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Research Article

Looking for a Location: Dissociated Effects of Event-Related Plausibility and Verb–Argument Information on Predictive Processing in Aphasia

Rebecca A. Hayes,[a] Michael Walsh Dickey,[a,b] and Tessa Warren[a]

Purpose: This study examined the influence of verb–argument information and event-related plausibility on prediction of upcoming event locations in people with aphasia, as well as older and younger, neurotypical adults. It investigated how these types of information interact during anticipatory processing and how the ability to take advantage of the different types of information is affected by aphasia.
Method: This study used a modified visual-world task to examine eye movements and offline photo selection. Twelve adults with aphasia (aged 54–82 years) as well as 44 young adults (aged 18–31 years) and 18 older adults (aged 50–71 years) participated.
Results: Neurotypical adults used verb argument status and plausibility information to guide both eye gaze (a measure of anticipatory processing) and image selection (a measure of ultimate interpretation). Argument status did not affect the behavior of people with aphasia in either measure. There was only limited evidence of interaction between these 2 factors in eye gaze data.
Conclusions: Both event-related plausibility and verb-based argument status contributed to anticipatory processing of upcoming event locations among younger and older neurotypical adults. However, event-related likelihood had a much larger role in the performance of people with aphasia than did verb-based knowledge regarding argument structure.

Recent research suggests that prediction or anticipation plays a crucial role in language comprehension (Federmeier, 2007; Kuperberg, 2013; Yoshida, Dickey, & Sturt, 2013). In adults without language impairment, anticipation can rely on either event-related plausibility (e.g., Kamide, Altmann, & Haywood, 2003; McRae & Matsuki, 2009) or lexically stored information about argument structure and participant roles (e.g., Boland, 2005; Koenig, Mauner, & Bienvenue, 2003; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Kim, 1998). There is controversy in the literature regarding when these two sources of information are recruited during sentence comprehension and how (and whether) they interact during the comprehension process (e.g., Mauner, 2015).

To date, there has been relatively limited investigation of predictive processing in aphasia (Dickey, Warren, Hayes, & Milburn, 2014; Hanne, Burchert, De Bleser, & Vasishth, 2015; Hanne, Burchert, & Vasishth, 2015; Mack, Ji, & Thompson, 2013; Warren, Dickey, & Lei, 2016). Study results have been mixed, with some finding evidence of intact prediction in aphasia (Dickey, Warren, Hayes, & Milburn, 2014; Hanne, Burchert, De Bleser, & Vasishth, 2015; Warren et al., 2016), and others finding evidence of impaired predictive processing (Mack et al., 2013). However, these studies have not attempted to tease apart the contribution of these two types of information in predictive processing in aphasia, even though language-specific processing and conceptual–semantic processing can be dissociated among people with aphasia (Dickey & Warren, 2015; McNeil & Pratt, 2001).

The current study investigated the relationship between these two sources of predictive information in aphasia, as well as in aging. In particular, it examined how aphasia (e.g., Shapiro, Gordon, Hack, & Killackey, 1993) and healthy aging (e.g., DeLong, Groppe, Urbach, & Kutas, 2012; Federmeier & Kutas, 2005) might affect the way that comprehenders take advantage of those sources of

[a]University of Pittsburgh, PA
[b]VA Pittsburgh Healthcare System, PA
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information to predict and integrate *locations,* event participants that may be either arguments or adjuncts.

Sources of Information Used in Anticipatory Language Processing

There has been considerable investigation of prediction during comprehension in unimpaired populations (see DeLong, Troyer, & Kutas, 2014; Kuperberg & Jaeger, 2016, for reviews). One important source of information contributing to prediction is stored knowledge regarding the lexical or syntactic properties of particular linguistic forms (DeLong, Kutas, & Urbach, 2005; Hale, 2003; Levy, 2011; Staub & Clifton, 2006). A particularly important lexical characteristic is information about the participant roles associated with verbs or the verbs' *argument structure properties*. These lexical properties specify the number and type of event participants that are entailed by a verb, the semantic role they have in the event being described (e.g., Dowty, 1991), and the syntactic role that the event participants take in the sentence containing the verb (Levin, 1993; Levin & Hovav, 2005). For example, the verb *ride* entails an agent (a rider) and a theme (a thing being ridden), and it also specifies that an noun phrase (NP) expressing the agent is syntactically obligatory, whereas an NP expressing the theme is optional (both *The child rode the bicycle* and *The child rode* are acceptable). Argument structure information has been shown to be activated automatically when comprehenders read or hear a verb, both among healthy adults (Boland, Tanenhaus, Garnsey, & Carlson, 1995; Shapiro, Zurif, & Grimshaw, 1987; Trueswell & Kim, 1998; Trueswell, Tanenhaus, & Kello, 1993) and among people with aphasia (DeDe, 2013a, 2013b; Shapiro et al., 1993; Shapiro & Levine, 1990).

