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The influence of event-related knowledge on verb-argument processing in aphasia

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Abstract

Event-related conceptual knowledge outside the language system rapidly affects verb-argument processing in unimpaired adults (McRae & Matsuki, 2009). Some have argued that verb-argument processing is in fact reducible to the activation of such event-related knowledge. However, data favoring this conclusion have come primarily from college-aged healthy adults, for whom both linguistic and conceptual semantic processing is fast and automatic. This study examined the influence of event-related knowledge on verb-argument processing among adults with aphasia (n=8) and older unimpaired controls (n=60), in two self-paced reading studies. Participants read sentences containing a plausible verb-argument combination (*Mary used a knife to chop the large carrots before dinner*), a combination that violated event-related world knowledge (*Mary used some bleach to clean the large carrots before dinner*), or a combination that violated the verb's selectional restrictions (*Mary used a pump to inflate the large carrots before dinner*). The participants with aphasia naturally split into two groups: Group 1 (n=4) had conceptual-semantic impairments (evidenced by poor performance on tasks like Pyramids & Palm Trees) but reasonably intact language processing (higher Western Aphasia Battery Aphasia Quotients), while Group 2 (n=4) had intact conceptual semantics but poorer language processing. Older unimpaired controls and aphasic Group 1 showed rapid on-line disruption for sentences with selectional-restriction violations (SRVs) and event-related knowledge violations, and also showed SRV-specific penalties in sentence-final acceptability judgments (Experiment 1) and comprehension questions (Experiment 2). In contrast, Group 2 showed very few reliable differences across conditions in either on-line or off-line measures. This difference between aphasic groups suggests that verb-related information and event-related knowledge may be dissociated in aphasia. Furthermore, it suggests that intact language processing is more critical for successful verb-argument integration than intact access to event-related world knowledge. This pattern is unexpected if verb-argument processing is reducible to activation of event-related conceptual knowledge.

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1. INTRODUCTION

How world knowledge influences language understanding is a topic of long-standing debate in the cognitive science and psycholinguistic literature. Early approaches to this question were inspired by the existence of specialized systems for the perception of visual and other stimuli (such as feature detectors in primary visual cortex, Hubel & Wiesel, 1959, and the "what" and "where" visual pathways, Goodale & Milner, 1992; Haxby, Grady, Horwitz, Ungerleider, Mishkin, et al., 1991). The models inspired by these approaches claimed that language was initially processed by similarly-specialized cognitive modules (Fodor, 1983; Frazier, 1987; Katz & Fodor, 1963), with general world knowledge being used only later, after language-specific processes have completed their work.

More recent work rejects this view. Results from a variety of experimental paradigms suggest that world knowledge may have a very rapid effect on language comprehension, as evidenced by event-related potentials (e.g., Bicknell, Elman, Hare, McRae, & Kutas, 2010), reading (e.g., Matsuki, Chow, Hare, Elman, Scheepers & McRae, 2011), and the visual-world paradigm (e.g., Kamide, Altmann & Haywood, 2003). These findings, in combination with evidence that world knowledge drives verb-argument processing (e.g. Bicknell, et al., 2010) are consistent with the hypothesis that everything we know about verbs is reducible to world knowledge.

However, there is growing evidence that there may be important processing differences between verb knowledge and world knowledge, even though they are not processed by separate modules and verb knowledge might develop from abstractions across world knowledge (see Warren, Milburn, Patson & Dickey, under review). In the current paper, we use *verb knowledge* to refer to knowledge of a verb's core semantic and combinatorial requirements – for example, that *drink* entails both an agent and a theme (a person who drinks and an object being drunk) and requires that its object be liquid. In contrast, world knowledge is broad, experience-based knowledge about the objects and events that are described using language – for example, that humans and dogs typically drink different things, and the some liquids are much more likely to be drunk than others (for example, tea versus rubbing alcohol). The current paper addresses the relationship between event- and verb-knowledge during reading comprehension. In the following, we review previous evidence relevant to deciding whether these kinds of knowledge are represented or processed differently or similarly.

Hagoort, Hald, Bastiaansen and Petersson (2004) compared ERPs and fMRI activity elicited in response to sentences that violated readers' world knowledge about the world versus sentences that contained a semantically mismatching subject-predicate adjective combination (e.g. *The Dutch trains are* <u>*white*</u> *and very crowded* versus *The Dutch trains are* <u>*sour*</u> *and very crowded*). BOLD response in fMRI and ERP waveforms were almost identical for the world-knowledge and semantic-mismatch conditions, with only oscillatory

EEG responses differing. Hagoort and colleagues concluded that the brain does not distinguish between world knowledge and lexical semantic information. The embodied approach to cognition (e.g., Barsalou, 2008; Pulvermüller, 2013) argues for a similar view, claiming that all cognition (including language) is grounded in and cannot easily be distinguished from sensory and motor representations in the mind and brain. These approaches all agree that language and world knowledge are likely not distinct, and they also do not give priority to language-specific knowledge in language comprehension.

The processing of verbs and verb-argument combinations have been central to the question of how distinct language and non-language processes are, and whether language-specific knowledge has a special role in guiding language understanding. For example, the processing of action verbs has been one of the primary sources of evidence for embodied approaches to language representation. fMRI studies show that literal (Hauk, Johnsrude & Pulvermüller, 2004) as well as figurative uses of verbs (Boulenger, Hauk & Pulvermüller, 2009) are associated with activation of motor and pre-motor areas corresponding to the body parts used to carry out the actions described by those verbs. In addition, the degree of effort implied by a predicate (throwing a frisbee vs. throwing a javelin) also appears to mediate the degree to which different cortical regions are recruited, with greater effort being associated with greater BOLD response in both left inferior frontal gyrus and middle frontal gyrus (Moody & Gennari, 2010).

Interestingly, the processing of verb-argument combinations has provided evidence for both sides of this debate. For instance, in a reading study of college-aged healthy adults, Warren and McConnell (2007) showed that verb-argument combinations that violate a verb’s core selectional restrictions (such as *Mary used a pump to inflate the large carrots*) elicited earlier-emerging and longer-lasting disruption than combinations which violated world knowledge about likely events and participants (such as *Mary used bleach to clean the large carrots*), even when such combinations were rated very unlikely to occur in the real world. Rayner, Warren, Juhasz, and Liversedge (2004) found similar results in a separate reading study of college-aged adults, and Warren, McConnell, and Rayner (2008) found that the early penalty for an SRV persisted even when sentences were placed in fictional contexts which should have rendered the violations sensible (e.g., *Harry taught the bread* in the context of a paragraph about wizards bewitching objects and interacting with them as if they were animate).

Parallel to these findings, Paczynski & Kuperberg (2012) found different ERP responses among college-aged adults to SRVs (in this case, animacy restrictions on arguments) and violations of real-world expectations about likely verbal arguments. Both types of violations elicited an N400 response, but the SRV elicited an additional P600 response. Furthermore, having semantic associates of the critical word in the preceding linguistic context attenuated the N400 response to the world-knowledge violation, but did not attenuate either the N400 or P600 response to the verb animacy violation.

In addition to this evidence from rapid verb-argument combination, evidence from visual-world studies suggests that verb-specific knowledge may play a special role in anticipating upcoming verbal arguments. Boland (2005) showed that college-aged listeners gazed anticipatorily at both likely and unlikely indirect objects when the verb required an indirect object. For example, they looked at a picture of a toddler when hearing *The newspaper was difficult to read, but the mother suggested it anyway to* …, even though toddlers are highly unlikely indirect objects (recipients) in this context.

These findings point to the importance of verb-specific knowledge (such as semantic restrictions on potential arguments) in rapid understanding of verb-argument combinations. They also suggest that such knowledge may play a special role in comprehension, facilitating prediction or rapid integration or both prediction and integration of verbal arguments that fit the verb's core semantic restrictions.

In contrast to these findings, there is also evidence suggesting that verb-argument processing is not accomplished with reference to special verb-specific knowledge, but instead draws critically on general world knowledge about events. For example, in a study of college-aged adults, Bicknell et al. (2010) found faster reading times for likely verbal objects (*The journalist checked the spelling*) than for unlikely verbal objects (*The mechanic checked the spelling*) as well as an N400 for unlikely objects. Both likely and unlikely objects are compatible with the verbs' selectional restrictions, suggesting that a different source of knowledge (like event-related world knowledge) must be responsible for these differences. Furthermore, a separate lexical-priming study showed that the semantic association between the agent nouns (journalist/mechanic) and the critical object (spelling) was comparable across conditions, suggesting that facilitation of the likely object was due to activation of event-related knowledge by the agent-verb combination rather than simple associative priming.

In a similar vein, Matsuki, et al. (2011) found that college-aged adults were faster to read likely objects than unlikely objects in sentences similar to those tested by Warren and McConnell (2007). In early reading measures, people were slower to read *hair* following *Donna used the hose to wash* than following *Donna used the shampoo to wash*. Again, this effect did not appear to be driven by lexical associations between the verb (*wash*) and the preverbal instrument (*hose/shampoo*): a separate priming experiment found comparable priming between these words across conditions.

Complementing this evidence suggesting that event-related knowledge facilitates rapid integration of likely objects, there is also evidence that event-related knowledge may guide the anticipation of likely upcoming verb arguments. In a visual-world study, Kamide, et al. (2003) found that college-aged adults gazed at objects which are not only compatible with a verb's semantic constraints but are likely event participants, given the agent. Upon hearing *The girl rode the*, listeners were more likely to gaze at a carousel than an equally ride-able motorcycle (and vice versa when hearing *The man rode the*).

These findings point to the important role that world knowledge about typical events and event participants plays in the rapid understanding of verb-argument combinations. This knowledge, stored in semantic memory and activated in response to words like verbs, has a strong and fast-acting effect on the processing of verbs and their arguments. As noted above, these findings support the hypothesis that verb-specific knowledge about arguments (like selectional restrictions) cannot be meaningfully distinguished from and may in fact be reducible to event-related world knowledge. Under this view, automatic activation of event-related knowledge is an automatic and obligatory component of the rapid understanding of verb-argument combinations.

The data that have informed this question regarding the role of language-specific versus more general knowledge in the domain of verb-argument processing have come primarily from monolingual, young (college-aged), healthy adults. This question may be difficult to resolve based on data from such populations, since young healthy adults have intact systems for both language-specific processes (such as verb retrieval and verb-argument composition) and non-linguistic knowledge (such as event-related world knowledge, stored in semantic memory). Verb-specific and event-related knowledge can each presumably influence performance on tasks measuring verb-argument understanding. Because young healthy adults are able to recruit and rapidly use both kinds of knowledge to facilitate comprehension, it may be difficult to disentangle how these two sources of knowledge contribute to rapid verb-argument processing for this group.

Another approach to resolving this issue is to examine the performance of neurogenically-impaired populations, for whom one or both of these sources of knowledge may be impaired. There is significant evidence that these two kinds of knowledge and processing may be differentially impaired, either following brain damage (as in stroke-related aphasia) or in neurodegenerative disorders (such as semantic dementia). Aphasia is a central impairment of language processing abilities subsequent to focal brain injury to the language-dominant hemisphere. Aphasic impairments in language abilities cannot be attributed to any concomitant impairments in non-language cognitive capacities (e.g., McNeil & Pratt, 2001). Although adults with aphasia may have co-occurring deficits in non-language cognitive abilities, these deficits are not the cause of those language deficits, in contrast to, for example, semantic dementia (e.g., Reilly & Peelle, 2008; Warrington, 1975).

The separability of linguistic and non-linguistic performance in aphasia points to the independence of language and non-linguistic knowledge. It also highlights the potential importance of testing the performance of neurogenically-impaired adults to disentangling the contribution of language-specific processes (verb retrieval, verb-argument composition) and non-linguistic knowledge (event-related world knowledge) to rapid verb-argument understanding. If language-specific processes play a critical role in verb-argument processing (e.g., Warren & McConnell, 2007; Paczynski & Kuperberg, 2012), then prominent impairments of language-processing ability (as in aphasia) might be expected to disrupt verb-argument processing. In contrast, if event-related knowledge is the critical determinant of verb-argument processing (e.g, McRae, Ferretti & Amyote, 1997; Ferretti, McRae & Hatherell, 2001), impairments in access to non-linguistic event-related knowledge might be expected to disrupt verb-argument processing.

