memory load compared to neurologically intact adults on category judgments resulting in larger change scores.

Method

Design

This project was a post hoc quasi-experimental design. Data collection was completed in conjunction with a larger ongoing study to collect normative data for the TALSA (N. Martin et al., 2018).

Participants

There were 27 PWA (10 women, 17 men) due to left-hemisphere stroke who took part in the study. All participants were native English speakers. The average age of participants with aphasia was 58.23 years (SD = 7.30 years), and age ranged from 38 to 71 years. The average education was 13.96 years (SD = 2.5), and the average months postonset was 69.2 (SD = 72.67; see Table 1). Of the participants with aphasia, 16 identified as African American and 11 as Caucasian. For the majority of participants, the Western Aphasia Battery–Revised (WAB-R; Kertesz, 2006) was administered to determine aphasia severity and type. For the remainder of participants (N = 2), the Comprehensive Aphasia Test (Howard et al., 2004) was administered in place of the WAB-R. As Table 2 shows, the average WAB-R Aphasia Quotient for participants was 75.27 (SD = 17.81). All participants passed a hearing and vision screening prior to participation. The hearing screen required that they demonstrate the ability to hear tones presented at 30 dB in at least three of the four frequencies tested (500, 1000, 2000, and 4000 Hz) in each ear. Vision was screened with the tumbling E chart (Samar, 2009) at a distance of 10 feet. Additional exclusion criteria included positive history of learning differences or neurological injury or disease other than stroke.

Table 1. Demographics for people with aphasia (PWA) and neurologically intact adults.

Factor	PWA (N = 27) M (SD)	Neurologically intact (N = 14) M (SD)
Age	58.23 (7.30)	65.97 (8.40)
Education	13.96 (2.55)	14.71 (2.67)
Time Postonset	69.2 (72.67)	N/A[a]
MoCA score	N/A[a]	26.64/30 (2.01)
Sex		
Male	17	5
Female	10	9

Note. MoCA = Montréal Cognitive Assessment.

[a]N/A refers to factors that do not apply to certain demographics listed.

There were 14 neurologically intact adults (nine women, five men), with an average age of 65.97 years (SD = 8.40 years) and an average education level of 14.71 years (SD =2.67) who participated in this study. Seven identified as African American, and seven identified as Caucasian. The neurologically intact adults completed the Montréal Cognitive Assessment (Nasreddine et al., 2005) to screen for potential cognitive–linguistic differences. The average Montréal Cognitive Assessment score was 26.64 (SD = 2.01; see Table 1). Of the group of neurologically intact participants, 12 achieved a score of 26 or above, and two participants, who were African American, scored a 23. These participants were included in the sample based on updated normative data suggesting that 23 is an appropriate cutoff for this population (Milani et al., 2018). Overall, the group of PWA was significantly younger than the group of neurologically intact adults, $t(39) = -3.060$, mean difference (MD) = −7.746, SE = 2.532, p = .004, but there was no difference in education level, $t(39) = -0.880$, MD = −0.751, SE = 0.853, p = .384.

Participants with aphasia and neurologically intact adults were administered two tasks, digit and word pointing spans, to assess verbal short-term memory. For the participants with aphasia, the mean digit pointing span was 3.54 (SD = 1.44), and the mean word pointing span was 2.97 (SD = 1.04). Performance was higher in neurologically intact adults, with a mean digit pointing span of 6.64 (SD = 0.70) and a mean word pointing span of 5.76 (1.15). See Supplemental Material S1. The reduced spans observed in the participants with aphasia are consistent with other studies demonstrating this pattern of performance on verbal span tasks (e.g., N. Martin & Ayala, 2004).

Materials

The Category Typicality Test was administered as part of a larger test battery, the TALSA (N. Martin et al., 2018), used to assess phonological and semantic abilities as well as verbal short-term memory and working memory capacity in aphasia. Additionally, the TALSA measures the effects of increased working memory load and characteristics of linguistic stimuli (e.g., imageability, frequency, lexicality) on performance of language tasks such as naming, repetition, perception, and comprehension. The Category Typicality Test has recently been developed and added to the group of subtests in the TALSA to evaluate access to and maintenance of semantic representations within the

Table 2. Aphasia assessment results and aphasia classification.

Western Aphasia Battery (*N* = 25)					
	Subtests				
	Aphasia Quotient (out of 100)	Auditory Verbal Comprehension (out of 10)	Spontaneous Speech (out of 20)	Repetition (out of 10)	Naming and Word Finding (out of 10)
Mean	75.27	8.68	14.83	7.17	7.81
Minimum	18	4.83	0	.03	1.2
Maximum	97	9.75	20	10	9.8
Standard deviation	17.81	1.15	4.30	2.33	1.88

Comprehensive Aphasia Test (*N* = 2)					
	Subtests				
	Comprehension of Spoken Language (out of 66)	Comprehension of Written Language (out of 62)	Repetition (out of 74)	Naming (out of 69)	Reading (out of 70)
Participant 1	52	48	64	N/A	N/A
Participant 2	55	50	0	N/A	N/A

Aphasia classification (*n* = 27)							
Broca's	Wernicke	Anomia	TCM[a]	TCS[b]	Conduction	Mixed	Not classified[c]
3	2	14	2	1	3	1	1

Note. N/A = not applicable.

[a]TCM = transcortical motor. [b]TCS = transcortical sensory. [c]One participant was not able to be classified into typical aphasia classification types. This participant has limited, unintelligible verbal output. However, they do demonstrate exceptional comprehension skills.

context of a categorical judgment task. The test includes two versions, one with picture stimuli and one with word stimuli (see the Appendix for sample score sheet). Working memory load was manipulated by varying the number of items being presented simultaneously as two, four, or six items. The tasks always required determining if any one item above a line was in the same category as any one item below that line (e.g., see Figures 1 and 2). As the number of choices for a match increased, the number of comparisons needed to identify a matching pair increased. Item pairs also differed by being in the same or different category. Categories included musical instruments (e.g., cello), fruit (e.g., tangerine), clothing (e.g., dress), animals (e.g., rabbit), vehicles (e.g., truck), and body parts (e.g., eye). Item typicality was varied as follows: typical–typical (TT; clarinet–guitar), typical-atypical (TA; cherry–fig), and atypical–atypical (AA; bike–subway).