Lexically stored argument structure information facilitates the processing of verbal arguments, such as agents and themes (e.g., Boland et al., 1995). Furthermore, it facilitates the processing of verbal arguments compared with verbal adjuncts, which are not lexically specified (Koenig et al., 2003). Verbal adjuncts are phrases that specify additional information about an event being described, such as the physical location of the event or the time when it occurred. In contrast to arguments, adjuncts are not syntactically obligatory or semantically distinctive: They need not be syntactically expressed, nor do they help distinguish one verb sense from another (e.g., Koenig, Roland, Yun, & Mauner, 2015; Roland, Yun, Koenig, & Mauner, 2012). For example, the adjunct location phrase *in the park* in *The child rode the bicycle* <u>*in the park*</u> describes where this event took place, but it is not required. *The child rode the bicycle* is equally acceptable, and the verb *rode* expresses the same meaning regardless of whether *in the park* appears in the sentence or not. A processing advantage for verbal arguments over adjuncts has been demonstrated for young adults in both self-paced reading and eye-movement reading studies (Clifton, Speer, & Abney, 1991; Liversedge, Pickering, Branigan, & van Gompel, 1998; Schütze & Gibson, 1999; Speer & Clifton, 1998; Tutunjian & Boland, 2008).

In parallel to lexically stored argument structure information, event-related world knowledge also has an important role in rapid language processing (Ferretti, McRae, & Hatherell, 2001; Matsuki et al., 2011; McRae & Matsuki, 2009). That knowledge regarding events or situations resides in semantic memory and is derived from people's experiences with common events, event participants, locations, and other event-related information. These schema-type representations are prototypes on the basis of specific event exemplars (Ferretti et al., 2001). They, therefore, specify which event participants and properties are common or likely, given a comprehender's experience. Likelihood (on the basis of event-based world knowledge) and verb–argument status may be dissociated. It is possible for implausible or unlikely event participants to satisfy a verb's argument-structure requirements (Rayner, Warren, Juhasz, & Liversedge, 2004; Warren, Milburn, Patson, & Dickey, 2015), and likely event participants need not be lexically specified as part of a verb's argument structure (e.g., a likely event location, such as *at the rink* in *The child ice skated at the rink*).

Event-related world knowledge can also facilitate processing of verbal arguments. For example, there is evidence from both self-paced reading and event-related potentials that younger adults rapidly make use of event-related world knowledge to integrate likely arguments, such as themes (Bicknell, Elman, Hare, McRae, & Kutas, 2010; Matsuki et al., 2011; Metusalem et al., 2012). Adults with aphasia are also faster at reading likely, compared with highly unlikely, verb arguments (Dickey & Warren, 2015). Event-related knowledge also facilitates processing of adjuncts. Evidence from priming and the visual-world paradigm shows that young adults have a processing advantage for likely event locations (Boland, 2005; Ferretti, Kutas, & McRae, 2007) and instruments (objects required for carrying out an event; Ferretti et al., 2001). As long as adjuncts are likely in the context of the event being described, they will be activated along with the relevant event-related schemas during comprehension (McRae & Matsuki, 2009).

Both of these sources of information—lexically specified argument-structure information and event-related world knowledge—are likely used in anticipatory processing to anticipate upcoming verbal arguments, such as themes. Especially clear evidence of their effects on the anticipation of upcoming verbal arguments comes from the visual-world paradigm. For example, Altmann and Kamide (1999) investigated anticipation of verbal arguments (in this case, themes), using sentences that contained either restrictive verbs (e.g., *eat*) or unrestrictive ones (e.g., *move*), paired with images of objects, some of which were likely arguments of the restrictive verb (e.g., CAKE), and some of which were only compatible with the unrestrictive verb (e.g., BALL, TRUCK). They found that young, healthy participants gazed anticipatorily at objects upon hearing the restrictive verbs. These verbs all entailed a theme argument as part of their lexically specified argument structure. Furthermore, participants gazed more often at images that were likely arguments of those verbs. This suggests that anticipation of a likely upcoming theme is driven by both verb–argument structure information

and event-related knowledge. Similar evidence of anticipatory processing of verbal arguments has been reported for young, healthy speakers of German and Japanese (Kamide, Altmann, & Haywood, 2003; Kamide, Scheepers, & Altmann, 2003) and for children as young as 3 years (Borovsky, Elman, & Fernald, 2012).

There is also evidence that lexically specified verb–argument structure information and event-related knowledge contribute independently to anticipatory processing. In a visual-world study, Boland (2005) found that young adults gazed anticipatorily at likely and unlikely recipient arguments (the person who receives an object, lexically specified for a verb such as *give*). This finding suggests that lexically specified verb–argument information can guide anticipatory processing of upcoming verbal arguments, independent of whether they are likely, given world knowledge. In addition, participants were faster to gaze at likely instruments (for example, an image of a stick for a sentence such as *The farmer beat the donkey with …*). Roland et al. (2012) found similar facilitation for likely upcoming instruments in a separate visual-world study. These findings suggest that event-related world knowledge can guide anticipatory processing of adjunct event participants that are not lexically specified, such as instruments and locations (Ferretti et al., 2001, 2007).

The independent contributions of verb–argument structure and event-related world knowledge to anticipatory processing have important implications for the processing of location phrases. Unlike some other types of event participants, such as instruments or themes, locations may have either an argument or an adjunct role depending on the sentence's verb. For example, the verb *put* requires a location, a constraint that is lexically specified as part of *put*'s verb–argument structure, whereas the verb *rode* does not. The location *in the park* is thus an argument in 1a and an adjunct in 1b:

1. a. The child put the bicycle in the park.
   b. The child rode the bicycle in the park.