The current study tested verb-argument processing among a sample of adults with aphasia in an effort to disentangle the contribution of language-specific processes and non-language knowledge to verb-argument understanding. These adults had varying levels of language-processing impairment, as well as varying levels of impairment in their access to non-language conceptual semantic representations. These conceptual-semantic impairments were comorbid with, but independent of, their aphasia. Comparing the performance of individuals with more pronounced language-processing impairments but relatively good conceptual-semantic processing with that of individuals with conceptual-semantic impairments provided a test of the alternative approaches to verb-argument understanding described above.

2. STUDY

Eight adults with aphasia and two separate samples of age-matched (older) healthy adults participated in two self-paced reading experiments. The critical materials in the experiments were the stimuli used by Warren and McConnell (2007) in their study of verb-argument processing among college-aged adults. Warren and McConnell compared reading times for plausible verb-argument combinations, highly unlikely verb-argument combinations (violating world knowledge about events), and impossible verb-argument combinations (violating the verb's core semantic requirements, or selectional restrictions). A set of example sentences is found in (1) below.

(1) **a.** Maria used a knife to chop the large carrots before dinner last night.

b. Maria used some bleach to clean the large carrots before dinner last night.

c. Maria used a pump to inflate the large carrots before dinner last night.

The critical word in these sentences is the head noun of the verb's object, *carrots* (underlined above). It is at this word that Warren and McConnell (2007) found disruption in conditions (b) and (c), with larger and earlier-emerging disruptions in condition (c). Specifically, they found that the impossible condition (c) had longer first fixations than either plausible condition (a) or the highly unlikely condition (b). Conditions (b) and (c) were both slower than condition (a) in later reading measures (like regression path duration and total times).

The two self-paced reading studies used the same stimuli, but they had different sentence-final tasks. In Experiment 1a–b, participants rendered an acceptability judgment after each sentence. In Experiment 2a–b, they answered yes-no comprehension questions about each sentence. Acceptability judgments require shallower processing than comprehension questions: they simply require participants to judge whether the linguistic units of the sentence can be combined and result in a reasonable interpretation. In contrast, comprehension questions require readers to build a mental model of the events being described, and maintain that in memory to respond to the question.

2.1 EXPERIMENT 1A–B

Experiment 1a–b had the same stimuli and procedures but different participants: Experiment 1a involved healthy older adults, while Experiment 1b involved adults with aphasia. Experiment 1a participants were in the same age range as Experiment 1b participants. The methods for the two experiments will therefore be presented together. The results will be presented separately.

2.1.1 METHODS

2.1.1.1 PARTICIPANTS: Thirty-six community-dwelling native English-speaking older adults with normal or corrected-to-normal vision and without self-reported history of speech-language, hearing, or neuropsychological disorders participated in Experiment 1a. These participants (26 female) ranged in age from 50 to 85 years (mean: 71.6), and had between 12 and 20 years of education (mean: 14.5). In order to exclude the presence of unreported memory or other cognitive disorders, participants were given the Mini-Mental State Exam (MMSE: Folstein, Folstein & McHugh, 1975) and the Arizona Battery for Communication in Dementia (Bayles, Tomeoda & Dharmaperwira-Prins, 1993). All participants scored 27 or better on the MMSE (mean: 29.6), above lower-quartile cutoff scores for healthy older adults (Bleecker, Bolla-Wilson, Kawas & Agnew, 1988). All participants also had a delayed:immediate recall ratio of .70 or better on the ABCD (mean: .97), above the reported scores for adults with dementia (Bayles, Boone, Tomoeda, Slauson & Kaszniak, 1989). Furthermore, all participants passed a 40dB pure-tone hearing screen (unaided) at 500, 1000, 2000, and 4000 Hz bilaterally.

Eight adults with aphasia participated in Experiment 1b. These adults were community-dwelling stroke survivors with previously-diagnosed aphasia and were referred from the Western Pennsylvania Patient Registry, a participant registry of stroke survivors with a variety of language and non-language cognitive disorders. Their demographic characteristics and lesion information (where available from medical records) are presented in Table 1.

These participants (5 female) ranged in age from 47 to 82 (mean age: 60.6) and were between 24 and 419 months post onset (MPO) of aphasia (mean MPO: 103.9). They had between 12 and 16 years of education (mean: 13.6 years). All had normal or corrected-to-normal vision, reported being premorbidly right-handed, and reported no history of speech-language, hearing, or neuropsychological disorders prior to their stroke. In addition, none of the participants were diagnosed with visual agnosia or other visuo-perceptual disorders that could have interfered with their performance on reading tasks or picture-based cognitive measures. Those participants for whom lesion information was available were reported to have unilateral left-hemisphere lesions, extending to frontal as well as temporal and/or parietal regions.

Language testing information for these adults is presented in Table 2.

The Western Aphasia Battery-Revised (WAB-R: Kertesz, 2007) was administered as the primary measure of overall language impairment and as a diagnostic tool. All participants with aphasia had WAB-R Aphasia Quotients (AQs) below the cut-off score of 93.8, confirming the presence of aphasia. These participants were mildly to moderately impaired based on their WAB-R Aphasia Quotient (range: 52.6–90.6; mean: 74.4) and were classified as having a variety of different aphasia types, both fluent (4 anomic aphasia, 1 conduction aphasia) and non-fluent (2 Broca’s aphasia, 1 transcortical motor aphasia). In addition, all participants with aphasia also performed well on color and object word-picture matching comprehension subtests of the WAB-R, providing more evidence that they did not suffer from frank agnosia or visuo-perceptual deficits.

Because the focus of the current study was sentence-level reading comprehension, participants were also given detailed assessments of their reading and auditory comprehension using the SOAP Test (Love & Oster, 2002) and portions of the Reading Comprehension Battery for Aphasia-2 (RCBA-2: LaPointe & Horner, 1998). The RCBA-2 is a criterion-based assessment of reading comprehension for words, sentences and paragraphs, using sentence- and word-picture matching to measure reading performance. Reading comprehension for single words was unimpaired for these participants: all had mean scores of 8.5 or higher (out of 10) on RCBA-2 Subtests I–IV (mean: 9.28). Their comprehension of strongly contextually-constrained simple sentences (like exit signs and prescription labels) was also good: all scored 8 or higher on RCBA-2 Subtest VI (mean: 9.5). The participants performed more poorly as a group on comprehension of complex sentences where morphosyntactic information was critical: they scored between 4 and 9 on RCBA-2 Subtest X (mean: 6.88). Consistent with this pattern, these participants also performed relatively poorly on the SOAP. The SOAP uses sentence-picture matching to measure sentence comprehension ability, testing the auditory comprehension of semantically unconstrained simple (active, subject-relative clause) and complex (passive, object-relative) sentences. The participants as a group performed more poorly on complex (mean: 55.6%) than simple sentences (mean: 74.4%). Of note, the degree of impairment on the SOAP was strongly correlated with performance on the WAB-R, the overall language-impairment measure, the correlation between SOAP complex sentence comprehension scores and WAB AQ being $r=.76$ ($p<.05$).

These adults' non-language cognitive testing data are presented in Table 3.

All participants had a delayed:immediate recall ratio of .70 or better on the ABCD (mean: 1.06; range:0.84–1.50), suggesting that these adults' communicative disorders were not likely due to frank memory disorders (viz. McNeil & Pratt, 2001). All participants were also administered the Raven's Colored Progressive Matrices (RCPM: Raven, 1965), a visual test of nonverbal reasoning and problem solving. Participants varied significantly in their performance on the RCPM, ranging from 11 to 36 (out of 36; mean: 28.6).

The adults with aphasia were also administered two tests which measured their access to non-language conceptual-semantic representations: the picture version of Pyramids and Palm Trees (PPT: Howard & Patterson, 1992) and a novel test of sensitivity to knowledge of event likelihood, the Event task. These picture-based tests of semantic memory for objects and events provide a measure of the non-language conceptual-semantic representations that McRae and colleagues (e.g., McRae, et al. 1997) have argued are critical for rapid language understanding. Participants varied significantly in their performance on PPT, ranging from 62% accuracy to 96% accuracy. Mean accuracy was 85.8%, slightly below the mean score of 88.1% for a sample of 140 adults with aphasia in the Moss Aphasia Project Psycholinguistic Database (Mirman, Strauss, Brecher, Walker, Sobel, Dell & Schwartz, 2010).

The Event task is a novel test of event-related conceptual knowledge, based on stimuli from an ERP study of action processing among young healthy adults (Proverbio & Riva, 2009).

Proverbio and Riva presented college-aged adults with pictures of likely or highly unlikely actions and events (see Figure 1).

Highly unlikely events could have unusual event participants (agents, themes, or instruments) or unusual locations. In their experiment, participants were presented with 130 likely and 130 highly unlikely pictures in a passive viewing task. Highly unlikely events elicited a robust N400 effect compared to likely events, with the same latency and scalp distribution as N400s elicited by unexpected verbal stimuli (Proverbio & Riva, 2009). The Event task presented the same 130 likely and highly unlikely event pictures and asked participants to decide whether the pictures depicted something that "might normally happen." The correct response for likely events was "yes," and the correct response for highly unlikely events was "no." Much as for the RCPM and PPT, participants varied considerably in their performance in the Event task, with accuracies ranging from 63% to 95% (mean: 84.2%).

Of note, performance on the non-language cognitive measures was strongly correlated, much as language-impairment measures were correlated. Performance on the Event task was highly correlated with PPT ($r=.931$, $p<.01$) and RCPM ($r=.865$, $p<.01$). PPT and RCPM performance were also strongly correlated ($r=.850$, $p<.01$). The wide range of performance on these non-language cognitive measures suggests that some of the participants with aphasia had comorbid impairments of conceptual-semantic knowledge, particularly knowledge regarding events.

These participants thus exhibited varying levels of language-processing and non-language conceptual semantic impairments. These differing impairments are important for testing the hypotheses under consideration here, because different models of rapid verb-argument understanding ground verb-argument processing in either language-specific knowledge (e.g., Warren & McConnell, 2007) or in non-language conceptual-semantic representations (e.g., McRae, et al., 1997; Ferretti, et al., 2001). These impairments also divide the participants with aphasia into natural groups, based on their relative language or event-related knowledge impairments. These groups will be discussed further in the Results for Experiment 1b below.

2.1.1.2 MATERIALS: Participants read 30 sentences like the ones in (2) below, along with 80 fillers.

(2)

a. Maria | used | a knife | to chop | the | large | carrots | before dinner | last night.

b. Maria | used | some bleach | to clean | the | large | carrots | before dinner | last night.

c. Maria | used | a pump | to inflate| the | large | carrots | before dinner | last night.

The pipes (|) mark presentation regions for the self-paced reading task. The sentences appeared in one of three conditions: the plausible *baseline* condition (a), describing a likely event; the *event-knowledge violation* (EKV) condition (b), describing a possible but highly unlikely event (it is possible to clean carrots with bleach but highly unlikely); and the *SRV* condition (c), describing a genuinely impossible event involving a violation of the verb's core semantic requirements (*inflate* requires an object which can expand).

These items were versions of the items from Warren & McConnell's (2007) eye-tracking study, segmented for self-paced reading presentation. The critical segment of the sentences (underlined above) is segment 7, the head noun of the direct object. This is the first point at which a semantic mismatch between verb and object could be detected (condition [c]) or the event could be judged unlikely (condition [b]). This is the position at which Warren and McConnell first saw eye-movement disruption to the SRV and EKV conditions. The following two segments correspond to Warren and McConnell's post-target region, where they found continuing disruption for the SRV (*inflate the large carrots*).

Warren and McConnell (2007) conducted both possibility and plausibility norming on these stimuli to establish that the EKV and SRV conditions were both highly unlikely, but differed in whether the verb-object combination was possible. They found both the baseline and EKV conditions were most often judged possible (94% and 74% of trials, respectively), while the SRV condition was most often judged impossible (90% of trials). In contrast, both the EKV and SRV conditions were judged highly unlikely, and the baseline highly likely. On a scale of 1 ("very likely") to 7 ("very unlikely"), the EKV condition and SRV conditions received ratings of 5.84 and 6.74 respectively, while the baseline condition received a rating of 1.63. These patterns are consistent with both conditions (b) and (c) being highly unlikely, and condition (c) further involving a frank semantic violation.

2.1.1.2 PROCEDURE: All participants in this study provided informed consent prior to completing any study procedures. After consenting, all participants completed demographic questionnaires regarding their age, educational and language background, and medical history. (The spouses or caregivers of participants with aphasia in Experiment 1b sometimes completed these forms on the participant's behalf.) All participants also completed hearing screening and the ABCD. Experiment 1a participants (healthy older adults) also completed the MMSE, while Experiment 1b participants (adults with aphasia) also completed the RCPM, the RCBA-2, the WAB, the SOAP, the PPT, and the Event task.