Stimuli

Item typicality was determined with ratings that we collected using methods based on Uyeda and Mandler's (1980) Prototypicality Norms for 28 Semantic Categories*,* along with their reported norms (Uyeda & Mandler, 1980). We collected typicality ratings from 22 adult participants without prior brain injury or insult, aged 30–80 years, with

Figure 1. Example of the six-item picture condition.

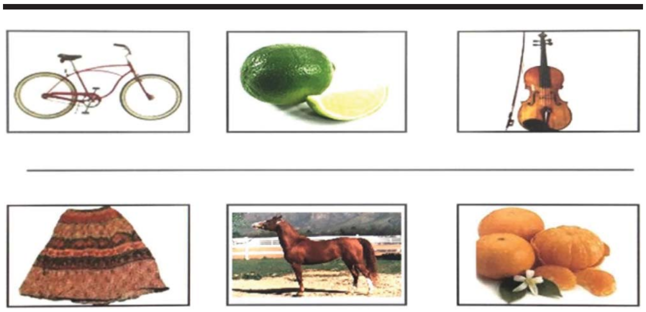
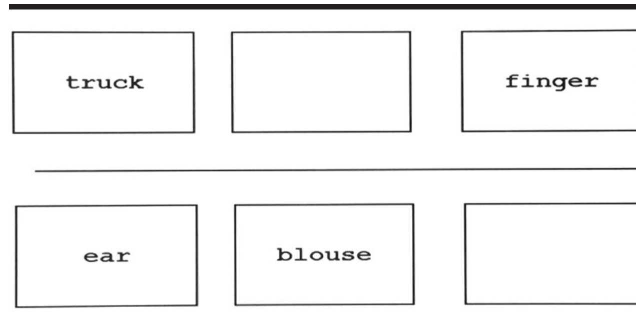


Figure 2. Example of four-item word condition.



a mean age of 56 years. Fifty-two percent of the participants were women (12/22). These participants were instructed to rate how typical of a category the item was on a scale of 1–7 (1 = *very typical*, 7 = *not typical at all*). Participants rated items in terms of 11 categories: clothing, animals, types of fabric, musical instruments, body parts, vehicles, vegetables, tools, kitchen utensils, fruit, and furniture. From these scores, six categories were chosen: musical instruments, fruit, clothing, animals, vehicles, and body parts.

From each category, six typical and six atypical items were chosen. Typical items were defined as having a typicality rating < 2.5 on both the scores that we collected as well as the scores reported by Uyeda and Mandler (1980). Atypical items received a typicality rating of > 2.8 on both measures. Stimuli were also controlled for length and frequency. Length was determined by the number of syllables, and frequency counts were based on Pastizzo and Carbone (2007).

The typical items had a mean typicality rating of 2.08, a mean length of 1.67, and a mean frequency of 9.42. The atypical items had a mean typicality rating of 3.84, a mean length of 1.75, and a mean frequency of 9.72. Items with more than one possible meaning or that could belong to more than one category (e.g., slip, chest) were eliminated.

Procedure

Each participant provided informed consent to take part in an ongoing study to provide normative data for the TALSA, which included first undergoing screenings (hearing and vision) and background assessments (global aphasia tests and other specific aphasia tests required for the ongoing study). Participants then completed the Category Typicality Test as a part of TALSA administration. There are two versions of the Category Typicality Test, one based category judgments on pictures of objects and the other based category judgments on written names of objects. For both versions, the names were also presented auditorily using a synthetic voice created with Natural Reader (Version 14; NaturalSoft Ltd, 2016). This test was administered electronically via computer, using E-Prime 2.0 software (Version 2.0; Psychology Software Tools, 1996–2018). All participants were given both the picture and word versions of the test on separate visits, and there were at least 2 weeks between administrations of the different versions.

Each test consisted of three practice trials (one trial with two pictures/words, one trial with four pictures/words, and one trial with six pictures/words) and 108 experimental trials. Individual items within a trial and the trials themselves were randomized; thus, working memory load and typicality of category matches were randomized. For the working memory load variable, there were 36 trials with two items, 36 trials with four items, and 36 trials with six items. There were 36 TT matches, 36 TA matches, and 136 AA matches. For each trial, half of the items were presented above and below a horizontal line. After hearing and seeing the stimuli, the participant was instructed to determine if any one item above the line was in the same category as any one item below the line. Participants responded by hitting marked yes/no keys on a keyboard.

Data Analysis

Research Questions 1, 2, and 3a were answered by conducting a four-way mixed analysis of covariance, 2 (participant group: PWA and neurologically intact adult) × 3 (working memory load: two, four, and six items) × 3 (typicality: TT, TA, and AA) × 2 (stimuli: pictures and words) design, covaried for word frequency. Follow-up pairwise comparisons and Bonferroni post hoc analyses were used to evaluate differences between conditions. Assumptions of normality ($p < .063$) and homogeneity of variances ($p < .001$) were not met. Greenhouse–Geisser corrections were used for Working Memory Load × Typicality and Working Memory Load × Typicality × Stimuli ($p < .05$). Assumption of sphericity was met for all other factors ($p \geq .132$). Since the analysis of covariance test is robust to violations of normality and homoscedasticity (Olejnik & Algina, 1984), the parametric test was conducted to examine the interaction between factors. Word frequency did not have an impact on test performance, $f(1, 31) = 0.942$, $p = .339$, $\eta^2 = .029$.

Research Question 3b was evaluated by calculating change scores between the highest working memory load condition (six-item trials) and the lowest working memory load condition (two-item trials) and comparing the change scores between the group of PWA and the group of neurologically intact adults using independent-samples *t* tests ($\alpha = .05$). The same procedure was completed to compare change scores in the accuracy of TT category match trials and the accuracy of AA category match trials. A separate change score was calculated for picture and word conditions.

Results

Research Question 1: How do working memory load and typicality of stimuli impact the accuracy of semantic category judgments completed by PWA and neurologically intact adults on the Category Typicality Test?

Main effects of memory load and typicality of stimuli were present (see Table 3). A significant two-way interaction of working memory load and typicality was also present. As typicality decreased (i.e., items became less typical) and working memory load increased (i.e., number of items to compare increased), overall performance decreased (see Table 3).