Verb–argument information should, therefore, facilitate prediction of *in the park* in 1a (e.g., Boland, 2005), but not in 1b. However, event-related knowledge should facilitate processing of the likely location of the bike-riding event described in 1b (e.g., Ferretti et al., 2007), even though it is an adjunct. The anticipatory processing of location arguments and adjuncts can, therefore, reveal how older adults and people with aphasia draw on these two sources of information to drive predictive processing.

Predictive Processing in Aphasia and Healthy Aging

Although there is clear evidence that young, healthy adults engage in anticipatory processing during language comprehension, there is less evidence that older, healthy individuals do so. Event-related potential and reading evidence suggests that older, neurotypical (ON) adults predict less than do younger, neurotypical (YN) adults (DeLong et al., 2012; Federmeier & Kutas, 2005). Older adults' degree of predictive processing appears to be mediated by verbal fluency (Federmeier, McLennan, De Ochoa, & Kutas, 2002) and working memory function (Federmeier & Kutas, 2005). These patterns could indicate that healthy aging may reduce older adults' ability to use lexically specified verb–argument representations or event-related world knowledge to engage in anticipatory processing. Examining these adults' processing of location arguments and adjuncts can shed light on whether their reduced predictive processing reflects a reduction in use of event-related world knowledge, lexically specified verb–argument information, or both.

In comparison with ON adults, there has been less investigation of predictive processing among people with aphasia (PWA). Some studies have found evidence suggesting that PWA do engage in prediction, particularly when provided with strong morphosyntactic cues (Hanne, Burchert, De Bleser, & Vasishth, 2015; Warren et al., 2016). Others have not found evidence of predictive processing among PWA. In one such study, Mack et al. (2013) examined how PWA and ON adults anticipate theme arguments. In their restrictive condition, the sentence's verb limited the set of possible themes to only one of the images, but in the unrestrictive condition, the verb could plausibly take any of the images as a theme. For example, participants heard "Sam will open the jar" or "Sam will break the jar" while looking at images of a jar, a pencil, a plate, and a stick. All of these objects are breakable, but only one of them is able to be opened (the target object). Neither the participants with aphasia nor their age-matched controls showed anticipatory gazes at the target before hearing it named. Nonetheless, both groups did gaze more at the target toward the end of the sentence in the restrictive condition (*Sam will open …*). The lack of anticipatory processing by the ON controls is consistent with many findings noted above (e.g., Wlotko, Lee, & Federmeier, 2010).

In a second experiment, the target noun was removed from the auditory stimuli, so that participants never heard the target object mentioned. This expanded the window for potential anticipatory looks to the target object following the verb. In this experiment, ON adults showed an effect of restriction within the first 0–500 ms after the verb, such that they were more likely to gaze at the target object in the restricted condition than in the unrestricted condition. Individuals with aphasia also demonstrated this effect, but not until 1,000–1,500 ms after the verb.

These findings provide no evidence of predictive processing of verbal arguments by PWA or ON adults. However, this study's design did not distinguish the potential contributions of event-related world knowledge and argument-structure information to predictive processing. Either or both of these sources of knowledge could have led to the facilitation seen for the likely theme in the restrictive condition (the jar, in *Sam will open …*) because this object both fit the argument-structure requirements of the verb and was a likely theme, given the event being described in the sentence. Thus, a reduction in use of either verb–argument information or event-related world knowledge could have been responsible for the reduction in predictive processing reported by Mack et al. (2013).

A related question left open by the Mack et al. (2013) study is what aspects of these particular PWA's language impairment were responsible for their reduced predictive processing. All of the PWA in the Mack et al. study had agrammatical, language-impairment profiles. On the basis of that profile, they should all have had impairment in both verb-related processing and sentence formulation (Goodglass, 1976). This, again, makes it difficult to disentangle which aspect of language impairment was responsible for the reduction in predictive processing that they reported. Because that impairment could manifest in different degrees across different individuals with aphasia, it would be useful to test a more varied sample of PWA to gain additional insight into which types of PWA and which specific impairment or language-impairment profiles are associated with reduced predictive processing.

There is evidence in favor of both of these explanations for reduced anticipation of verbal arguments among PWA. Many studies have demonstrated verb-related deficits in aphasia, across aphasia subtypes and language-impairment profiles (e.g., Mätzig, Druks, Masterson, & Vigliocco, 2009). In contrast, access to world knowledge, including event-related plausibility (Caramazza & Zurif, 1976; Gahl et al., 2003), appears to be preserved in many PWA. PWA regularly show advantages in comprehending sentences with strong plausibility information (including reversible sentences; Heilman & Scholes, 1976; Schwartz, Saffran, & Marin, 1980). Event-related world knowledge is also likely broadly distributed cortically, possibly including right-hemispheric regions (Metusalem, Kutas, Urbach, & Elman, 2016) and is, therefore, likely to be robust to focal, left-hemispheric (LH) injury, such as that experienced by many PWA. If verb-related knowledge is relatively impaired among PWA (either all PWA or those with specific language-impairment profiles), whereas event-related world knowledge is relatively intact, verb–argument structure information should have a reduced effect on predictive processing among PWA. This would predict that locations that are arguments should not show an advantage over locations that are adjuncts during predictive processing.