After completing these screening and language and cognitive measures, all participants completed a self-paced reading task. This task began with instructions, presented both on the computer screen and read aloud to participants, along with 5 practice sentences. The experimenter verified that each participant understood the study procedures at the end of the practice session, prior to starting the main experiment. Participants read 30 experimental sentences like (1) above along with 80 fillers of varying length and structure on a laptop computer. The experimental sentences appeared in one of the three conditions above according to a Latin Square design, such that each participant saw each experimental sentence in only one condition, and saw an equal number of experimental sentences in each condition during the experiment.

Sentences were presented phrase-by-phrase in a self-paced moving window format by the Linger experiment-running program (Rohde, 2002). Each sentence was preceded by an underline preview. Participants pressed the space bar to reveal each segment of the sentence. After each sentence, they were presented with the word ‘ACCEPTABLE?’ centered on the screen, with the words ‘YES’ and ‘NO’ beneath it. Participants pressed ‘YES’ to indicate that the sentence they had just read was acceptable, and ‘NO’ to indicate that it was not. There were two breaks during the study, during which participants were told they could rest, and participants were also encouraged to take breaks as needed between sentences.

The self-paced reading study took between 25 and 45 minutes to complete. The entire experimental session (including screening tasks and other testing) took between 1 and 2 hours for healthy older participants in Experiment 1a, and between 3 and 4 hours for participants with aphasia in Experiment 1b. Participants with aphasia completed the study over two sessions, separated by no more than two weeks.

2.1.2 RESULTS

2.1.2.1 EXPERIMENT 1A: Reading times for the healthy older adults are presented in Figure 2.

Reading times were analyzed using analysis of variance, with t-test comparisons between conditions for segments with reliable ANOVA effects. Prior to the critical word there were reliable differences only at segment 3, describing the instrument used in the event (a knife/some bleach/a pump). There was a main effect of condition at this segment, F1(2,70)=14.62, p<0.01, F2(2,58)=6.37, p<0.01, likely due to lexical differences. At the critical word, carrots, there was again a reliable main effect of condition, F1(2,70)=5.06, p<0.05, F2(2,58)=5.82, p<0.05. Pairwise comparisons revealed that both the EKV condition (980 ms) and the SRV condition (984 ms) were read more slowly than the baseline condition (859 ms) (EKV vs. baseline: t1[35]=3.26, t2[29]=2.58, both p<0.05; SRV vs. baseline: t1[35]=2.45, t2[29]=3.01, both p<0.05). The EKV and SRV conditions did not reliably differ from one another. A reliable main effect of condition also appeared at the sentence-final segment, segment 9 (F1[2,7])=5.54, p<0.05, F2[2,58]=6.04, p<0.01). Here, the baseline (1926 ms) and EKV (1749 ms) conditions were both read more slowly than the SRV condition (1435 ms) (baseline vs. SRV: t1[35]=2.93, t2[29]=3.19, both p<0.05; EKV vs. SRV: t1[35]=2.82, t2[29]=2.89, both p<0.05). The baseline and EKV conditions did not differ reliably from one another.

Mean accuracy rates for the acceptability judgments are presented in Figure 3.

Accuracy rates were again analyzed using analysis of variance, with t-test comparisons where relevant. There was a main effect of condition on accuracy, F1(2,70)=5.38, p<0.05, F2(2,58)=3.38, p<0.05). The SRV condition (96.8%) was correctly judged unacceptable more often than the EKV condition (89.2%) (t1[35]=3.98, t2[29]=2.33, both p<0.05), and the baseline condition (92.8%) (t1[35]=1.86, p<0.08; t2[29]=2.18, p<0.05).

The older healthy adults in Experiment 1a thus showed reading-time disruption at the critical word in both the EKV condition (involving violations of event-related world knowledge) and the SRV condition (involving additional violations of verb-specific semantic requirements). This is consistent with the pattern seen for younger healthy adults in previous eye-movement reading studies using the same materials (Warren & McConnell, 2007). Participants also showed evidence of particular sensitivity to SRVs in their sentence-final acceptability judgments, with highest accuracy in the SRV condition.

2.1.2.2 EXPERIMENT 1B: As noted above, the participants with aphasia in Experiment 1B varied in both their levels of language impairment and their non-language cognitive testing performance. Because the focus of this study was on the effect of access to event-related conceptual-semantic knowledge on verb-argument processing, the adults with aphasia were divided into two groups based on a median split for the Event Task (median = 86.7%). This split created two groups of 4 participants. Their mean language-impairment and non-language cognitive testing scores are presented in Table 4.

Group 1 had relatively mild language impairments, with a mean WAB-R AQ (85.1) in the mildly impaired range (Kertesz, 2007) and relatively high RCBA and SOAP scores. However, Group 1 exhibited impaired conceptual-semantic processing, based on non-language cognitive testing: these participants' mean Pyramids and Palm Trees score (79%) was below the MAPPD median score of 88.1% (Mirman, et al., 2010), and the group's mean accuracy on the Event task (measuring sensitivity to conceptual-semantic knowledge regarding events, of the sort highlighted by Matsuki & McRae, 2009) was similarly poor (77%). This pattern of performance suggests that Group 1 had relatively mild language impairments, but a significant comorbid conceptual-semantic impairment. In contrast, Group 2 had more pronounced language impairments, with a mean WAB-R AQ (63.8) in the moderately impaired range (Kertesz, 2007) and poorer RCBA and SOAP scores. However, this group showed good performance on tests of conceptual-semantic processing. The mean Pyramids and Palm Trees score was 92%, above the MAPPD median score (Mirman, et al., 2010), and the mean Event task score was similarly high, 91%. Mann-Whitney U comparisons revealed that Group 1 had reliably higher mean WAB AQs than Group 2 ($Z=2.02$, two-tailed $p<0.05$), while Group 2 had reliably higher Event scores than Group 1 ($Z=2.32$, two-tailed $p<0.05$).

Group 1 and Group 2 thus differ in their relative degree of language-processing and conceptual-semantic impairments. Group 1 has relatively mild impairments in their access to language-specific knowledge, but they had a co-occurring impairment of access to event-related conceptual-semantic representations. These impairments should affect Group 1's ability to draw on event-related knowledge to facilitate rapid language processing (McRae, et al., 1997; McRae & Matsuki, 2009). In contrast, Group 2 has relatively poor language-specific processing, but relatively good access to such event-related knowledge. Group 1 and 2's results will be presented separately below.

Reading times and acceptability-judgment accuracies for Group 1 are presented in Figure 5a–b.

Because of the small sample size and the uneven distribution of participants across experimental lists, non-parametric statistics were used (Friedman tests and Mann-Whitney U) to test for reliable differences. The reading time pattern for this group is very similar to the pattern seen for the healthy older participants in Experiment 1a. Prior to the critical word, there were reliable differences at segment 4, the verb following the instrument used in the event. Friedman tests revealed a main effect of condition at this segment, $\chi^2(2)=6.00$, $p<0.05$. This effect likely reflects the lexical differences in the preceding segment, much as in Experiment 1a, or the lexical differences at the verb itself. At the critical word, carrots, there was again a reliable main effect of condition, $\chi^2(2)=6.50$, $p<0.05$. Pairwise comparisons revealed that the EKV (1502 ms) and SRV (1576 ms) conditions were read more slowly than the baseline condition (1186 ms) (EKV vs. baseline: Mann-Whitney U: Z=1.83, one-tailed p<0.05; SRV vs. baseline: Mann-Whitney U: Z=1.83, one-tailed p<0.05). There was no reliable difference between the EKV and the SRV condition.

For the acceptability judgments, accuracy was high for all three conditions. Mann Whitney U tests were used to compare the performance of Group 1 to that of the healthy older participants in Experiment 1a. There were no reliable differences between the healthy older adults and Group 1 for any conditions (all Z<1.6, all one-tailed p>0.05).

Reading times and acceptability-judgment accuracies for Group 2 are presented in Figure 6a–b.

The reading time pattern for Group 2 is notably different from the pattern seen for the healthy older participants in Experiment 1a and from the pattern of Group 1. Group 2 showed no reliable effects of condition at any segment. Comparing Group 2’s accuracy to that of healthy older adults in Experiment 1a, Group 2 was reliably less accurate than the older controls in the baseline condition (65% vs. 92.8%; Mann-Whitney U: Z=3.21, one-tailed p<0.01) and in the SRV condition (70.8% vs. 96.8%; Mann-Whitney U: Z=2.37, one-tailed p<0.01). Interestingly, they did not differ from controls in their performance in the EKV condition (Mann-Whitney U: Z<1, p>0.05).

Group 1, with milder language-processing impairments but poor access to conceptual-semantic representations, thus performed similarly to controls from Experiment 1a. They showed reading-time disruption at the critical word in both the EKV condition (involving violations of event-related world knowledge) and the SRV condition (involving additional violations of verb-specific semantic requirements). Furthermore, they did not differ in their acceptability-judgment accuracy from healthy controls for any condition. Group 2, with more pronounced language-processing impairments but good access to conceptual-semantic representations, performed differently from the healthy older adults. They did not show any reading-time evidence of disruption for violations of event-related knowledge or verb-specific semantic constraints, and they were less accurate than controls in two of three conditions. The one condition where their accuracy did not differ from controls’ was the EKV condition.

2.1.3 DISCUSSION—Experiment 1a found the same basic pattern for healthy older adults that was previously reported for younger adults by Warren and McConnell (2007), using the same stimuli. Both the EKV and SRV conditions elicited reliable reading-time disruption. This finding is consistent with the claim that both event-related world knowledge and verb-specific constraints contribute to rapid verb-argument understanding, at least for unimpaired adults. The SRV condition did not show a larger or earlier reading-time penalty than the

EKV condition in this study, unlike in Warren and McConnell's (2007) study. However, this is likely due to differences in experimental method or task: Warren and McConnell monitored eye-movements during reading, which provides separate measures of earlier and later reading processes. The current study used self-paced reading, which collapses earlier and later reading processes into a single reading-time measure. An additional difference between the two studies is that Warren and McConnell's participants answered comprehension questions. The current participants performed acceptability judgments. It could be that these tasks encourage different depths-of-processing, which may influence the degree of disruption at the critical word.

In this study, the SRV condition did differ from the EKV condition in two ways. First, the SRV condition elicited higher accuracy in acceptability judgments than the baseline or EKV condition. This suggests that healthy older adults were especially sensitive to the presence of a violation of a verb's core semantic requirements. Second, the SRV condition was read faster than the EKV condition at the sentence-final segment. This late-emerging reading-time advantage for SRVs is plausibly due to the nature of the sentence-final task, acceptability judgment. Participants were asked to judge whether the sentence was acceptable or not. The presence of a clear violation of the verb's core semantic requirements at the head noun permitted them to make that judgment at that segment. As a result, the material in the remaining segments could be processed shallowly, and therefore read more quickly. The higher reading times for the baseline and EKV conditions suggest that participants may not yet have made an immediate decision regarding the upcoming acceptability judgment in those conditions.

Experiment 1b revealed two different patterns for the two groups of adults with aphasia. Group 1, with milder language impairments but poor conceptual-semantic processing (particularly in the Event task, tapping event-related world knowledge), performed very similarly to the unimpaired adults in Experiment 1a. They exhibited reading-time disruption in response to violations of both a verb's selectional restrictions and event-related world knowledge, and they also did not differ in their acceptability-judgment accuracy from Experiment 1a participants. Group 2, with more pronounced language impairments but good conceptual-semantic processing (again, particularly in the Event task), performed differently from the unimpaired adults in Experiment 1a. This group did not exhibit reading-time disruption to either kind of violation, at any position in the sentence. They were also less accurate in their acceptability judgments than Experiment 1a participants, with the exception of the EKV condition.

These very different patterns of results suggest that disruption of language-specific knowledge (as in Group 2) has a larger effect on rapid verb-argument understanding than disruption of event-related conceptual-semantic knowledge does (as in Group 1). Group 1 showed normal-like verb-argument processing despite measurable impairments in judgments regarding the relative likelihood of events in the Event task. It is just this sort of conceptual-semantic knowledge that has been argued to be critical to rapid verb-argument understanding (Bicknell, et al., 2010; McRae, et al., 1997; McRae & Matsuki, 2009). In contrast, Group 2 showed good performance in making likelihood judgments about depicted events, suggesting good access to event-related world knowledge. Despite this measurable advantage in access to such knowledge, these participants showed little on-line evidence of successful verb-argument comprehension. This pattern is surprising if verb-argument understanding (or language comprehension more generally) may be reduced to rapid activation of non-language knowledge about objects and events (cf. McRae & Matsuki, 2009). The one situation in which intact event-related knowledge may have had a positive effect was in Group 2's performance on sentence-final acceptability judgments in the EKV condition. In this condition, the violation of event-related knowledge may have helped raise participants' accuracy in judging these sentences unacceptable. However, weighing against this account, the SRV condition also described highly unlikely events, and Group 2's performance on this condition was poor. This suggests that intact event-related knowledge was of limited value even for judging sentence acceptability. We will return to these findings in the General Discussion below.