Pairwise comparisons were then performed to evaluate differences between specific performance conditions. A significant difference in accuracy was found between two- and four-item comparisons and between two- and six-item comparisons in all three typicality conditions. The difference between the four- and six-item comparison was shown in the TT match and AA match conditions, but not in the TA match conditions (see Table 4).

Research Question 2: How does stimulus condition (picture and word) interact with working memory load and typicality effects to impact accuracy of semantic category judgments of the Category Typicality Test?

Table 3. Omnibus table of mixed analysis of covariance to depict interactions between working memory load, typicality, participant group, and stimuli.

Source	Sum of squares	Mean square	*F*	*df*	Sig.	η_p^2	Power
Within-subjects factors							
Working memory load	79.388	39.694	27.146	2, 62	.000*	.467	1.000
Typicality	35.108	17.554	24.961	2, 62	.000*	.446	1.000
Working Memory Load × Participant Group	16.959	8.480	5.799	2, 62	.005*	.158	.854
Working Memory Load × Typicality[a]	8.799	2.730	4.355	3.224, 99.929	.005*	.123	.876
Working Memory Load × Stimuli	0.872	0.436	0.390	2, 62	.679	.012	.110
Typicality × Stimuli	3.792	1.896	3.979	2, 62	.024*	.114	.693
Typicality × Participant Group	0.421	0.211	0.300	2, 62	.742	.010	.096
Working Memory Load × Typicality × Stimuli[a]	5.580	1.718	2.913	3.248, 100.702	.034*	.086	.703
Working Memory Load × Typicality × Participant Group	5.803	1.451	2.873	4, 124	.026*	.085	.765
Working Memory Load × Typicality × Stimuli × Participant Group	1.184	0.296	0.618	4, 124	.650	.020	.199
Between-subjects factors							
Participant group	72.717	72.717	8.388	1, 31	.007*	.213	.801

[a]Greenhouse–Geisser corrections.
*$p < .05$.

There was a significant interaction between typicality and stimuli. Performance on pictures (mean accuracy and standard deviation for typicality averaged across working memory load conditions: TT matches= 11.476, *SD* = 0.141; TA matches= 11.183, *SD* = 0.167; AA matches = 11.045, *SD* = 0.171) was generally higher than words (mean accuracy for typicality averaged across working memory conditions: TT matches= 11.381, *SD* = 0.186; TA matches = 11.052, *SD* = 0.212; AA matches= 10.540, *SD* = 0.230). Pairwise comparisons showed significant differences for the picture version versus the word version for AA matches in the two-item (*MD* = 0.347, *SE* = 0.160, $p = .038$) and six-item (*MD* = 1.010, *SE* = 0.285, $p = .001$) conditions (see Table 5).

The interaction between working memory load and stimuli was not significant, but the three-way interaction of working memory load, typicality, and stimuli was significant (see Table 3).

Research Question 3: How does group (PWA and neurologically intact adults) impact accuracy of category judgments on the Category Typicality Test?

3a. How does group interact with working memory load and typicality effects to impact accuracy?

To answer this question, we examined the four-way interaction of working memory load, participant group, typicality, and stimuli condition; the three-way interaction of working memory load, typicality, and participant group; and the two-way interactions of working memory load and participant group and of typicality and participant group.

The four-way interaction of working memory load, typicality, stimuli, and participant group was not significant (see Table 3). There was a significant interaction between working memory load, typicality, and participant group (see Table 3). At the lowest working memory load condition, two items, PWA did not perform differently from neurologically intact adults with TT matches and TA matches. However, PWA did perform significantly less accurately on AA matches. When stimuli became more complex at the four-item condition, the group difference became significant in all three typicality pairings. The same pattern

Table 4. Descriptive information and pairwise comparisons of category judgment accuracy in typicality and working memory load conditions covaried for word frequency.

Typicality	Working memory load	*M*	*SD*	Memory load comparison	*MD*	*SE*	*p*
Typical–typical	2 items	11.835	0.079	2 items–4 items	0.403	0.113	.004*
	4 items	11.432	0.112	4 items–6 items	0.411	0.162	.049*
	6 items	11.020	0.201	2 items–6 items	0.814	0.167	.000*
Typical–atypical	2 items	11.526	0.114	2 items–4 items	0.408	0.161	.049*
	4 items	11.118	0.169	4 items–6 items	0.410	0.185	.104
	6 items	10.708	0.217	2 items–6 items	0.817	0.169	.000*
Atypical–atypical	2 items	11.534	0.117	2 items–4 items	0.851	0.138	.000*
	4 items	10.684	0.191	4 items–6 items	0.525	0.191	.030*
	6 items	10.159	0.190	2 items–6 items	1.375	0.140	.000*

Note. MD = mean difference.
*$p < .05$.

Table 5. Descriptive information and comparisons of category judgment accuracy based on typicality condition, working memory load, and stimuli condition covaried for word frequency.

Typicality	Working memory	Pictures *M*	Pictures *SD*	Words *M*	Words *SD*	Stimulus comparisons *MD*	Stimulus comparisons *SE*	Stimulus comparisons *p*
Typical–typical	2-item	11.914	0.052	11.756	0.142	0.158	0.144	.280
	4-item	11.511	0.114	11.352	0.180	0.160	0.202	.434
	6-item	11.004	0.258	11.036	0.237	−0.032	0.289	.913
Typical–atypical	2-item	11.522	0.128	11.529	0.147	−0.007	0.153	.964
	4-item	11.230	0.152	11.006	0.229	0.224	0.190	.247
	6-item	10.797	0.222	10.620	0.260	0.177	0.213	.411
Atypical–atypical	2-item	11.708	0.103	11.361	0.171	0.347	0.160	.038*
	4-item	10.764	0.173	10.603	0.284	0.161	0.274	.562
	6-item	10.664	0.238	9.654	0.236	1.010	0.285	.001*

Note. *MD* = mean difference.
**p* < .05.

was seen at the six-item difficulty, except for the AA pairing. See Table 6 for details.

To examine differences in the impact of working memory load conditions between participant groups, a two-way interaction of working memory load and participant group was examined, and a significant interaction was found (see Table 3). In general, the performance accuracy of PWA and neurologically intact adults decreased as working memory load increased. However, significant differences in accuracy were found between PWA and neurologically intact adults for the four- and six-item conditions, but not for two-item conditions (see Table 6).