Others have argued that verb-related knowledge may, in fact, be relatively preserved in aphasia, both grammatical verb–argument representations (Russo, Peach, & Shapiro, 1998; Shapiro et al., 1993; Shapiro & Levine, 1990) and probabilistic knowledge regarding verb–argument structure (DeDe, 2013a, 2013b; Gahl, 2002; Gahl et al., 2003). The Gahl (2002) Lexical Bias Hypothesis claims that PWA may in fact overrely on verb-related, probabilistic biases during comprehension. Consistent with that view, DeDe (2013a) presented self-paced reading evidence that PWA may ignore strong plausibility information and unambiguous morphosyntactic cues during online comprehension when those cues conflicted with a verb's probabilistic argument-structure biases. It is possible that access to event-related world knowledge can be impaired among PWA, perhaps, because accessing such plausibility or likelihood information is dependent on formulating message-level representations (a process that may itself be impaired for some PWA). If so, then event-related world knowledge should have a reduced effect on predictive processing among PWA, but verb–argument structure information should still be relatively available to guide anticipation. Under that view, argument locations should show a clear advantage over adjunct locations, but there may not be an advantage for likely event locations over unlikely ones.

There are not only theoretical but also clinical implications to understanding whether event-related world knowledge and verbal argument-structure representations are available and guide anticipatory processing in PWA. This is important to illuminating the mechanisms that underlie successful models of verb treatment, such as Verb Network Strengthening Training (VNeST; Edmonds & Babb, 2011; Edmonds, Nadeau, & Kiran, 2009). VNeST stimulates the hypothesized connections among likely event participants (McRae & Matsuki, 2009) to facilitate recovery of verbs used to describe those events. Establishing that PWA (either all PWA or PWA with specific language-impairment profiles) are able to use event-related world knowledge to guide anticipatory processing will provide critical insight into the mechanisms hypothesized to underlie VNeST's efficacy.

The Current Study

Given these open questions, the current research sought to investigate the following questions:

1. How do argument status and event-related plausibility affect anticipation of locations (arguments and adjuncts) among PWA and ON adults?
2. Do PWA exhibit less anticipatory behavior than age-matched controls do (cf., Mack et al., 2013), for either arguments (facilitated by argument-structure representations) or adjuncts (facilitated by event-related world knowledge)?
3. Do ON adults exhibit reduced or slowed evidence of anticipatory behavior compared with YN adults (DeLong et al., 2012; Federmeier & Kutas, 2005)?
4. Do different PWA, with different language impairments, exhibit different degrees of reduction in anticipatory processing of argument or adjunct locations?

The current study answered these questions by testing predictive processing of argument and adjunct locations in a modified, visual-world study, such as that used by Mack et al. (2013).

Method

Participants

There were three groups of participants in this study: 12 individuals with diagnosed aphasia after an LH stroke, 18 ON controls in a similar age range to the participants with aphasia, and 44 YN controls. Older, unimpaired participants were recruited through the Research Participant Registry, a registry of community-dwelling adults with ages

across the life span, and younger, unimpaired participants were recruited through the University of Pittsburgh's Introduction to Psychology participant pool. PWA were recruited through the Western Pennsylvania Participant Registry, a registry of community-dwelling stroke survivors. Younger controls participated in exchange for course credit, whereas the other two groups received $10/hr for their participation.

Unimpaired participants were native, monolingual English speakers with self-reported normal or corrected-to-normal vision and normal hearing. Older participants were between 50 and 71 years old (M = 59.31, SD = 6.43), whereas younger participants were between 18 and 31 years (M = 18.84, SD = 2.13). Unimpaired participants were excluded from testing if they reported any history of head injury with cognitive sequelae, progressive neurodegenerative disorder, or other speech-language or neuropsychological disorders. Older, unimpaired participants were also screened for frank cognitive and/or memory problem impairment with the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). None scored below 25 of 30 scores (see Table 1 for scores). All unimpaired participants completed Raven's Coloured Progressive Matrices (Raven, Raven, & Court, 1998), a test of general cognitive ability. Older participants had lower scores on the Raven's Coloured Progressive Matrices (M = 30.61 out of 36 scores) than younger participants had (M = 32.93; p = .035), $t(21.193) = -2.25$.

PWA were native, monolingual English speakers, whose aphasia was the result of a unilateral, LH lesion. These participants ranged from 54 to 82 years old (M = 66.83, SD = 8.20; see Table 1 for full demographic data). Testing took place from 17 to 276 months after the onset of aphasia. Aphasia was diagnosed via clinical documentation and performance on the Comprehensive Aphasia Test (CAT; Porter & Howard, 2005). The Northwestern Assessment of Verbs and Sentences (NAVS; Thompson, 2011) was used to further characterize the verb-processing and sentence-level performance of the PWA. Selected results from the CAT and NAVS are presented (see Table 2). Medical records and self-reports of the participants with LH damage indicated no premorbid history of head injury with cognitive sequelae, progressive neurodegenerative disorder, or other speech-language or neuropsychological disorders. These participants additionally had no frank cognitive and/or memory problems, as determined by the cognitive screening portion of the CAT.

The ON participants were younger than the PWA were, $t(22.21) = 2.52$, p = .019. Fisher exact test revealed that the highest level of education completed by individuals in each group (high school graduate or equivalent, undergraduate study, or graduate study) did not differ significantly between the ON participants and the PWA (p = .14).