The results of Experiment 1a–b therefore suggest that language-specific processing may play a particularly important role in rapid verb-argument understanding (Boland, 2005; Paczynski & Kuperberg, 2012; Rayner, et al., 2004; Warren & McConnell, 2007), and that language-specific impairments may be especially disruptive of verb-argument processing. Experiment 2a–b examined this issue further by testing the same populations on the same sentence stimuli, but with a different experimental task.

2.2 EXPERIMENT 2A–B

Experiment 2a–b tested a separate group of healthy older adults and the same group of adults with aphasia as in Experiment 1b, in a self-paced reading task using the same sentence stimuli. However, this study used a different sentence-final task. Participants were asked sentence-final comprehension questions instead of providing acceptability judgments. Comprehension questions should elicit deeper processing than acceptability judgments, since they require participants to create and maintain a mental model of the events being described in order to answer the question. Performance on comprehension questions might therefore be differently affected by violations of selectional restrictions and event-related world knowledge, compared to acceptability judgments. A violation of selectional restrictions results in an uninterpretable sentence, one for which a coherent mental model is difficult or impossible to create. In contrast, a violation of event-related world knowledge results in an interpretable but unlikely representation. Mental models associated with these sentences may be unlikely, but they will be coherent.

2.2.1 METHOD

2.2.1.1 PARTICIPANTS: Experiment 2a involved a separate sample of twenty-four community-dwelling older adults in the same age range as the participants with aphasia from Experiments 1b/2b. These adults had normal or corrected-to-normal vision and no self-reported history of speech-language, hearing, or neuropsychological disorders. These participants (19 female) ranged in age from 47 to 74 years (mean: 58.5), and had between 12 and 20 years of education (mean: 15.4). All participants scored 26 or better on the MMSE (mean: 29.3) and had a delayed:immediate recall ratio of .70 or better on the ABCD (mean: .995). Furthermore, all participants passed a 40dB pure-tone hearing screen (unaided) at 500, 1000, 2000, and 4000 Hz bilaterally.

The same eight adults with aphasia who participated in Experiment 1b participated in Experiment 2b. There was a gap in testing of between 6 and 12 months between Experiment 1b and Experiment 2b, in order to minimize the likelihood that participants would be affected by their previous exposure to the stimuli.

2.2.1.2 MATERIALS: The same materials were used as in Experiment 1. However, each sentence was followed by a comprehension question. For experimental sentences, participants were asked directly about the verb-argument combination being described in the sentence. An example is given in (3) below.

(3)

a Maria | used | a knife | to chop | the | large | carrots | before dinner | last night.

b Maria | used | some bleach | to clean | the | large | carrots | before dinner | last night.

c Maria | used | a pump | to inflate| the | large | carrots | before dinner | last night.

Q Did Maria cut/wash/blow up the carrots?

Participants responded by pressing keys marked “Y” and “N” for ‘yes’ and ‘no.’ Half the questions had “Y” as the correct answer, while half had “N” as the correct answer. All questions with “N” as the correct answer involved a different verb, describing an event that could plausibly involve the object. For questions with “Y” as the correct answer, the verb was a synonym or near-synonym of the verb in the sentence. This substitution helped ensure that participants processed the meaning of the question, and did not simply base their response on whether the question overlapped lexically with the sentence they had read.

As in Experiment 1a–b, there were three experimental lists, distributing the items across conditions according to a Latin Square design. In order to minimize the likelihood that Experiment 1b participants would be affected by their previous exposure to the stimuli, they were presented with a different experimental list from the one they had seen in Experiment 1b. This ensured that they did not read the same item in the same condition across the two experiments.

2.2.1.3 PROCEDURE: The same procedures as in Experiment 1a–b were also used in Experiment 2a–b. All participants provided informed consent prior to completing any study procedures. All participants also completed 40dB pure-tone hearing screenings and completed the same demographic and health history questionnaires as in Experiment 1a–b. In addition, Experiment 2a participants (healthy older adults) completed the MMSE and the ABCD. The same procedures for the self-paced reading task were used in Experiment 2a–b as in Experiment 1a–b.

2.2.2 RESULTS

2.2.2.1 EXPERIMENT 2A: The reading times and comprehension-question accuracy for healthy older adults is presented in Figure 7a–b.

The overall pattern of results is similar to that found in Experiment 1a. Prior to the critical word the only effect was a marginal main effect of condition at segment 3, the instrument used in the event (a knife/some bleach/a pump), F1[2,46]=3.32, p<0.05; F2[2,58]=1.64, p>0.1. At the critical word, carrots, there was marginal main effect of condition, which was reliable in the by-items analysis (F1[2,58]=7.03, p<0.01) but not the by-participants analysis (F2[2,46]=1.96, p>0.1). At the segment following the critical word, however, there was a fully reliable main effect of condition, F1(2,46)=8.47, p<0.01, F2(2,58)=6.43, p<0.01. Pairwise comparisons revealed that the SRV condition (844 ms) was read reliably more slowly than the baseline condition (702 ms) (t1[23]=3.37, t2[29]=3.12, both p<0.05) and marginally more slowly than the EKV condition (768 ms) (t1[23]=3.37, p<0.05, t2[29]=1.95, p=0.061). The EKV condition was also read marginally more slowly than the baseline (t1[23]=2.45, p<0.05, t2[29]=1.99, p=0.051). In contrast to Experiment 1a, there were no reliable differences across conditions at the final segment.

Turning to the comprehension questions, there was a reliable main effect of condition on accuracy (F1[2,46]=7.46, p<0.01, F2[2,58]=5.50, p<0.01). Pairwise comparisons revealed that accuracy for the SRV condition (87.1%) was reliably lower than accuracy for the baseline (97.5%) (t1[23]=3.82, t2[29]=3.59, both p<0.01) and marginally lower than for the EKV condition (94.2%) (t1[23]=2.25, p<0.05, t2[29]=1.72, p=0.095). The baseline and EKV condition did not reliably differ from one another. Like in Experiment 1a, the different performance for the SRV condition suggests that healthy older adults were especially strongly affected by a violation of a verb's selectional restrictions.

2.2.2.2 EXPERIMENT 2B: The reading times and comprehension-question accuracy for aphasia Group 1 (with milder language impairments but poorer conceptual-semantic performance) are presented in Figure 8a–b.

Like in Experiment 1b, the pattern of results here is numerically similar to that found for healthy older adults. Prior to the critical word, there were reliable differences at segment 6, the segment immediately preceding the critical noun (large), $\chi^2(2)=6.50$, p<0.05. Pairwise comparisons revealed that the SRV condition (1697 ms) was read more slowly than both the baseline condition (1163 ms) (Mann-Whitney U: Z=1.83, one-tailed p<0.05) and the EKV condition (1232 ms) (Mann-Whitney U: Z=1.83, one-tailed p<0.05). But the EKV condition and baseline conditions did not differ (Mann-Whitney U: Z<1, one-tailed p>0.05). At the critical word, reading times were numerically longer in the SRV condition than in the EKV and baseline conditions, although these large numerical differences failed to be reliable. At the critical word, the EKV condition (1819 ms) was read reliably more slowly than the baseline condition (1397 ms; Mann-Whitney U: Z=1.83, one-tailed p<0.05), but the SRV condition (2221 ms) was not reliably slower than the baseline (Mann-Whitney U: Z<1, one-tailed p>0.05) or the EKV condition (Mann-Whitney U: Z<1.5, one-tailed p>0.05). At the segment following the critical word, the SRV condition (2375 ms) was read more slowly than the EKV condition (1757 ms) (Mann-Whitney U: Z=1.83, one-tailed p<0.05). However, the SRV condition was not read reliably more slowly than the baseline condition (1622 ms) at this segment (Mann-Whitney U: Z<1.5, one-tailed p>0.05), nor was the EKV condition read reliably more slowly than the baseline (Mann-Whitney U: Z<1.5, one-tailed p>0.05). No further main effects of condition were reliable until the sentence-final segment,

$\chi^2(2)=6.50$, $p<0.05$. At this segment, the SRV condition (1941 ms) was read more slowly than the EKV condition (1343 ms) (Mann-Whitney U: Z=1.83, one-tailed $p<0.05$), the baseline (1944 ms) was read more slowly than the EKV condition (Mann-Whitney U: Z=1.83, one-tailed $p<0.05$), but the SRV and baseline segments did not differ (Mann-Whitney U: Z<1, one-tailed $p>0.05$).

Accuracy for the comprehension questions was relatively high for all three conditions. However, Group 1 participants were less accurate than controls for the EKV condition (75% vs. 94.2%, Z=2.66, one-tailed $p<0.05$). There were no reliable differences between the healthy older adults and Group 1 for the other two conditions (both Z<1.5, both one-tailed $p>0.05$). This pattern of results suggests that Group 1 participants may have experienced greater difficulty in responding to comprehension questions in the EKV condition.

The reading times and comprehension-question accuracy for aphasia Group 2 (with good conceptual-semantic performance but more severe language impairments) are presented in Figure 9a–b.

As for Experiment 1b, the patterns for Group 2 are notably different from the pattern for healthy older adults in Experiment 2a. Prior to the critical word, there was a reliable effect of condition at segment 4, the verb (<u>chop/clean/inflate</u>), $\chi^2(2)=6.0$, $p<0.05$. This difference is likely due to lexical differences among the verbs. The only other position where there was a reliable effect of condition was the segment following the critical word ($\chi^2[2]=6.0$, $p<0.05$). At this segment, the SRV condition (1344 ms) was read <u>faster</u> than the baseline (1576 ms) (Z=1.83, one-tailed $p<0.05$) and the EKV conditions (1629 ms) (Z=1.83, one-tailed $p<0.05$).

Turning to the comprehension questions, Group 2 had lower accuracy than Group 1. Group 2's accuracy for the baseline condition (75%) did not differ reliably from that of the healthy older participants from Experiment 2a (98%). However, they did have lower accuracy for both the EKV condition (60% for Group 2 vs. 94.2% for healthy controls; Z=2.40, one-tailed $p<0.05$) and the SRV condition (60% for Group 2 vs. 87.1% for healthy controls; Z=2.73, one-tailed $p<0.05$). This pattern suggests that these participants' comprehension question accuracy was similarly poor for both the SRV and EKV conditions.

Like in Experiment 1b above, the two groups of participants with aphasia showed qualitatively different patterns. Group 1, with milder language-processing impairments but poor access to event-related conceptual-semantic representations, performed broadly similarly to controls from Experiment 2a. They showed particular reading-time disruption in the SRV condition (involving violations of verb-specific semantic requirements). This pattern held from the segment before the critical word through the segment following it, though not all of the differences between the SRV condition and the other conditions were statistically reliable at all of these segments. They also differed from healthy controls in their comprehension-question accuracy in only the EKV condition (involving violations of event-based world knowledge). Group 2, with more pronounced language-processing impairments but good access to event-related conceptual-semantic representations, performed differently from the healthy older adults. They showed <u>faster</u> reading times for the SRV condition, and they were less accurate than controls in both the EKV and SRV conditions.

2.2.3 DISCUSSION—The pattern of results for Experiment 2a–b is similar to the pattern found in Experiment 1a–b. Healthy older adult participants in Experiment 1b showed disruption at the critical word for violations of both event-related knowledge (in the EKV condition) and verb-specific constraints (in the SRV condition), and they were particularly strongly affected by SRVs in their comprehension question accuracy. However, there were two notable differences in the results of Experiment 2a compared to Experiment 1a. First, participants in Experiment 2a showed a larger reading-time penalty for the SRV condition than for the EKV condition. This pattern is actually more similar to the pattern found for young healthy adults by Warren & McConnell (2007) than the pattern in Experiment 1a. This difference may have to do with the sentence-final task: as noted above, comprehension questions require participants to create and maintain a mental model of the depicted events, and a strong violation of the verb's semantic requirements is likely to be particularly disruptive to creating a coherent mental model. Second, the robust effect of SRVs on the sentence-final task in Experiment 2a is in the opposite direction from Experiment 1a. The presence of an SRV increased accuracy for acceptability judgments, but it decreased accuracy for comprehension question responses. Again, this difference is likely due to the different nature of the sentence-final task in this study. SRVs should have a negative impact on comprehension-question accuracy because they make forming a coherent mental model difficult or impossible. However, SRVs should improve acceptability-judgment accuracy because they involve a clear violation of a verb's core semantic requirements.