To determine how typicality impacted performance in participant groups, the interaction between typicality and participant group was examined. We found no significant interaction between typicality and participant group, but the main effect of typicality was significant (see Table 3). Participants responded most accurately to TT matches (*M* = 33.857, *SD* = 2.338), followed by TA matches (*M* = 32.810, *SD* = 2.860), and AA matches (*M* = 31.846, *SD* = 3.075) were least accurate (see Table 7).

3b. Is there a significant difference between the magnitude of change in accuracy observed between (a) high and low typicality conditions and (b) high and low working memory conditions when comparing PWA to neurologically intact adults?

PWA (*M* = 1.615, *SD* = 2.080) did not show statistically different change scores between accuracy in AA match trials and TT match trials in the picture version compared to neurologically intact adults (*M* = 1.214, *SD* = 1.122), $t(38) = 0.668$, $MD = -0.401$, $SE = 0.600$, $p = .508$. The same pattern was demonstrated in the word version. PWA (*M* = 2.870, *SD* = 1.687) did not show a significantly larger difference score for AA and TT accuracy on the word version compared to neurologically intact adults (*M* = 2.231, *SD* = 2.555), $t(34) = 0.904$, $MD = 0.639$, $SE = 0.706$, $p = .372$.

In regard to working memory load effect, PWA (*M* = 3.926, *SD* = 3.112) showed statistically greater change scores

Table 6. Descriptive information and comparisons of category judgment accuracy based on typicality, working memory load, and group covaried for word frequency.

Typicality	Working memory	People with aphasia *M*	People with aphasia *SD*	Neurologically intact *M*	Neurologically intact *SD*	Group comparisons *MD*	Group comparisons *SE*	Group comparisons *p*
Typical–typical	2 items	11.788	0.098	11.882	0.125	−0.094	0.159	.558
	4 items	11.097	0.138	11.766	0.176	−0.668	0.224	.006*
	6 items	10.433	0.248	11.607	0.315	−1.174	0.401	.006*
Typical–atypical	2 items	11.479	0.141	11.573	0.180	−0.094	0.229	.683
	4 items	10.741	0.210	11.495	0.266	−0.754	0.339	.034*
	6 items	10.072	0.268	11.345	0.341	−1.272	0.434	.006*
Atypical–atypical	2 items	11.263	0.144	11.806	0.183	−0.542	0.233	.027*
	4 items	10.152	0.236	11.215	0.300	−1.063	0.382	.009*
	6 items	9.795	0.235	10.523	0.299	−0.728	0.380	.065
Total	2 items	11.510	0.110	11.753	0.140	−0.244	0.178	.182
	4 items	10.664	0.171	11.492	0.217	−0.828	0.276	.005*
	6 items	10.100	0.225	11.158	0.286	−1.058	0.364	.007*

Note. *MD* = mean difference.
**p* < .05.

Table 7. Average of typicality and working memory load total collapsed across conditions.

Condition	Typicality		Working memory load	
	M	*SD*	*M*	*SD*
Low	31.846	2.965	34.568	1.968
Moderate	32.810	2.860	32.506	3.131
High	33.857	2.338	31.000	3.947

Note. Low typicality = atypical–atypical; low working memory load = two-item matches. Moderate typicality = typical–atypical; moderate working memory load = four-item matches. High typicality = typical–typical; high working memory load = 6-item matches.

between two- and six-item trials on the picture version compared to neurologically intact adults (M = 1.643, SD = 1.550), $t(38.983) = 3.135$, MD = 2.283, SE = 0.728, p = .003, and showed greater change scores between two- and six-item trials on the word version compared to neurologically intact adults (PWA: M = 4.963, SD = 3.684; neurologically intact adults: M = 2.000, SD = 1.958), $t(37.496) = 3.318$, MD = 2.963, SE = 0.893, p = .002. See Table 8.

Discussion

The goals of this study were to evaluate how working memory load and category typicality impact accuracy on a test of semantic processing that uses a category matching task. Our findings revealed a significant interaction between these two variables that impacted the ability of the participants with aphasia and neurologically intact adults to accurately determine whether two pictures or two words share the same semantic category (e.g., clothing). Furthermore, our results confirmed that increasing working memory load significantly reduced accuracy of category judgments in the picture and word conditions, supporting our hypothesis that this factor would affect access to and maintenance of semantic information across stimuli conditions and should be considered in clinical decision making. We also observed that access to semantic concepts from pictures is more robust and less susceptible to typicality effects than access to semantic concepts from phonologically and lexically mediated stimuli (words) and that increasing working memory load disproportionately impacts performance of PWA compared to neurologically intact adults. Below, we discuss each research question in detail.

How Working Memory Load and Category Typically Interact on Semantic Category Tasks

A significant interaction was present between working memory load and the typicality of items to be compared. As the number of items to be compared increased (working memory load) and the typicality of those items decreased (category typicality), performance became less accurate. The combination of these factors interacted to influence performance more than increasing a single level of complexity. Follow-up pairwise comparisons revealed significant differences in accuracy for TT matches in the two- and four-item trials, two- and six-item trials, and four- and six-item trials. This finding indicates that increasing the number of items to compare reduced accuracy even in the context of typical items, which represents a lower level of linguistic complexity. The same pattern was observed when evaluating AA matches in the two- and four-item trials, two- and six-item trials, and four- and six-item trials. However, mean accuracy was lower in the atypical conditions, which demonstrates the confounding effect of the cognitive processing variable (working memory load) and the linguistic variable (typicality). Accuracy for TA matches diverged somewhat from the above pattern with significant differences when comparing items in the two- and four-item trials and two- and six-item trials, but not in the four- and six-item trials.

How Category Typicality and Working Memory Interact With Pictures and Words

A significant interaction between stimuli (picture vs. word), typicality, and working memory load was present.

Table 8. Performance accuracy for high and low typicality and working memory load in people with aphasia (PWA) and neurologically intact adults (NI) and magnitude of change scores.