Materials

This study had a 2 × 2 design, crossing the factors of argument status (argument vs. adjunct) and plausibility (plausible/implausible). There were 40 items with four conditions each (as shown in 2a–d below; see also Supplemental Material S4):

2. (a) The medal is valuable, so the detective is TUCKING it wisely in the SAFE (plausible argument).
   (b) The medal is valuable, so the detective is TUCKING it wisely in the TRASH (implausible argument).
   (c) The medal is valuable, so the detective is LOOKING AT it wisely in the SAFE (plausible adjunct).
   (d) The medal is valuable, so the detective is LOOKING AT it wisely in the TRASH (implausible adjunct).

Each sentence ended with a location phrase. Argument status of the locations was manipulated by using verbs that either take a location argument (e.g., *tuck*) or do not (e.g., *look at*). The sentences introducing the location were in the present progressive ("… so the detective is looking at it …") because previous studies (Ferretti et al., 2007) have found that typical event locations are more likely to be activated in memory when the depicted events are presented as ongoing.

Verbs were categorized as taking a location argument or not based on the three syntactic tests suggested by Schütze (1995): relative clause extraction, use of a pro-form, and prepositional phrase (PP) preposing for *wh*- questions. For each pair of verbs used in an experimental item, the following three syntactic tests were applied (asterisks indicate agrammatic syntactic constructions):

- Active form: The detective tucked the medal into the safe.
  The detective looked at the medal in the safe.
- Relative clause test: *The detective tucked the medal, which happened in the safe.
  The detective looked at the medal, which happened in the safe.
- Pro-form test: *What the detective did in the safe was tuck the medal.
  What the detective did in the safe was look at the medal.
- PP preposing test: *In the safe, who tucked the medal?
  In the safe, who looked at the medal?

The acceptability of the test sentences was judged by the first author and confirmed by a second author. All verbs in argument sentences failed all three syntactic tests, whereas all verbs in adjunct sentences passed all three.

The stimuli were written so that the locations were either plausible or implausible, given event-related world knowledge (e.g., *safe* or *trash,* respectively). To verify that, a norming study was run in which 39 young, neurotypical adults rated the plausibility of the items on a scale from 1 to 5 (1 = *highly unlikely,* 5 = *highly likely*). There was no main effect of argument status on plausibility ratings, $F(1, 1{,}550) = 0.48$ (p = .491), but a significant effect of plausibility, $F(1, 1{,}550) = 46.95$ ($p < .001$), and an interaction between argument status and plausibility, $F(1, 1{,}550) = 4.27$ (p = .039). The implausible sentences were rated nearly equally across argument status, with argument sentences receiving an average rating of 2.51 (SD = 0.81) and adjunct sentences receiving a rating of 2.59 (SD = 0.86). The plausible sentences were rated within 1 SD of one

Table 1. Demographic characteristics of people with aphasia (PWA) and older neurotypical (ON) control participants.

Participant, No.	Sex	Age, years	(Premorbid) handedness	Months after onset	Occupation	Education
PWA						
203	M	62	R	68	Electronic engineer/ computer programmer	BS in computer science
205	F	54	R	71	Teacher	Master of education
207	F	64	R	30	Homemaker	High school GED
210	M	59	R	Approximately 276	Chief	Bachelor degree
211	M	74	R	19	Institutional researcher	PhD
212	M	78	R	120	Professor	PhD in English
213	M	62	R	58	Grocery warehouse worker	Associate degree in criminology
216	M	67	R	52	Engineer	Bachelor degree
219	M	82	R	23	Metallurgical engineer	BS plus some graduate work
221	M	71	No response	17	Private contractor	BS plus some graduate work
222	M	68	No response	No response	Marketing	Bachelor degree
226	F	61	No response	Approximately 204	Accounting	High school
M		66.83		85.27		
ON						
526	F	56	R	30	Accountant	MBA
529	M	69	R	30	Retired	BS, MBA, Ass.
531	M	66	RL	27	Retired	Some college
532	F	50	R	29	Daycare provider	High school
533	F	No response	R	30	Analyst	MBA, BS
534	F	53	R	28	Unemployed	High school GED
536	F	50	R	30	Higher education admin.	MA
537	M	55	R	25	Unemployed d/t Disability	High school
538	M	61	R	30	Instructor	Master of teaching
539	F	68	R	28	Retired	No response
540	F	63	R	27	Retired	High school
541	F	67	R	28	Sales associate	Cosmetology school
542	M	55	R	30	Unemployed	High school GED
543	F	NR	R	30	Retired	High school
544	F	71	R	30	Veterinary technician	BA
545	F	51	R	29	Paralegal	BS
548	F	53	R	30	Homemaker	Some college
549	F	61	R	29	Mathematics teacher	BS
M		59.3125		28.9		

Note. M = male; F = female; R = right; L = left; BS = bachelor of science; GED = General Education Development; PhD = doctor of philosophy; MBA master of business administration; Ass. = associate degree; admin. = administrator; d/t = due to; MA = master of arts; BA = bachelor of arts; RL = ambidextrous.

another, with adjunct sentences receiving a slightly lower average rating of 3.84 (SD = 0.82) than argument sentences' average of 4.17 (SD = 0.53). A comparison of verbs in the argument and the adjunct conditions revealed that the adjunct verbs had a longer mean length in syllables (M = 2.55) than argument verbs had (M = 2.10; $p < .001$), $t(55.8) = 4.025$. In addition, three verbs in the adjunct condition were followed by a preposition (e.g., *looking at*), whereas no such verbs were included in the argument condition. These prepositions were included in the analysis of syllable length.