The patterns found in Experiment 2b, particularly the difference in performance between aphasia Group 1 and Group 2, are again similar to what was found in Experiment 1b. The reading-times patterns for Group 1 are generally similar to those of the healthy older adults in Experiment 2a, particularly in showing the largest disruption in the SRV condition. This disruption appeared before the critical segment for Group 1, for reasons that are unclear. One possibility is that this surprisingly early-emerging effect may reflect spillover associated with lexical differences in the verbs or instrument nouns in the different conditions. Possibly weighing against this, the reading times for the different conditions converge on the determiner (*the*) before the pre-critical word. Regardless of the source of this early-emerging difference, the reading-time penalty for SRVs appeared at the critical word and persisted at the following segments. These differences were not fully reliable in all regions, but the reading-time patterns for this group were overall similar to that seen for healthy older adults.

In contrast, Group 2's pattern was quite different. They did not show particular disruption for the SRV condition. If anything, they read sentences with SRVs more quickly than sentences depicting plausible or highly unlikely events. The reason for this pattern is unclear. However, regardless of its source, it is clearly different from the pattern seen for healthy controls. In addition to this different pattern of on-line performance, Group 2 differed from healthy controls in their comprehension-question performance in both the EKV and SRV conditions. This pattern suggests that they were similarly disrupted in both the EKV condition (involving highly unlikely verb-argument combinations) and the SRV condition (involving even more unlikely impossible verb-argument combinations).

Interestingly, performance on comprehension questions in this experiment differed from the patterns seen for acceptability judgments in Experiment 1. Group 1's accuracy was lower for comprehension questions than for acceptability judgments, and they showed particular difficulty in responding to comprehension questions in the EKV condition. This differs from the pattern of acceptability judgments in Experiment 1b, in which Group 1 did not differ from healthy controls in any condition. In the current experiment, Group 2 had poor comprehension-question accuracy in both the EKV and SRV conditions. This is strikingly different from Experiment 1b, in which Group 2 had their highest acceptability-judgment accuracy in the EKV condition (also the only condition where they did not differ from healthy controls). We will return to these patterns in the General Discussion below.

Once again, the distinct patterns of results for Groups 1 and 2 in Experiment 2b suggest that more severe language impairments (as in Group 2) are more disruptive to rapid verb-argument understanding than impaired access to conceptual-semantic event representations (as in Group 1). Group 1 showed normal-like reading-time patterns despite having poor performance on tasks measuring conceptual-semantic representations for events (the Event task). In contrast, Group 2 showed different patterns from controls, despite having good performance on the Event task. The advantage for Group 1, with milder language impairments, is consistent with the claim that language-specific representations and processes play an important role in rapid verb-argument processing (e.g., Boland, 2005; Paczynski & Kuperberg, 2012). However, it is surprising under views of verb-argument processing which downplay the role of language-specific knowledge in verb-argument understanding (Bicknell, et al., 2010; Feretti, et al., 2001; McRae & Matsuki, 2009).

3. GENERAL DISCUSSION

Recent work on the cognitive mechanisms underlying language comprehension has highlighted the contributions of non-language knowledge and representations. For example, work in the embodiment literature has focused on the importance of sensory and motor representations in providing a grounding for semantic representations in language (e.g., Barsalou, 2008; Hauk, et al., 2004, Zwaan, Stanfield & Yaxley, 2002). Other work has shown that violations of world knowledge and linguistic constraints evoke similar (and similarly rapid) neural and behavioral responses (e.g., Hagoort, et al., 2004). These findings support the hypothesis that there may not be a meaningful difference between language and non-language representations, and that language processing obligatorily involves consulting relevant non-language representations (e.g., McRae & Matsuki, 2009; Matsuki, et al., 2011). In contrast, there is also evidence that linguistic knowledge may play a distinct and possibly privileged role in language comprehension. For example, other work has found that violations of linguistic constraints elicit earlier and larger disruption in behavioral measures than world-knowledge violations (e.g., Warren & McConnell, 2007; Rayner, et al., 2004), as well as a different pattern of EEG (Paczysnki & Kuperberg, 2012) and MEG (Pylkkänen, Oliveri & Smart, 2009) responses. Disruptions due to linguistic violations also appear to be less affected by contextual factors (like the presence of supporting context or strong lexical-semantic associations) than do disruptions due to world-knowledge violations (e.g., Paczynski & Kuperberg, 2012; Warren, McConnell & Rayner, 2008).

The current study tested these competing views of the contribution of linguistic and non-linguistic knowledge to language comprehension by examining rapid verb-argument understanding among healthy older adults and adults with aphasia. Examining the performance of neurogenically-impaired adults can be particularly informative for this debate, because linguistic and non-linguistic knowledge may be differentially impaired in these populations. Adults with aphasia consistently have impairments of language performance, but they may or may not have co-occurring deficits in non-linguistic knowledge, such as conceptual-semantic representations for objects or events (McNeil & Pratt, 2001; Reilly & Peelle, 2008). These dissociations can help disentangle the contribution of these two sources of knowledge to language comprehension.

In two self-paced reading studies using stimuli adapted from Warren & McConnell (2007), older healthy adults performed very similarly to what has previously been reported for young healthy adults (Warren & McConnell, 2007). The older adults showed disruption in response to both violations of verb-related semantic constraints on arguments and violations of event-related world knowledge regarding likely and unlikely events. Furthermore, they showed evidence of particular sensitivity to SRVs in several measures. First, they showed more reading-time disruption for sentences with SRVs than for sentences describing highly unlikely events in Experiment 2a. Second, they showed particular sensitivity to SRVs in two different sentence-final comprehension tasks: they were more accurate in their acceptability judgments for sentences with SRVs in Experiment 1a, and less accurate in their comprehension-question responses in Experiment 2a. Together, these findings suggest that older healthy adults make rapid use of both verb-specific knowledge and event-related world knowledge during verb-argument understanding, and may be slightly more sensitive to violations of verb-specific semantic requirements (c.f. Warren & McConnell, 2007; Rayner, et al., 2004).

Two different groups of adults with aphasia completed the same self-paced reading experiments. These adults varied in the degree of their language impairment as well as in their access to non-language conceptual-semantic representations relevant to verb-argument understanding. The first group had relatively mild language impairments but poor access to conceptual-semantic representations, especially for events (as measured by the Event task). The second group exhibited the reverse pattern: they had more pronounced language impairments but good access to conceptual-semantic representations for events. It is important to note that this second group's language impairment was not severe enough to disrupt their basic language comprehension. Both groups of adults with aphasia showed similar performance on comprehension questions for the baseline condition, and participants in the second group were in the mild-to-moderate range for their overall language impairment (given their WAB AQs) and performed well on comprehension of simple written sentences (given their RCBA-2 scores). The fact that both groups retained the ability to process basic linguistic relationships suggests that the second group's patterns of performance are likely not attributable to frank difficulty in decoding the verb-argument structure of the sentence.

The performance of these two groups can thus diagnose the relative importance of language-specific impairments versus event-related conceptual-semantic knowledge to rapid verb-argument understanding. In both experiments, for both reading-time and sentence-final comprehension measures, the first group closely resembled the healthy older adults in their performance. In contrast, the second group exhibited qualitatively different patterns of performance. This finding indicates that the contributions of language-specific knowledge (and impairments of that knowledge) can be distinguished from the contributions of event-related world knowledge. It also indicates that language-processing ability appears to play a more important role in rapid verb-argument understanding, and that language impairments are more disruptive to verb-argument processing than impairments to conceptual-semantic processing.

The different performance of the two groups also sheds interesting light on how aphasia may affect access to verb-argument information. Previous research on verb-argument processing in aphasia has found that many adults with aphasia exhibit intact access to verb-argument information, such as the type and number of arguments the verb may take (e.g., Shapiro & Levine, 1990). Evidence for this intact sensitivity appears in many different tasks – including well-formedness judgments (Gahl, 2002; Kim & Thompson, 2000), cross-modal lexical decision or priming tasks (Myers & Blumstein, 2005; Shapiro & Levine, 1990; Shapiro, Gordon, Hack & Killackey, 1993), self-paced reading (DeDe, 2013), and the visual-world paradigm (Mack, Ji & Thompson, 2013) – and can be found even in the presence of syntactic comprehension deficits (e.g., Kim & Thompson, 2000). Preserved verb-argument sensitivity was originally reported for adults with Broca's aphasia but not fluent aphasia syndromes (Russo, Peach & Shapiro, 1998; Shapiro & Levine, 1990; Shapiro, Gordon, Hack & Killackey, 1993). However, subsequent work has found evidence of sensitivity to verb-argument information among adults with both fluent and non-fluent aphasia types (Gahl, 2002; DeDe, 2013).

The current results suggest that rapid sensitivity to verb-argument knowledge may vary across adults with aphasia, and that this variability depends (at least in part) on those individuals' overall language impairment (WAB AQ and RCBA-2 and SOAP scores, in the current study). This finding is in contrast to what has been reported in the previous literature on verb-argument processing in aphasia, described above. However, the verb-argument knowledge examined in the current study – the semantic restrictions imposed by a verb on its arguments – is different from the syntactically-oriented verb-argument constraints which have been tested in most previous studies (such as the number of obligatory or optional arguments a verb takes; e.g., Kim & Thompson, 2000). Interestingly, the current results are in line with recent findings by Mack, Ji and Thompson (2013), which showed reduced or delayed prediction of upcoming verb arguments among adults with Broca's aphasia in a visual-world study. The verb-argument constraints Mack and colleagues tested were also semantic in nature: control participants gazed anticipatorily at breakable but not unbreakable objects upon hearing a semantically-constraining verb like "break" (viz. Altmann & Kamide, 1999), but participants with Broca's aphasia did not show evidence of predicting upcoming arguments. Similarly, in a priming-based study examining participants' processing of verb-noun sequences involving potential SRVs and EKVs, Myers and Blumstein (2005) found that SRV verb-noun sequences (e.g., *persuade the letter*) elicited slowed RTs for their control participants, but this disruption was only present in some conditions for their participants with Broca's aphasia. Further research is needed to determine whether sensitivity to syntactic and semantic verb-argument constraints (like those tested by Myers and Blumstein, Mack and colleagues, and in the current study) may be dissociated in aphasia.

An open question regarding these two groups' different performance is what deficits are responsible for Group 2's abnormal performance in Experiment 1b–2b. As noted above, the language-testing data suggest that this group's overall language impairment is in the mild-to-moderate range, and that their comprehension of simple written sentences is relatively good. One possibility is that the Group 2 participants may have relatively subtle undiagnosed deficits in verb-based knowledge regarding the combinatorial requirements of verbs. Such impairments may be too specific to be captured by broad measures of language impairment (like the WAB-R or the RCBA-2) or by standardized sentence-comprehension performance measures (like the SOAP), which focus on the effects of sentence type on comprehension. Additional testing – for example, using the Northwestern Assessment of Verbs and Sentences, in particular the argument-structure production subtest (Cho-Reyes & Thompson, 2012) – would be necessary to investigate this potential deficit. The presence of semantic errors on these tests (for example, producing semantically ill-formed verb-argument sequences) would be one potentially informative measure of the presence and degree of such deficits. It is an open question why such verb-specific deficits should reduce Group 2's on-line sensitivity to EKVs as well as SRVs, since EKVs should presumably be less closely related to the combinatorial semantic requirements of verbs than SRVS are. Group 2's reduced sensitivity to both SRVs and EKVs suggests that these deficits may affect all rapid verb-argument understanding, even when that understanding could in principle draw on non-linguistic sources of knowledge (as in the case of EKVs). Regardless of the ultimate account of Group 2's pattern, the fact that Group 2 exhibited reduced sensitivity to both types of violations indicates that rapid verb-argument understanding leans primarily on linguistic rather than non-linguistic processing streams.