Stimulus/ condition	PWA				NI				PWA-NI comparisons		
	Low		High		Low		High		Magnitude of change		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*MD*	*SE*	*p*
Pictures											
Typicality	31.923	2.576	33.539	2.336	33.857	1.657	35.071	0.917	0.401	0.600	.508
WM	34.704	1.295	30.778	3.755	35.429	0.756	33.786	1.929	2.283	0.728	.003*
Words											
Typicality	29.960	3.234	32.739	2.783	33.154	2.996	35.385	0.768	0.639	0.706	.372
WM	33.704	2.743	28.741	4.212	35.154	1.519	33.154	2.267	2.963	0.893	.002*

Note. Low typicality = atypical–atypical matches; high typicality = typical–typical matches. Low working memory = two-item matches; high working memory = six-item matches. WM = working memory.

*$p \leq .003$.

However, the two-way interaction was significant for category typicality and stimuli, but not for working memory load and stimuli. Evaluating the follow-up pairwise comparisons revealed that the three-way interaction was driven by significantly lower performance for AA word matches in the two- and six-item trials when compared to accuracy in the picture conditions. The significant interaction between item typicality and the stimuli condition supports our hypothesis and provides evidence that the typicality effect is stronger when accessing semantic concepts from phonological/lexical information than when more direct access to conceptual semantics is available (with pictures). This is consistent with evidence that pictures have more direct access to the concepts they represent than words (Paivio & Csapo, 1973; Shepard, 1967; Taikh et al., 2015).

We found no interaction between working memory load and stimuli condition, which confirmed our hypothesis that increasing working memory load would have a similar effect on category judgment accuracy in both picture and word conditions. These findings suggest that maintenance of semantic concepts and lexical information related to those concepts occurs via short-term memory (e.g., Dell et al., 1997; N. Martin et al., 2018; Potter, 2012). When the capacity of short-term memory is reached, that reduces the ability to manipulate information in working memory, which is required to make category comparisons in this task. As noted, the PWA in this study demonstrated reduced short-term memory capacity and thus were less accurate at making category judgments, regardless of stimuli condition, when there were more items to be compared.

Differences in Interactions of Category Typicality and Working Memory With Neurologically Intact Adults and PWA

A significant interaction between working memory load, category typicality, and group was present. However, evaluation of the two-way models only revealed a significant interaction between group and working memory, not between group and category typicality. The significant interaction between working memory load and participant group indicates that the increase in working memory load had a larger effect on the accuracy of category judgments in PWA than in neurologically intact adults. This finding was further supported by follow-up pairwise comparisons that revealed statistically significant differences when comparing accuracy between groups in the four- and six-item trials across typicality conditions (see Table 6). Neurologically intact adults demonstrated a similar pattern to the group of PWA in relation to working memory load, with accuracy declining as working memory load increased, but PWA were disproportionately affected by increasing working memory load. This pattern was also demonstrated when evaluating the difference in the magnitude of change in accuracy from two- and six-item trials. PWA demonstrated significantly larger change scores compared to neurologically intact adults, further supporting that accuracy in the category judgment task was disproportionately impacted by increasing the number of items to be compared.

There was not a significant interaction between group and typicality. PWA performed similarly in relation to neurologically intact adults with the highest levels of accuracy on TT matches, followed by TA matches and then AA matches. However, further analysis of their performance reveals some differences. For example, a significant difference in accuracy for AA matches in the two-item trials was found when comparing the group of PWA to neurologically intact adults (see Table 6), providing evidence of a typicality effect for PWA even in the least complex cognitive condition (only two items to compare). However, the magnitude of change was not significantly different when comparing PWA to the group of neurologically intact adults in the picture or word condition, contrary to our hypothesis that PWA would have an exaggerated typicality effect in the word condition. This finding suggests that accuracy may not be sensitive enough to capture the differences that PWA may demonstrate when making category judgments of less typical items compared to neurologically intact adults. Reaction time could be a better approach to capturing an exaggerated typicality effect but presents challenges for clinical application.

General Discussion

Overall, effects of concept typicality were more robust in the word condition than picture condition in both groups (PWA and neurologically intact adults). This qualitative similarity between the two groups indicates that, for this sample of PWA, access to semantics via pictures was stronger (and more resistant to typicality differences) than access via words. Importantly, for this group of participants, the change scores between high and low typicality conditions (for pictures and words) were not significantly different. Although we expected an exaggerated difference in making category judgments via words by PWA due to the potential for impaired connections from phonological and/or lexical and phonological levels of word representation with the concepts they represent, this was not the case for the current data set. See Table 9 for descriptive data. This finding could potentially be a result of our methodology. For example, evaluating reaction time would be more likely to capture the impact of item typicality on the ability to make category judgments. It is also possible that people with specific aphasia types perform more like neurologically intact adults than other aphasia types, as demonstrated by Kiran and Thompson (2003a). The current project sought to evaluate the effect of typicality on accuracy, and we found that there was an effect, especially with word stimuli (vs. picture). However, this effect was not significantly different in PWA versus neurologically intact adults.

Two findings in this study reinforce previous research indicating that the language performance of PWA can be disproportionately impacted by increasing the cognitive demands of the task (N. Martin et al., 2012). First,

Table 9. Mean proportions of correct category judgments for pictures and for words as a function of category typicality and memory load condition.

Group		Stimulus/ memory load	Typical–typical		Typical–atypical		Atypical–atypical	
			M	*SD*	*M*	*SD*	*M*	*SD*
People with aphasia (n = 27)	Pictures	2 items	11.889	0.320	11.308	0.838	11.519	0.700
		4 items	11.074	0.917	10.926	0.917	10.385	1.098
		6 items	10.482	1.626	10.222	1.396	10.074	1.567
	Words	2 items	11.720	0.891	11.423	0.902	10.852	1.099
		4 items	10.792	1.179	10.296	1.540	9.885	1.751
		6 items	10.185	1.618	9.692	1.761	8.962	1.400
Neurologically intact adults (n = 13)	Pictures	2 items	11.929	0.267	11.643	0.633	11.857	0.363
		4 items	11.643	0.633	11.429	0.756	11.071	0.730
		6 items	11.500	0.650	11.357	0.929	10.929	1.072
	Words	2 items	11.846	0.376	11.539	0.660	11.769	0.599
		4 items	11.846	0.376	11.539	0.660	11.308	1.182
		6 items	11.692	0.630	11.385	0.650	10.077	1.553

there was a significant interaction between working memory load/group (discussed above), and second, there was a significant difference between the magnitudes of change in accuracy associated with increased working memory load when comparing the two groups. PWA demonstrated a significantly larger change score between two- and six-item trials compared to the change scores of neurologically intact adults (in picture and word conditions). Thus, although both neurologically intact adults and PWA demonstrated reduced accuracy of category judgments in higher working memory load conditions, the impact was greater for PWA.