All experimental sentences were recorded by a female native English speaker. Following the Mack et al. (2013) Experiment 2, sentences were all were truncated after the preposition (e.g., *in*). Each sentence was assigned a set of four corresponding images: one depicting the agent of the sentence (DETECTIVE), one depicting the direct object/ theme (MEDAL), one depicting the PP referent (SAFE or TRASH CAN), and one depicting an unrelated, implausible object (ICED TEA). This unrelated object was a theme from a different item, but a different picture was used to ensure against familiarity effects. The images were all copyright-free, photographic images (rather than line drawings or cartoons), found via an Internet search. These images were displayed in the four quadrants of the computer screen (their position was randomized across trials) when the participants heard the sentence (see Figure 1 for example).

The experimental task was to listen to the sentence fragment and click on the image that "best completed" the sentence (see Mack et al., 2013). The sentences' truncation after the preposition provided a strong cue that the sentence ended in a location.

Procedure

Older and YN participants were tested in a laboratory at the University of Pittsburgh in a single session lasting

Table 2. Results from tests of linguistic and semantic processing.

Participant, No.	Comprehensive Aphasia Test (*t* score)							KDT % correct	PPT % correct	NAVS Sentence Comprehension (% correct)		NAVS verb tests (% correct)	
	Mean modality	Written sentence comprehension	Object naming	Action naming	Word fluency	Spoken picture description	Sentence repetition			Canonical	Noncanonical	Comprehension	Naming
203	56.6	51	64	63	60	73	60	96	83	80	6.7	100	72.7
205	63.6	67	64	59	61	`68	63	96	87	100	86.7	100	100
207	66.1	72	66	69	71	75	63	92	98	100	100	100	100
210	50.7	47	51	50	56	51	48	100	94	46.7	6.7	95.5	31.8
211	45.6	41	47	52	45	39	45	60	85	13.3	0	63.6	9.1
212	62.1	61	64	56	60	75	53	96	98	73.3	33.3	100	95.5
213	44.4	44	50	56	45	46	48	63	79	46.7	6.7	72.7	59.1
216	47.9	46	54	59	47	39	53	85	87	53.3	40	81.8	72.7
219	60.1	68	62	54	51	58	63	88	94	80	100	95.5	86.4
221	61.7	55	74	63	66	75	63	85	81	53.3	13.3	95.5	86.4
222	54.14	48	54	47	58	65	48	88	77	—	—	—	—
226	47.25	51	49	50	49	47	48	94	90	6.7	0	81.8	45.5
M	50.6	48.6	51.3	49	54.3	59.5	48	94	87	59.39	35.76	89.67	69.01

Note. Em dashes indicate data not available; KDT = Kissing and Dancing test; PPT = Pyramids and Palm Trees test; NAVS = Northwestern Assessment of Verbs and Sentences.

Figure 1. Sample displays for prediction task. Image of medal copyright © Bodlina. Modified and reprinted under Creative Commons Attribution-Share Alike 3.0 license. Image of trashcan copyright © Wiertz Sébastien. Modified and reprinted under Creative Commons Attribution 2.0 Generic license. Remaining images used are in the public domain.

"The medal is valuable, so the detective is…"		
	Plausible	**Implausible**
Argument	"… tucking it wisely in the safe."	"… tucking it wisely in the trash can."
Adjunct	"… looking at it wisely in the safe."	"… looking at it wisely in the trash can."

Picture array

1–2 hr. PWA were tested in two 3-hr sessions at least 1 week apart, either in a laboratory at the University of Pittsburgh or in their homes, according to their preferences and mobility requirements. During the first testing session, PWA completed a variety of tasks intended to assess their linguistic and semantic processing (see Table 2 for results). The first of those tests, the CAT, provided several characterizations of language impairment, including a measure of overall severity (Mean Modality T-Score) as well as subscores reflecting comprehension and production of written and oral language at the single-word, single-sentence, and discourse levels. Participants' conceptual–semantic processing was measured using computerized versions of the Pyramids and Palm Trees, three-picture version (Howard & Patterson, 1992) and the Kissing and Dancing test (KDT; Bak & Hodges, 2003). These tasks are designed to measure access to conceptual–semantic information about objects and actions, respectively.

PWA completed the visual-world experiment during the second testing session. Testing of the unimpaired participants, which did not include the language or conceptual–semantic processing tasks, took place during a single laboratory-based session lasting approximately 2.5 hr. All participants underwent a four-item, computerized, functional screening protocol during the testing session with the prediction task. That protocol tested visual and auditory acuity and the ability to use a mouse by requiring participants to click on an image, out of a field of four images, which matched a single word played via the computer's speakers. Participants all had 75% or greater accuracy (three of four items; one error was permitted to allow for adjustments to the stimulus volume) on this task before beginning the visual-world task.

During the visual-world task, participants' eye movements were recorded by either a tower-mounted Eyelink 1000 or a desktop-mounted, remote-viewing Eyelink 2000 system (SR Research, Ltd., Mississauga, Ontario, Canada), with a minimum sampling rate of 1 ms. Participants viewed stimuli on a computer monitor from approximately 65 cm away. Head movements were either minimized using forehead and chin rests or tracked using the remote-viewing system's target-tracking feature. Each participant underwent a 13-point calibration procedure at the beginning of the testing session to ensure accurate readings, with at most an average error of 1° of visual field and a maximum individual error of 1.5° of visual field. Participants were instructed to use the hand with which they were most comfortable to manipulate the computer mouse, to reduce any possible influence of hemiplegia among PWA.