Another factor which may contribute to Group 2's abnormal patterns are some possible aphasia syndrome-specific deficits. Group 2 had participants with conduction and Broca's aphasia, and neither of these aphasia types was present in the Group 1 participants. In addition, the Group 1 participants were more uniform in their aphasia type than the Group 2 participants: three of four Group 1 participants were classified as having anomic aphasia based on their WAB-R performance, while Group 2 participants had three different aphasia syndromes (Broca's, anomic, and conduction aphasia). We cannot exclude the possibility that syndrome-specific deficits or the wider range of aphasia types contributed to the variability or the overall pattern seen for Group 2. However, Group 1 and 2 did overlap in terms of both specific aphasia syndromes and broad aphasia types: both contained participants with anomic aphasia, and both contained fluent aphasia types (anomic in Group 1; conduction and anomic in Group 2) as well as non-fluent aphasia types (transortical motor in Group 1; Broca's in Group 2). Additional testing is needed with larger groups of people with aphasia, with a variety of different aphasia syndromes, to help elucidate the contribution of syndrome-specific deficits to these processes.

Although our aim in these experiments was to contrast the performance of the controls with the two groups of participants with aphasia, it is possible to speculate about how Group 1 and Group 2's language-specific and conceptual-semantic impairments might relate to their performance in on-line and off-line tasks. Group 1's self-paced reading times showed evidence of rapid disruption in response to both SRVs and EKVs, much as the reading times of healthy controls did. Group 1's sharp disruption in the EKV condition might seem surprising given their conceptual-semantic deficits. However, this on-line reading pattern could reflect sensitivity to linguistic cues such as encountering a very unlikely word (c.f. Levy, 2008). Group 1 participants may remain sensitive to the statistical co-occurrences of words or phrases, and this could explain their slowed reading times in response to a highly unlikely verb-noun sequence in the EKV condition. (See DeDe, 2013, for self-paced reading evidence of retained sensitivity to statistical co-occurrence information in aphasia.) This retained sensitivity could also drive Group 1's normal-like performance on acceptability judgments. However, spared sensitivity to such linguistic cues would not likely influence comprehension question answering, which involves building and querying mental models of the described events. The fact that Group 1 participants performed less well on comprehension questions than acceptability judgments and experienced particular difficulty in responding to comprehension questions in the EKV condition could be related to their conceptual-semantic impairment. Perhaps a conceptual-semantic deficit related to event knowledge causes or is caused by difficulty in building mental models of events, leading to poorer comprehension question answering. One possibility that does not seem consistent with Group 1's performance is that event-related conceptual deficits can eliminate on-line processing differences between plausible and implausible sentences.

In contrast to the pattern seen for Group 1, Group 2 showed little evidence of reading slow-downs in response to either SRVs or EKVs. In off-line tasks, they were less accurate on acceptability judgments than controls in the baseline and SRV conditions, and less accurate on comprehension-question performance in the SRV and EKV conditions. Group 2's abnormal on-line performance and poor performance on acceptability judgments in the baseline condition plausibly reflect their impaired language processing abilities. One possible speculation regarding this pattern of results is that these participants may rely more heavily on meaning or event-related knowledge than on linguistic structure (e.g., Caramazza & Zurif, 1976), given their impaired language processing but relatively intact conceptual-semantic processing. This pattern of impairment may have led them to ignore or maintain higher uncertainty regarding the details of the sentences' linguistic representations (e.g., Levy, Bicknell, Slattery & Rayner, 2009), and possibly modify those representations to be in line with more plausible interpretations grounded in event-related conceptual-semantic representations (e.g., Gibson, Bergen, & Piantadosi, 2013). For example, they may have substituted more-plausible lexical items in the EKV or SRV conditions to make the described event more likely (changing "used a glove to tickle the large goose" to "used gloves to tackle the large goose"). If these participants somehow re-interpreted the SRV and EKV conditions to assign them more plausible interpretations (e.g. Gibson, et al., 2013; Levy, et al., 2009), that would explain their poor comprehension question performance in both the SRV and EKV conditions. It is possible that Group 2's relatively intact event-related knowledge could underlie their more normal-like performance for acceptability judgments in the EKV condition, as well. However, this noisy-channel-based account predicts that Group 2 should have shown elevated reading times in the EKV or SRV conditions, associated with revising the previously-read material in the face of new input (Levy, et al., 2009). This was not the case. Furthermore, this account does not explain Group 2's poor performance in the SRV conditions, which also violated event expectations.

More research is needed in order to understand the relationship between patterns of deficits and patterns of sentence comprehension at a detailed level. However, Group 2's abnormal on-line performance indicates that they exhibited impaired verb-argument integration, which was associated with their language-processing impairments. Furthermore, the pattern of findings across both groups suggests that acceptability-judgment performance may not be as strongly affected by long-term memory representations for events as comprehension question performance is.

The findings reported in this paper all point to the importance of language processing ability for verb-argument understanding, particularly in on-line measures. The conclusion that language impairments are especially disruptive to rapid verb-argument understanding is consistent with views of language comprehension that assign a special and important role to verb-specific knowledge and representations (e.g., Boland, 2005; Kuperberg, 2013; see also Roland, Yun, Koenig & Mauner, 2012). It is surprising under views of verb-argument understanding in which such processing requires or reduces to accessing non-language conceptual-semantic representations of events (e.g., Ferretti, et al., 2001; McRae & Matsuki, 2009; see also Pulvermüller, 2013; Zwaan, Stanfield & Yaxley, 2002). Such accounts predict that measurable impairments in accessing non-language event representations (as indicated by performance on the Event task) should impede verb-argument processing. The fact that the participants in Group 1 had normal-like verb-argument processing despite impairments like these casts doubt on how obligatory access to such non-language representations is for verb-argument integration and interpretation.

Nonetheless, there is significant evidence that healthy adults do take advantage of event-related world knowledge when it is available to facilitate verb-argument processing. For example, young healthy adults respond differently to likely and unlikely arguments even when they both satisfy the semantic requirements of a verb (Bicknell, at al., 2010), and they also anticipate likely upcoming verbal arguments in visual-world studies (Kamide, et al., 2003). There is even evidence that scene-based information regarding likely event participants may be just as helpful as verb-related information in guiding prediction of upcoming verbal arguments (Milburn, Warren & Dickey, 2014). The current study simply suggests that accessing event-related world knowledge may not be necessary to accomplish rapid verb-argument understanding.

Because the current study tested violations, it focused on verb-argument *integration*, the process of combining a verb and an object and rapidly assigning them an interpretation. The findings here indicate that accessing event-related world knowledge may not be as crucial for verb-argument integration as has sometimes been assumed, and that verb-specific knowledge may play a particularly important role in such processing. However, the relative importance of these two sources of information in verb-argument *prediction* – the process of anticipating upcoming verbal arguments based on verb-related and event-related knowledge – is unknown. Prediction and integration may well engage different neural (Federmeier, 2007) and cognitive (Pickering & Garrod, 2013) mechanisms. Some of the most compelling evidence for the rapid use of knowledge about likely event participants during comprehension also comes from studies of verb-argument prediction (e.g., Borovsky, Elman & Fernald, 2012; Kamide, et al., 2003). The advantage for language-specific processing seen in verb-argument integration here may or may not hold for verb-argument prediction.

Given the importance of event-related knowledge in language comprehension among healthy populations, and its importance in verb-argument prediction, measuring the relative availability or impairment of such knowledge in neurogenically-impaired populations is also important. The Event task used here holds promise as a measure of just such knowledge. There are relatively few clinical measures of non-language knowledge about actions and events, especially in comparison to measures of object-related conceptual-semantic knowledge (like Pyramids and Palm Trees, Howard & Patterson, 1992, or the Camels and Cactus Test, Bozeat, Lambon Ralph, Patterson, Garrad & Hodges, 2000). Further development and validation of the Event task may provide a clinically valuable tool for the assessment and measurement of deficits in event-related conceptual-semantic representations. Such deficits could be present in a variety of neurogenically-impaired populations, not only adults with aphasia but adults with semantic dementia or other progressive neurodegenerative disorders (Warrington, 1975; Reilly & Peelle, 2008).

4. CONCLUSION

This study provides new evidence regarding the contribution of event-related world knowledge to rapid language comprehension, in particular verb-argument understanding. The current results suggest that such knowledge may play an important but more limited role than has sometimes been argued (e.g., McRae & Matsuki, 2009). It also underlines the importance of language-specific processes and representations in language comprehension. The goal of future research in this area should be to identify how comprehenders trade off between these different types of knowledge, across different comprehension processes (e.g., verb-argument integration, verb-argument prediction) and different populations (e.g., healthy adults, neurogenically-impaired adults, language learners).

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APPENDIX

Stimulus items, Experiments 1–2. Presentation regions for self-paced reading are marked with |.

1. **a.** Mary | used | a knife | to chop | the | large | carrots | before dinner | last night.

   b. Mary | used | some bleach | to clean | the | large | carrots | before dinner | last night.

   c. Mary | used | a pump | to inflate | the | large | carrots | before dinner | last night.

2. **a.** The man | used | a shovel | to spread | the | small | stones | on the driveway | this afternoon.

   b. The man | used | a cradle | to rock | the | small | stones | on the driveway | this afternoon.

c. The man | used | a sponge | to absorb | the | small | stones | on the driveway | this afternoon.

3. **a.** The man | used | a strainer | to drain | the | thin | spaghetti | yesterday | evening.

b. The man | used | a blowdryer | to dry | the | thin | spaghetti | yesterday | evening.

c. The man | used | a photo | to blackmail | the | thin | spaghetti | yesterday | evening.

4. **a.** The woman | used | a knife | to cut | the | tough | bread | before dinner | last night.

b. The woman | used | the band-saw | to cut | the | tough | bread | before dinner | last night.

c. The woman | used | a book | to teach | the | tough | bread | before dinner | last night.

5. **a.** The woman | used | the paper | to wrap | the | small | package | yesterday | morning.

b. The woman | used | the oven | to roast | the | small | package | yesterday | morning.

c. The woman | used | the map | to instruct | the | small | package | yesterday | morning.

6. **a.** Bill | used | the knife | to cut | the | hard | cheese | that came | from Italy.

b. Bill | used | the stapler | to staple | the | hard | cheese | that came | from Italy.

c. Bill | used | the calculator | to compute | the | hard | cheese | that came | from Italy.

7. **a.** The man | used | a pot | to boil | the | big | lobster | in the kitchen | of the vacation house.

b. The man | used | a chain-saw | to cut | the | big | lobster | in the kitchen | of the vacation house.

c. The man | used | a typewriter | to type | the | big | lobster | in the kitchen | of the vacation house.

8. **a.** The woman | used | a sponge | to clean | the | ugly | dishes | at her aunt's house | in the country.

b. The woman | used | a steamroller | to crush | the | ugly | dishes | at her aunt's house | in the country.

c. The woman | used | a bugspray | to repel | the | ugly | dishes | at her aunt's house | in the country.

9. **a.** The woman | used | the mop | to clean | the | front | porch | for the party | last weekend.

b. The woman | used | the nail polish | to paint | the | front | porch | for the party | last weekend.

c. The | woman | used | the razor | to shave | the | front | porch | for the party | last weekend.

10. **a.** The hostess | used | a dish | to serve | the | small | enchilada | at dinner | on Thursday.

b. The hostess | used | a syringe | to inject | the | small | enchilada | at dinner | on Thursday.

c. The hostess | used | a key | to unlock | the | small | enchilada | at dinner | on Thursday.

11. **a.** Erin | used | the detergent | to wash | the | pretty | blanket | for her baby's | new crib.

b. Erin | used | the chopsticks | to carry | the | pretty | blanket | for her baby's | new crib.

c. Erin | used | a promise | to motivate | the | pretty | blanket | for her baby's | new crib.

12. **a.** Jenny | used | the net | to catch | the | pretty | butterfly | on the leaf | in the forest.

b. Jenny | used | the toothbrush | to clean | the | pretty | butterfly | on the leaf | in the forest.

c. Jenny | used | a violin | to play | the | pretty | butterfly | on the leaf | in the forest.

13. **a.** Patricia | used | a bucket | to carry | the | fresh | water | very carefully | in the yard.

b. Patricia | used | a case | to display | the | fresh | water | very carefully | in the yard.

c. Patricia | used | a knife | to peel | the | fresh | water | very carefully | in the yard.

14. **a.** George | used | a fence | to protect | the | many | flowers | in his | backyard garden.

b. George | used | a rope | to lasso | the | many | flowers | in his | backyard garden.

c. George | used | a tuning fork | to tune | the | many | flowers | in his | backyard garden.

15.
- **a.** Frank | used | a bag | to carry | the | heavy | book | from the library | on campus.
- **b.** Frank | used | a crane | to lift | the | heavy | book | from the library | on campus.
- **c.** Frank | used | a chocolate | to persuade | the | heavy | book | from the library | on campus.

16.
- **a.** Julie | used | a whistle | to summon | the | various | children | after recess | this afternoon.
- **b.** Julie | used | a sheepdog | to herd | the | various | children | after recess | this afternoon.
- **c.** Julie | used | a can-opener | to open | the | various | children | after recess | this afternoon.