Verbal short-term memory/working memory capacity is different for everyone, though it is known to be reduced for PWA (N. Martin & Ayala, 2004; R. C. Martin, Shelton, et al., 1994). However, there is no specific point at which the high working memory load is triggered. Rather, it is an interplay among short-term memory capacity, stimuli, and task that determines the working memory load. The data from this study also support a theoretical model in which the association of short-term memory and word processing variables is not coincidental but rather is due to a common underlying cognitive processing ability that supports both functions. Verbal span is positively associated with word processing ability (N. Martin & Gupta, 2004) and with verbal learning ability (N. Martin & Saffran, 1999). Word span and word processing abilities improve in tandem with recovery from aphasia (N. Martin, Dell, et al., 1994; N. Martin et al., 1996). The results of this study provide another indication of the close relation between short-term memory, working memory, and language performance. Greater accuracy on a category membership judgment task when there are fewer items to consider indicates that the language knowledge supporting these judgments is present but more difficult to access and maintain in working memory when the limits of the verbal short-term memory system are exceeded.

Ultimately, the functional use of language in everyday situations involves the use of working memory, and so it is timely that diagnostic and treatment regimens target this ability in the context of aphasia assessment. Furthermore, our findings reveal that the processing variable, working memory, which is compromised by the reduced short-term memory capacity in aphasia, had a more substantial impact on the ability of participants with aphasia to make category judgments than the stimulus variable, category typicality. This pattern is supported by the significant interaction between working memory load and group and suggests that PWA may be more sensitive to manipulation of processing variables. Incorporating this component into clinical practice could provide valuable information on how PWA perform under varied conditions.

Clinical Implications of Findings

The finding that typicality and working memory load impact accuracy in a category judgment task is not novel. Typicality effects have been reported on a number of different language tasks, including naming (Rossiter & Best, 2013), category verification (Fujihara et al., 1998), and lexical decision tasks (Rogers et al., 2004). Furthermore, this variable has been identified as an important factor in treatment stimuli selection and learning (Kiran & Thompson, 2003b). Similarly, a large body of research supports the finding that working memory load impacts language processing on a number of different tasks, including naming (Mayer & Murray, 2012), phonological and semantic processing of words (N. Martin et al., 2012), sentence comprehension (Friedmann & Gvion, 2003; Wright et al., 2007), and more. The novel feature of this study is the combination of these two variables into a clinical assessment for aphasia. By evaluating a commonly used semantic assessment task such as category judgment and then manipulating a linguistic and a processing variable, this assessment task is able to provide a more complete picture of semantic processing ability than assessment tasks that only evaluate semantic access in isolation. Working memory had a more exaggerated effect on the group of PWA, and PWA performed similarly to neurologically intact adults in response to varied item typicality; however, the combination of these two factors had a significant interaction that reduced accuracy in both groups. Although, the two factors individually can affect performance, as has been suggested in previous work, the combination resulted in a significant interaction and a reduction in accuracy, a form of measurement that can be easily captured in clinical settings. This finding provides further evidence that aphasia assessment should consider and manipulate variables that impact language processing and consider levels of complexity that would be more likely to reflect real-life communication situations (e.g., combinations of linguistic and cognitive complexity). Importantly, our findings related to increased processing demands (working memory load) suggest that this variable had a larger impact on the group of PWA's ability to accurately make category judgments. The effect of the typicality of stimuli was harder to capture. Although there was some evidence of an exaggerated typicality effect in the group with aphasia, this was not strongly supported by the analyses, indicating that accuracy may not be the best measure to detect the impact of this variable.

As noted in the introduction and above, sensitivity to semantic variables such as imageability and typicality with orthographically or aurally presented stimuli in someone with aphasia indicates the probability that processing of words at the phonological or lexical levels of representation is impaired, leading to a reliance on access to semantic representations. However, in the current study, the group of PWA performed similarly to the group of neurologically intact adults in terms of accuracy of category judgments in relation to item typicality. The addition of the working memory load variable provides evidence that the influence of semantic variables, such as typicality on semantic processing, is fluid and affected by variations in memory load in both neurologically intact speakers and those with aphasia, but it is affected further still by brain damage that affects verbal short-term memory capacity (which supports working memory capacity). Increasing working memory load and linguistic complexity increases the sensitivity of an assessment of semantic processing, which is influenced by both of these variables. This type of assessment is especially relevant when evaluating people with mild aphasia (Silkes et al., 2021), who often do well in most standardized assessments, but report language breakdowns in functional communication situations that place more processing demands on the language system. Although the current study included a range of aphasia severity, future work will focus specifically on people with mild aphasia.

Limitations of the Current Study

The current study is limited by the post hoc nature of the project, which impacted the battery of assessments that were administered and resulted in some inconsistency in procedures (e.g., WAB-R vs. Comprehensive Aphasia Test scores). Additionally, we evaluated changes in accuracy as the primary variable, although a measure such as reaction time would likely yield more sensitive results and could have led to more robust findings, especially for typicality. For example, Kiran and Thompson (2003a) reported that younger adults, older adults, and people with Broca's aphasia were significantly faster at judging category membership of typical items than atypical items, but this difference was not significant in people with Wernicke's aphasia, indicating that they needed more time to judge typical items of a category. Our rationale for evaluating change in accuracy was to determine if the impact of these variables could be easily captured in a clinical assessment for aphasia. The findings from Kiran and Thompson (2003a) also revealed differences in semantic processing across different groups of PWA. Our project did not evaluate performance based on aphasia type, and our sample only included two participants with Wernicke's aphasia and one with transcortical sensory aphasia, which could also be construed as a limitation (see Table 2 for a breakdown of participant aphasia types). Additionally, the low statistical power for the four-way interaction we completed (power = .169) is a limitation. Although the two- and three-way interactions in our analyses were appropriately powered (power > .693), the four-way interaction was not, which limits our ability to interpret that analysis. Lastly, the group of neurologically intact adults (N = 14) is much smaller than the group of PWA. Equal groups would have produced more generalizable results and greater statistical power.