Each trial began with a single-point drift correction. Then, the array of images associated with the current item was displayed. After a 500-ms familiarization period, the audio stimulus was presented via the computer's speakers. Participants' eye fixations were recorded during and after the sentence, until either they clicked on an image or 1,500 ms passed after the end of the audio stimulus. Of the 2,876 trials recorded, 12 trials timed out before the participant made a selection: four trials from four different YN participants, one trial from an ON participant, and seven trials from five different PWA participants. Participants' mouse-click response times and accuracy were recorded.

Analysis

Eye-tracking and response data were analyzed using mixed-effects modeling using the lme4 package in R (Bates & Sarkar, 2005; R Foundation for Statistical Computing, Wien, Austria). Argument status and plausibility and their interaction were included as fixed factors in mixed-effects logistic-regression models, which were run separately for each group. Separate models were run for fixations and image selection data. These models reflected both processing success or failure (image selection analysis) and the online influence of event-related plausibility and argument status on predictive-processing behaviors (fixation analyses). Because anticipatory processing of the location image was the most relevant to the research questions, analyses targeting location image are the focus of the results presented below.

Fixations were analyzed in two ways, via separate models. The first was a gross-fixation analysis, examining overall likelihood of fixating the location and other images in the first 2,000 ms after pronoun offset, when predictive gazes are expected to occur. The second was a separate analysis of each 100-ms bin within that period. This bin-by-bin analysis examined the detailed time course of the influence of argument status and event-related plausibility on gazes at the location and other images. Inclusion of the gross-fixation analysis helped to compensate for an increase in possible Type I errors associated with the multiple comparisons in the bin-by-bin analyses. Together, the models reveal how the argument status and the event-related plausibility affected the different groups' ability to rapidly identify the location as the upcoming constituent, while inhibiting distractors.

Because of the size of the data sets, direct statistical comparisons across groups were not possible. Models using *participant group* as a predictor variable failed to converge. Therefore, quantitative analysis was performed only for within-group contrasts. Results were then compared qualitatively across groups.

The research questions were addressed via the following analyses:

1. How do argument status and event-related plausibility affect anticipation of locations (arguments and adjuncts) among PWA and ON adults?
2. Do PWA exhibit less anticipatory behavior than their age-matched controls (cf. Mack et al., 2013) for either arguments (facilitated by argument-structure representations) or adjuncts (facilitated by event-related world knowledge)?

The first and second research questions were addressed through analyses examining the effects of argument status and event-related plausibility on fixation patterns and image selection responses for PWA and ON participants. Quantitative analyses of the effects of argument status and plausibility on the two groups' fixations (and image selection) addressed how these two factors influenced each group's anticipatory processing of locations. Qualitative comparison of the results for the PWA and ON adults addressed whether PWA showed reduced anticipatory processing compared with ON participants.

3. Do ON adults exhibit reduced or slowed evidence of anticipatory behavior compared with YN adults (DeLong et al., 2012; Federmeier & Kutas, 2005)?

This third research question was addressed through analyses examining gaze patterns and image selection responses for YN and ON participants. Qualitative comparison of the patterns of effects of argument status and event-related plausibility on fixations and image selection addressed whether ON adults showed reduced anticipatory processing compared with YN participants.

4. Do PWA who have different language impairments exhibit different degrees of reduction in anticipatory processing of argument or adjunct locations?

This fourth research question was addressed by correlational analyses examining the relationship between fixations and image selection performance and different specific language impairment among PWA. The data did not support mixed-model analyses with language-impairment variables as fixed effects. Measures of predictive processing focused on fixations to the location and the theme photo as indicators of successful attention to the location an inhibition of attention to a related distractor.