17.
- **a.** Melinda | used | a lock | to secure | the | yellow | cabinet | at night | for safety.
- **b.** Melinda | used | a blow-dryer | to dry | the | yellow | cabinet | at night | for safety.
- **c.** Melinda | used | a worm | to catch | the | yellow | cabinet | at night | for safety.

18.
- **a.** Donald | used | a pencil | to sketch | the | old | weathervane | at the farm | his family owned.
- **b.** Donald | used | a rocking chair | to rock | the | old | weathervane | at the farm | his family owned.
- **c.** Donald | used | a fertilizer | to feed | the | old | weathervane | at the farm | his family owned.

19.
- **a.** The woman | used | a bowl | to hold | the | thick | icing | for the cake | yesterday evening.
- **b.** The woman | used | a purse | to carry | the | thick | icing | for the cake | yesterday evening.
- **c.** The woman | used | a rag | to polish | the | thick | icing | for the cake | yesterday evening.

20.
- **a.** The woman | used | a blanket | to warm | the | chilled | hiker | in the ski lodge | at the end of the day.
- **b.** The woman | used | a magic marker | to mark | the | chilled | hiker | in the ski lodge | at the end of the day.
- **c.** The woman | used | a ladle | to skim | the | chilled | hiker | in the ski lodge | at the end of the day.

21.
- **a.** Nancy | used | a match | to light | the | white | cigarette | that a friend | gave her.

- **b.** Nancy | used | a dryer | to tumble | the | white | cigarette | that a friend | gave her.
- **c.** Nancy | used | a procedure | to de-claw | the | white | cigarette | that a friend | gave her.

22.
- **a.** The man | used | the anchor | to secure | the | reddish | tugboat | after the outing | to the harbor.
- **b.** The man | used | the shoe-polish | to shine | the | reddish | tugboat | after the outing | to the harbor.
- **c.** The man | used | the microwave | to cook | the | reddish | tugboat | after the outing | to the harbor.

23.
- **a.** Robert | used | a trap | to catch | the | large | goose | that weighed | ten pounds.
- **b.** Robert | used | a glove | to tickle | the | large | goose | that weighed | ten pounds.
- **c.** Robert | used | a check | to reimburse | the | large | goose | that weighed | ten pounds.

24.
- **a.** The woman | used | a brush | to apply | the | white | paint | on Sunday | afternoon.
- **b.** The woman | used | the spoon | to taste | the | white | paint | on Sunday | afternoon.
- **c.** The woman | used | a loom | to weave | the | white | paint | on Sunday | afternoon.

25.
- **a.** Justin | used | the leash | to control | the | black | Doberman | that he walked | in the park.
- **b.** Justin | used | the hair gel | to style | the | black | Doberman | that he walked | in the park.
- **c.** Justin | used | the shovel | to scatter | the | black | Doberman | that he walked | in the park.

26.
- **a.** Gloria | used | a shortcut | to avoid | the | annoying | potholes | on Main Street | in town.
- **b.** Gloria | used | spitballs | to bombard | the | annoying | potholes | on Main Street | in town.
- **c.** Gloria | used | a bowl | to mix | the | annoying | potholes | on Main Street | in town.

27.
- **a.** Nathan | used | a shovel | to clear | the | big | driveway | after the storm | last week.
- **b.** Nathan | used | his tongue | to lick | the | big | driveway | after the storm | last week.

- **c.** Nathan | used | clothespins | to hang | the | big | driveway | after the storm | last week.

28.
- **a.** John | used | a pick | to play | the | brown | guitar | last night | after closing.
- **b.** John | used | a meat-locker | to store | the | brown | guitar | last night | after closing.
- **c.** John | used | a straw | to drink | the | brown | guitar | last night | after closing.

29.
- **a.** Hannah | used | a harness | to lead | the | pale | horse | in the field | behind the house.
- **b.** Hannah | used | mascara | to beautify | the | pale | horse | in the field | behind the house.
- **c.** Hannah | used | a pitcher | to pour | the | pale | horse | in the field | behind the house.

30.
- **a.** Marta | used | an oven | to bake | the | warm | cupcakes | for Jim's birthday | last week.
- **b.** Marta | used | a blender | to puree | the | warm | cupcakes | for Jim's birthday | last week.
- **c.** Marta | used | an incubator | to hatch | the | warm | cupcakes | for Jim's birthday | last week.

Highlights

- Verb-argument processing was examined in older adults and people with aphasia (PWA)
- PWA with mild language deficits but poor conceptual semantics performed like controls
- PWA with worse language deficits but good conceptual semantics did not
- Language function is more important for verb-argument processing
- Access to conceptual semantics may not be necessary for verb-argument processing

(a)

(b)

Figure 1.
Likely (a) and highly unlikely (b) pictures from the Event task, taken from Proverbio and Riva (2009)

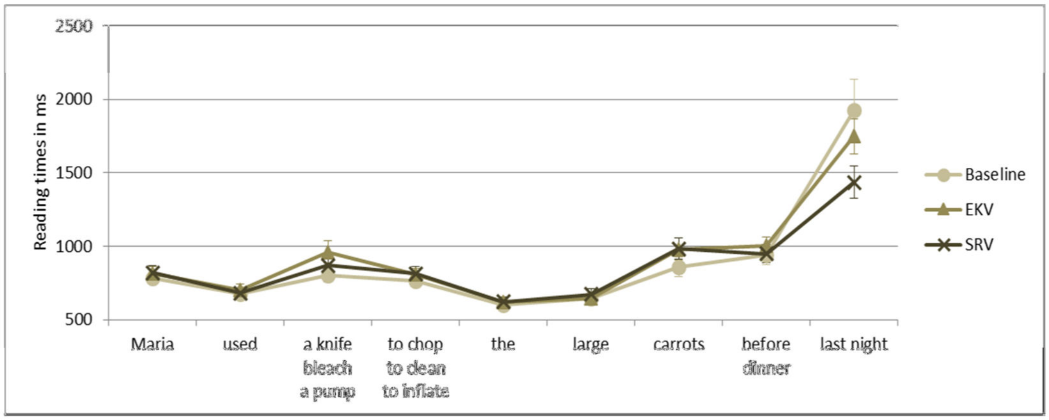


Figure 2.
Reading times by segment, Experiment 1a, healthy older adults. Error bars represent 1 standard error (SE).

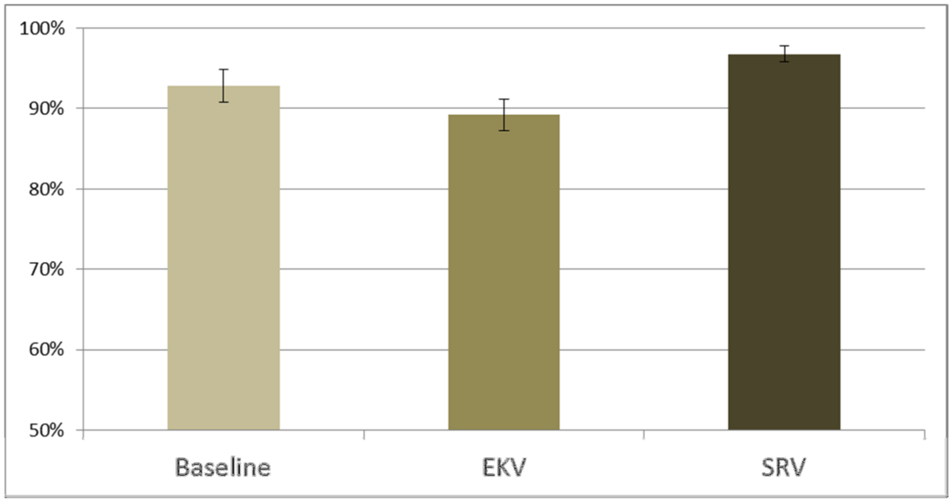


Figure 3.
Accuracy, acceptability judgment, Experiment 1a, healthy older adults. Error bars represent 1 SE.

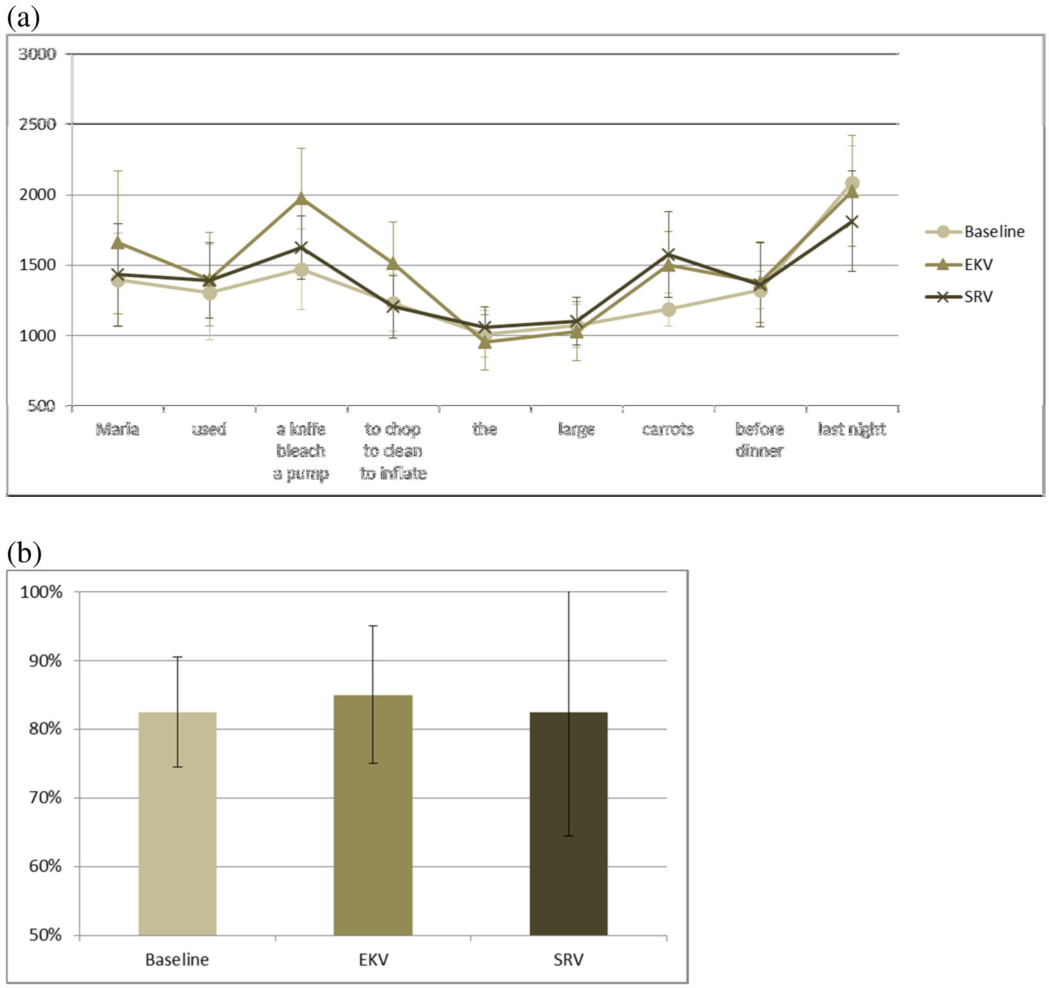
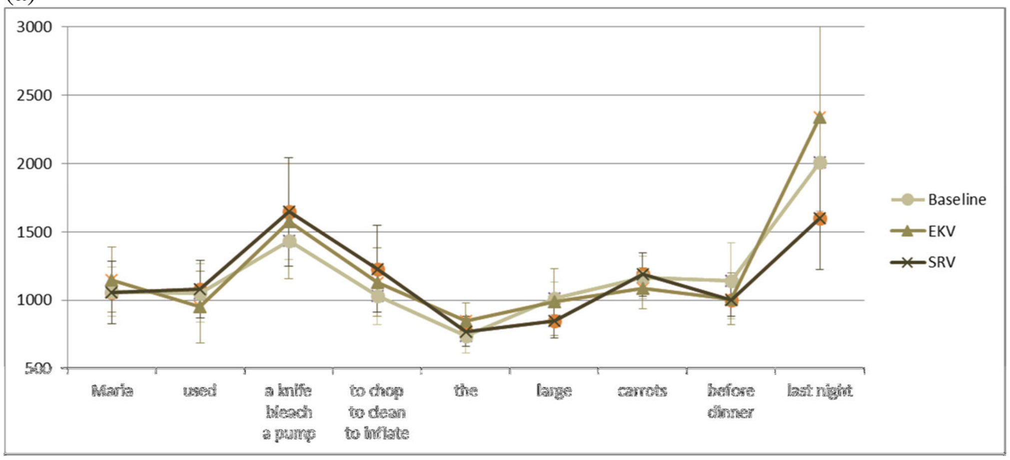


Figure 4.