Conclusions

The current study illustrates how variation in the linguistic and cognitive complexity of a semantic task can provide a more refined picture of semantic abilities (access and maintenance) in PWA. As current aphasia theories posit strong relationships between cognition and language, it is essential to consider how these theories should impact assessment and treatment of PWA. Development of clinical measures of verbal short-term memory and language tasks that are sensitive to the effects of working memory load on performance should lead to a more complete understanding of the nature of impairment in aphasia. Viewed as a processing impairment, therapies that aim to directly treat a semantic or phonological "impairment" in aphasia will be better able to focus on improving the rudiments of that processing impairment (accessing and maintaining activation of representations) by addressing processing load in addition to targeted language tasks. Our results on typicality are less clear, since we did not see a significant interaction between typicality and group or a significant difference in the magnitude of change score. Thus, clinically, the impact of the processing variable, working memory load, would be easier to capture. However, the interaction of typicality and working memory load provides evidence that increasing complexity of both variables had the strongest impact on accuracy for both groups.

There are three final points to note. First, working memory is not the only cognitive ability that influences functional language capabilities. Others that influence language performance include attention (Hula et al., 2007) and executive functions (Miyake et al., 2000). These may or may not be intrinsic to language processing, but their effect is to "control" or enable efficiency of processing information in language and other cognitive domains. At the behavioral level, executive functions refer to abilities such as planning, sequencing, sustaining attention, inhibiting irrelevant stimuli, coordination of simultaneous ability, and cognitive flexibility. Crawford (1998) and Ramsberger (1994) noted that executive abilities play a role in everyday communicative function where there is a need to attend to a communication partner, sustain that attention, sequence information to be communicated, monitor ongoing communication, and shift strategies in accordance with ongoing conversation. Thus, there is a clear need for research on the role of executive functions in language and development of clinical tools to evaluate and treat executive impairments (e.g., see Miyake et al., 2000; Murray et al., 2006).

The second point is that working memory, attention, and executive function abilities and their influence on language performance are likely *not* independent of each other. Thus, continued efforts to understand the role of each of these cognitive abilities in language processing should eventually give way to a better understanding of their integrated involvement in processing language. In conjunction with the theoretical aims of this research, efforts to apply this knowledge to diagnostic and treatment approaches to aphasia should continue. In turn, given the dynamic nature of these processes, treatment studies should provide an excellent vehicle for testing theories of the relation of language to short-term memory and other cognitive processes.

Lastly, the assessment task presented here was able to capture changes in accuracy by manipulating a processing variable and a linguistic variable to increase the complexity of an assessment task. There was a significant interaction between these two variables that reduced accuracy in PWA and neurologically intact adults. However, the impact of increased working memory load disproportionately impacted the accuracy of the PWA, while the typicality of stimuli did not. This suggests that varying the cognitive processing demands of tasks may be easier to implement and effects easier to capture in clinical settings, while the typicality variable may require more refined measures, such as reaction time. This task can be used clinically, and future research should target other assessment tasks that can be similarly crafted to provide theoretically consistent clinical information about language processing in PWA. Focus groups conducted with speech-language pathologists by Greenspan et al. (2021) revealed that, although speech-language pathologists endorse current theories that claim aphasia and cognition are intertwined, they are uncomfortable or unfamiliar with approaches to assessment of these abilities in tandem. This study provides an example of how a cognitive processing variable (working memory) and a linguistic variable (typicality) can be altered in the context of a typical assessment task. Additional research is required to incorporate cognitive processing variables into commonly used assessment tasks.

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Appendix (p. 1 of 3)

Category Typicality

TALSA 1
Word
ID: ___________
Date:_____________
Administrator: ________________

Practice

#	TYP/ ATYP	Trial #	Item1	Item2	Item3	Item4	Item5	Item6	Correct Response	Response
1		2	coat	gloves	-	-	-	-	Y	
2		4	tangerine	cymbals	deer	bra	-	-	N	
3		6	horse	cow	ear	peach	trousers	motorcycle	Y	

#		Trial #	Item1	Item2	Item3	Item4	Item5	Item6	Correct Response	Response
1	TT	4	knee	clarinet	tangerine	horse	-	-	N	
2	TA	6	tangerine	lime	skirt	viola	horse	bike	Y	
3	TT	2	cab	truck	-	-	-	-	Y	
4	TT	2	nectarine	ear	-	-	-	-	N	
5	TT	4	tangerine	dog	motorcycle	finger	-	-	N	
6	AA	2	antelope	prune	-	-	-	-	N	
7	TA	6	knee	lung	tiger	jet	clarinet	girdle	Y	
8	TT	6	trousers	skirt	deer	auto	plum	finger	Y	
9	AA	2	throat	liver	-	-	-	-	Y	
10	TT	6	knee	peach	truck	deer	coat	flute	N	
11	AA	2	rabbit	bull	-	-	-	-	Y	
12	TT	6	lion	cow	jeep	foot	sweater	trombone	Y	
13	TT	6	violin	trousers	dog	jeep	cherry	foot	N	
14	AA	4	tractor	jet	bra	xylophone	-	-	Y	
15	TT	4	motorcycle	auto	ear	lion	-	-	Y	
16	AA	2	cello	jet	-	-	-	-	N	
17	AA	2	cymbals	xylophone	-	-	-	-	Y	
18	AA	6	scooter	bike	gloves	rabbit	stomach	cello	Y	
19	TA	4	eye	bike	trombone	pomegranate	-	-	N	
20	AA	2	scarf	tractor	-	-	-	-	N	
21	TA	6	dress	cello	horse	bike	tangerine	liver	N	
22	TA	2	peach	coconut	-	-	-	-	Y	
23	TA	4	leg	tooth	plum	accordion	-	-	Y	
24	TT	2	eye	knee	-	-	-	-	Y	
25	TA	6	guitar	cymbals	tooth	plum	rabbit	bra	Y	
26	AA	2	tooth	bass	-	-	-	-	N	
27	TA	6	accordion	blouse	mule	taxi	prune	knee	N	
28	TT	4	nectarine	plum	trousers	ear	-	-	Y	
29	TA	2	blouse	lung	-	-	-	-	N	
30	TA	2	plum	girdle	-	-	-	-	N	
31	TT	4	ear	finger	blouse	truck	-	-	Y	
32	TT	4	dog	truck	violin	coat	-	-	N	
33	AA	6	hair	tooth	cello	mule	lime	gloves	Y	
34	AA	4	coconut	prune	helicopter	xylophone	-	-	Y	
35	TT	6	guitar	coat	lion	truck	cherry	ear	N	
36	AA	4	throat	hat	antelope	subway	-	-	N	
37	TA	6	auto	pomegranate	leg	viola	sweater	rabbit	N	
38	TA	2	eye	scooter	-	-	-	-	N	
39	AA	4	bass	accordion	scooter	liver	-	-	Y	
40	TA	6	stomach	tangerine	helicopter	dog	bra	clarinet	N	
41	TT	6	motorcycle	cherry	ear	violin	skirt	deer	N	
42	TA	6	clarinet	gloves	tiger	subway	nectarine	hair	N	
43	AA	2	lime	pomegranate	-	-	-	-	Y	
44	TT	4	trumpet	violin	strawberry	cow	-	-	Y	
45	TA	2	foot	hair	-	-	-	-	Y	
46	AA	6	accordion	hat	bull	subway	coconut	tooth	N	
47	AA	4	gloves	tractor	hair	fig	-	-	N	

Appendix (p. 2 of 3)

Category Typicality

Practice

#	TYP/ ATYP	Trial #	Item1	Item2	Item3	Item4	Item5	Item6	Correct Response	Response
48	TA	2	violin	moose	-	-	-	-	N	
49	TT	6	flute	trombone	sweater	lion	auto	peach	Y	
50	AA	6	cello	scarf	moose	jet	fig	liver	N	
51	AA	2	fig	accordion	-	-	-	-	N	
52	TT	6	foot	leg	trumpet	cherry	blouse	auto	Y	
53	TT	2	dog	tiger	-	-	-	-	Y	
54	TA	4	trombone	cello	knee	hat	-	-	Y	
55	TA	4	taxi	scooter	flute	raisin	-	-	Y	
56	TT	6	trumpet	dress	cow	motorcycle	strawberry	eye	N	
57	TA	6	cab	jet	deer	bass	finger	raisin	Y	
58	AA	4	lime	cymbals	girdle	rabbit	-	-	N	
59	TT	4	clarinet	dress	auto	peach	-	-	N	
60	TA	2	auto	mule	-	-	-	-	N	
61	TT	2	sweater	dress	-	-	-	-	Y	
62	AA	4	antelope	mule	vest	bike	-	-	Y	
63	TA	2	flute	viola	-	-	-	-	Y	
64	TT	2	sweater	cow	-	-	-	-	N	
65	TT	4	horse	deer	jeep	leg	-	-	Y	
66	TA	6	blouse	vest	trumpet	stomach	nectarine	rabbit	Y	
67	AA	4	viola	gloves	antelope	subway	-	-	N	
68	AA	6	moose	rat	viola	bra	hair	tractor	Y	
69	TT	2	deer	motorcycle	-	-	-	-	N	
70	TT	4	skirt	deer	cab	nectarine	-	-	N	
71	TA	4	guitar	mule	foot	raisin	-	-	N	
72	TA	6	antelope	dress	cymbals	taxi	pomegranate	leg	N	
73	AA	2	scooter	raisin	-	-	-	-	N	
74	AA	6	bull	scarf	xxylophone	helicopter	prune	throat	N	
75	AA	6	liver	coconut	tractor	bull	scarf	accordion	N	
76	TT	6	jeep	taxi	flute	nectarine	coat	eye	Y	
77	AA	2	bike	subway	-	-	-	-	Y	
78	AA	6	bass	vest	antelope	scooter	coconut	throat	N	
79	TA	6	tiger	mule	eye	lime	coat	scooter	Y	
80	TT	2	trombone	skirt	-	-	-	-	N	
81	AA	4	helicopter	prune	scarf	bull	-	-	N	
82	TT	4	jeep	cherry	skirt	foot	-	-	N	
83	AA	6	raisin	fig	girdle	bull	tooth	xylophone	Y	
84	TA	4	trousers	bull	finger	viola	-	-	N	
85	TA	4	cab	rabbit	guitar	lung	-	-	N	
86	TT	4	blouse	coat	lion	taxi	-	-	Y	
87	AA	4	stomach	lung	rat	girdle	-	-	Y	
88	AA	4	rat	throat	bass	coconut	-	-	N	
89	TT	6	dog	trousers	clarinet	motorcycle	plum	knee	N	
90	TT	2	leg	strawberry	-	-	-	-	N	
91	AA	6	viola	cello	rat	helicopter	liver	pomegranate	Y	
92	TT	2	clarinet	guitar	-	-	-	-	Y	
93	TA	2	motorcycle	helicopter	-	-	-	-	Y	
94	TA	2	horse	rat	-	-	-	-	Y	
95	TA	4	cow	moose	peach	stomach	-	-	Y	
96	TA	4	cherry	fig	trumpet	moose	-	-	Y	
97	TA	2	trousers	bra	-	-	-	-	Y	
98	TA	4	strawberry	vest	tiger	lung	-	-	N	
99	TT	2	tangerine	cherry	-	-	-	-	Y	
100	TT	2	taxi	finger	-	-	-	-	N	
101	AA	6	hat	girdle	cymbals	tractor	raisin	moose	Y	
102	TA	2	lion	stomach	-	-	-	-	N	
103	AA	4	bra	scarf	jet	pomegranate	-	-	Y	
104	TA	4	sweater	hat	flute	tooth	-	-	Y	
105	TT	6	peach	xstrawberry	coat	deer	truck	leg	Y	
106	AA	6	subway	fig	lung	cymbals	hat	antelope	N	
107	TA	4	tiger	lime	cab	hair	-	-	N	
108	AA	2	vest	gloves	-	-	-	-	Y	

Appendix (p. 3 of 3)

Category Typicality

Practice

#	TYP/ ATYP	Trial #	Item1	Item2	Item3	Item4	Item5	Item6	Correct Response	Response
	# Correct									
Two Trial	/36									
Four Trial	/36									
Six Trial	/36									
Total	/108									