Figure 4a–b. Reading times by segment (a) and acceptability judgment accuracy (b), Experiment 1b, aphasia Group 1 (−Event-related knowledge, +Language processing). Error bars represent 1 SE.

(a)



(b)

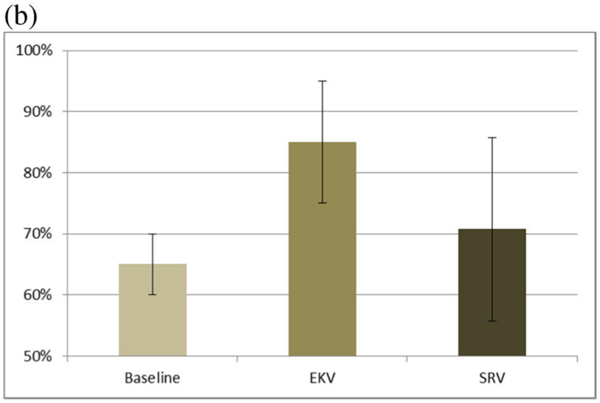


Figure 5.

Figure 5a–b. Reading times by segment (a) and acceptability judgment accuracy (b), Experiment 1b, aphasia Group 2 (+Event-related knowledge, −Language processing). Error bars represent 1 SE.

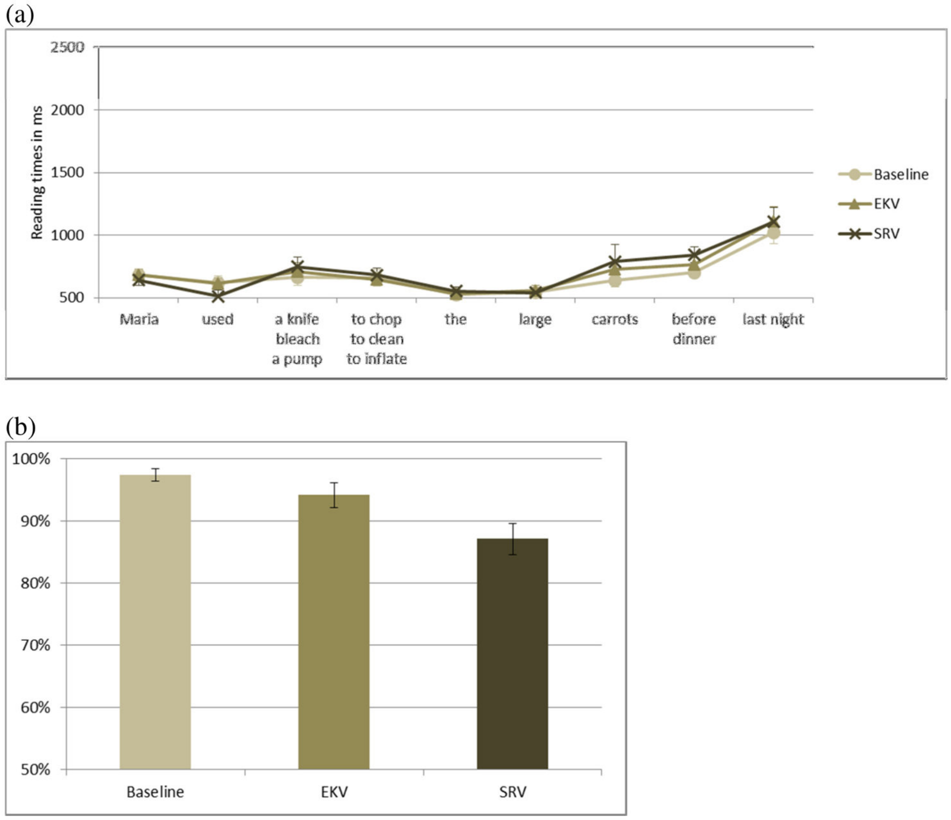
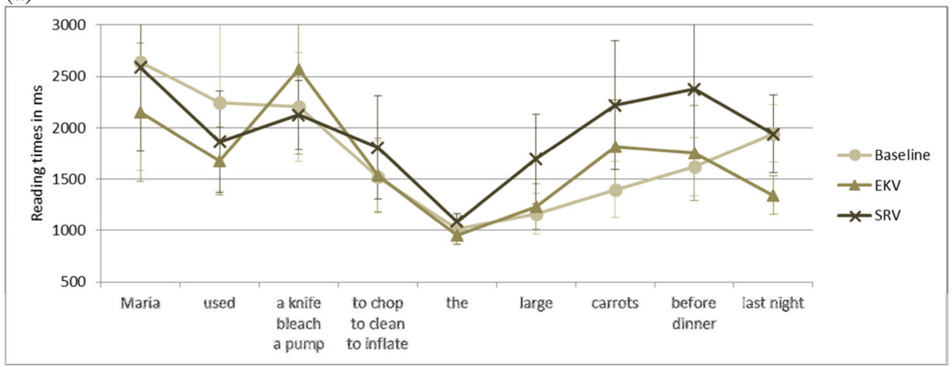


Figure 6.

Figure 6a–b. Reading times by segment (a) and comprehension question accuracy (b), Experiment 2a, healthy older adults. Error bars represent 1 SE.

(a)



(b)

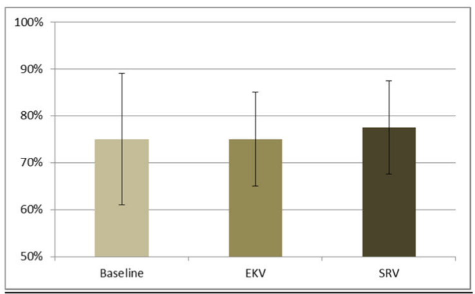
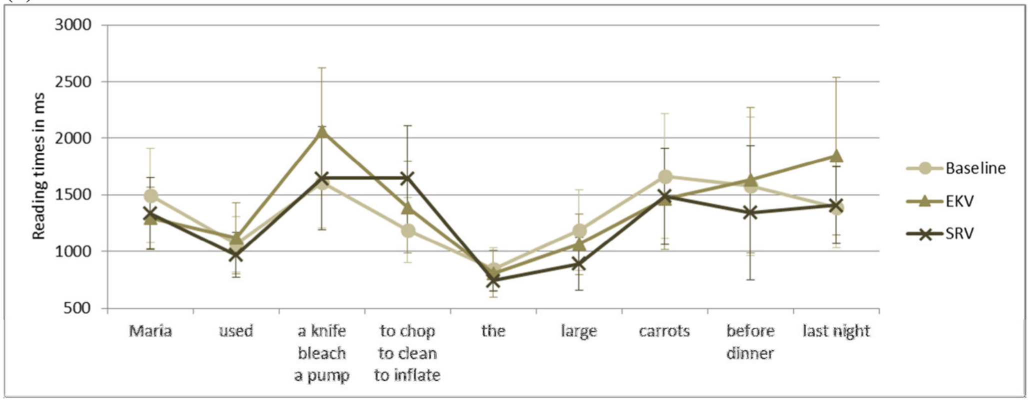


Figure 7.

Figure 7a–b. Reading times by segment (a) and comprehension question accuracy (b), Experiment 2b, aphasia Group 1 (−Event-related knowledge, +Language processing). Error bars represent 1 SE.

(a)



(b)

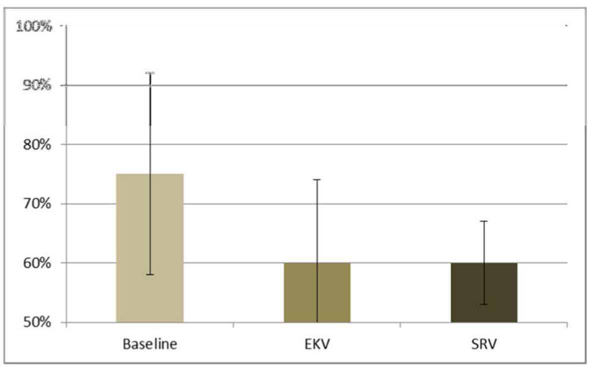


Figure 8.

Figure 8a–b. Reading times by segment (a) and comprehension question accuracy (b), Experiment 2b, aphasia Group 2 (+Event-related knowledge, −Language processing). Error bars represent 1 SE.

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Table 1

Demographic and lesion information for adults with aphasia, Experiments 1a–2a

Participant	Group	Sex	Age	MPO	Education (in years)	Lesion
103	1	M	62	99	14	Left frontal/temporal/parietal
108	1	F	65	55	15	Focal infarct L posterior frontal; old infarct L MCA territory: L frontoparietal
110	1	F	82	114	14	unknown
112	1	F	65	419	12	unknown
101	2	F	67	24	12	Infarction extends fully into L MCA territory including L insula, L frontal operculum, posterior L frontal lobe
104	2	M	50	36	12	Left frontal, left occipital, left temporal
105	2	F	47	53	16	Left MCA distribution involving posterior L frontal lobe, anterior L parietal lobe, and L basal ganglia
107	2	M	47	31	14	Left MCA distribution involving L frontal, parietal, and anterior temporal lobes

Abbreviations:

F: Female; L: Left; M: Male; MCA: Middle cerebral artery; MPO: Months post onset

Table 2

Language testing information for adults with aphasia, Experiments 1a–2a

Participant	Group	WAB AQ	Aphasia Classification	RCBA: Subtests I–IV (words)	RCBA: Subtest VI (constrained sentences)	RCBA: Subtest X (morphosyntax)	SOAP simple	SOAP complex
103	1	75.3	TCM	9.25	10	8	70%	60%
108	1	88.9	Anomic	10	10	9	100%	80%
110	1	90.6	Anomic	9.5	10	8	95%	65%
112	1	85.5	Anomic	8.75	10	4	75%	55%
101	2	77	Anomic	9.75	10	7	95%	65%
104	2	70.3	Conduction	9.75	10	9	35%	35%
105	2	55.2	Broca’s	8.75	8	4	60%	45%
107	2	52.6	Broca’s	8.5	8	6	65%	40%

Abbreviations:

RCBA: Reading Comprehension Battery for Aphasia-2 (LaPointe & Horner, 1998); SOAP: SOAP (Subject-Object Active-Passive) Test (Love & Oster, 2002); TCM: Transcortical motor aphasia; WAB AQ: Western Aphasia Battery-Revised Aphasia Quotient (Kertesz, 2007)

Table 3

Non-language cognitive testing information for adults with aphasia, Experiments 1a–2a

Participant	Group	ABCD Delayed:Immediate Story Retell	Raven's Coloured Progressive Matrices (out of 36)	Pyramids and Palm Trees	Event Task
103	1	1.50	30	77%	76%
108	1	1.00	30	94%	85%
110	1	1.06	11	62%	63%
112	1	0.84	27	85%	85%
101	2	1.00	31	92%	95%
104	2	1.23	32	96%	90%
105	2	0.88	32	92%	88%
107	2	1.00	36	88%	90%

Abbreviations:

ABCD: Reading Comprehension Battery for Aphasia-2 (LaPointe & Horner, 1998); SOAP: SOAP (Subject-Object Active-Passive) Test (Love & Oster, 2002); TCM: Transcortical motor aphasia; WAB AQ: Western Aphasia Battery Aphasia Quotient

Table 4

Language and non-language cognitive testing data for aphasia Groups 1 and 2, Experiments 1b–2b. Groups 1 and 2 were significantly different for those measures marked with *: WAB-AQ (Wilcoxon, Z=2.02, $p<0.05$), Raven's (Wilcoxon, Z=2.34, $p<0.05$), and Event Task (Wilcoxon, Z=2.32, $p<0.05$). All other comparisons were non-significant (Wilcoxon, Z<1.6, $p>0.1$).

	Language-impairment measures						Non-language cognitive measures			
Group	**WAB AQ***	**RCBA: Subtests I–IV (words)**	**RCBA: Subtest VI (constrained sentences)**	**RCBA: Subtest X (morphosyntax)**	**SOAP simple**	**SOAP complex**	**ABCD ratio**	**Raven's***	**Pyramids and Palm Trees**	**Event Task***
1 −E, +L	85.1	9.38	10	7.25	85%	65%	1.1	24.5	79%	77%
2 +E, −L	63.8	9.19	9	6.5	64%	46%	1.03	32.75	92%	91%