Results

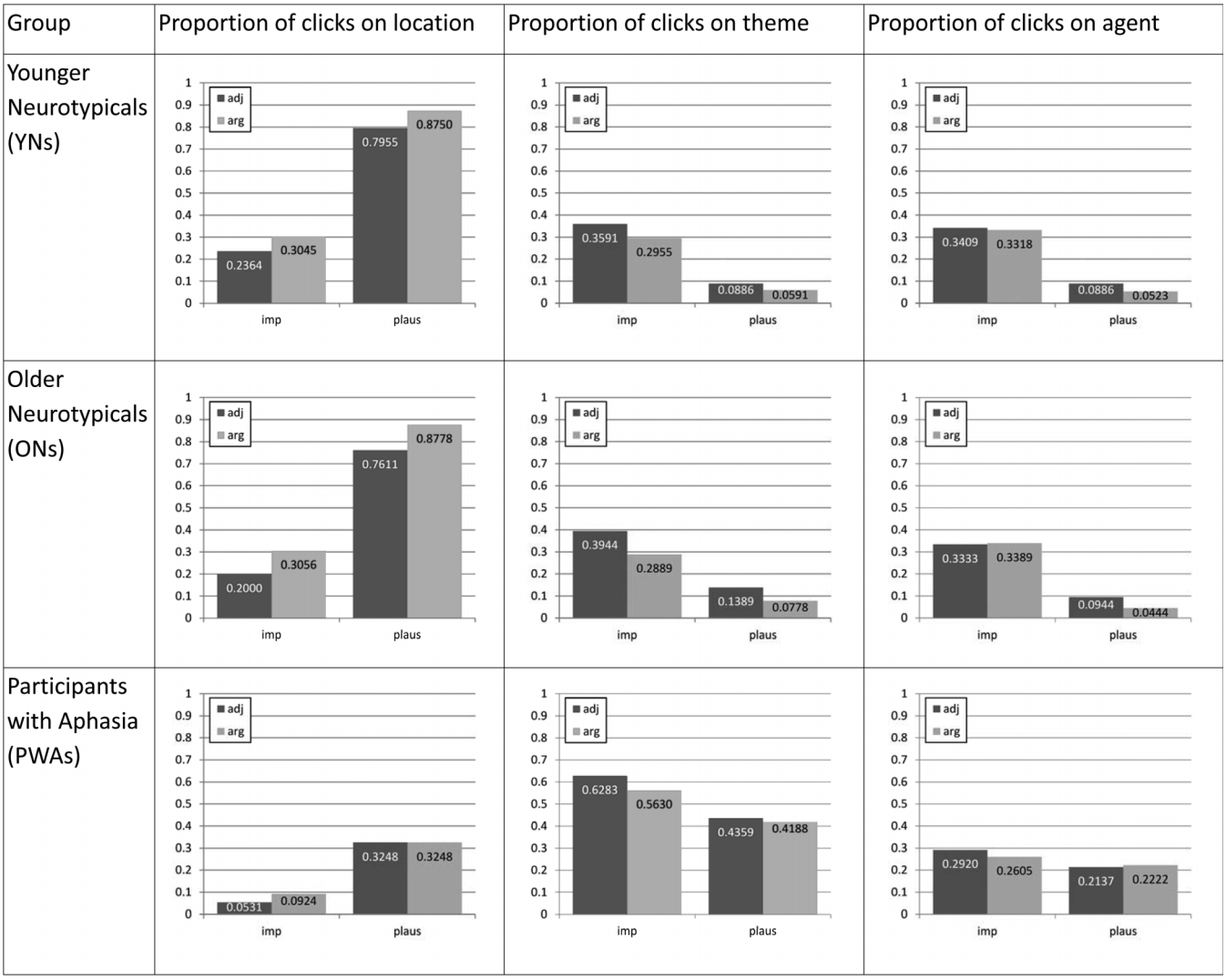
Image Selection Responses

Participants' response data were analyzed using linear mixed-effects logit models, with the dependent variable being the log odds of the participant choosing the image in question (e.g., location, agent). The general pattern of the proportion of clicks that were on each image in each group are shown (see Figure 2).

As noted above, separate models examined the patterns for the three groups (PWA, ON, and YN) for each of the images. The dependent variables in these models were the respective odds of image selection for location/target, theme, and agent, whereas the fixed effects comprised effects-coded variables of argument status and plausibility of the location. Because the data sets were too small to support a maximal random-effects structure, each model was first fit using a minimal random-effects structure with random intercepts for participants and items. Additional models were then fit, including random slopes of argument status and plausibility within participants. Each model with random slopes was compared with the minimal model involving only random intercepts using a likelihood ratio test and, unless otherwise noted, was found not to be a significantly better fit for the data ($p > .05$). Significance of fixed effects was determined using z-tests, with $\alpha = .05$.

The likelihood of selecting the location (target) image provides the primary measure of comprehension success. For the YN and ON participant groups, the odds of selecting the location (target) image were reliably and positively affected by argument status (YN: $\beta = 0.692$, $z = 2.206$, $p = .027$; ON: $\beta = 0.404$, $z = 2.971$, $p = .003$) and plausibility

Figure 2. Proportion of clicks on each image, by group. adj. = adjuct; arg. = argument.



(YN: β = 4.196, z = 12.011, p < .001; ON: β = 4.7358, z = 8.821, p < .001). The PWA group showed only a positive effect of plausibility (β = 2.306, z = 5.814, p < .001) (see Supplemental Material S1 for full model results). None of the three groups exhibited an interaction of argument status and plausibility on location image selection (YN: β = 0.170, z = 0.272, p = .785; ON: β = 0.413, z = 0.525, p = .600; PWA: β = −0.613, z = −0.88, p = .379).

The likelihood of selecting one of the competitor images (theme, agent) provides a complementary measure of comprehension success. Selection of the theme image was negatively affected by plausibility (i.e., the theme was less likely to be chosen if the location was plausible than if it was implausible) for all three groups (YN: β = −2.640, z = −7.582, p < .001; ON: β = −2.460, z = −5.592, p < .001; PWA: β = −0.901, z = −3.204, p = .001). Only the ON group showed a reliable, negative effect of argument status (β = −0.8732, z = −2.211, p = .027) because they were less likely to choose the theme image if the location was an argument than if it was an adjunct. The YN and PWA groups showed no reliable effect of argument status on theme image selection (YN: β = −0.483, z = −1.465, p < .001; PWA: β = −0.200, z = −0.724, p = .469), and no participant group showed an interaction between argument status and plausibility (YN: β = −0.057, z = −0.087, p = .931; ON: β = −0.171, z = −0.219, p = .826; PWA: β = −0.232, z = 0.42, p = .674) (see Supplemental Material S1 for full model results).

Participants in the YN and ON groups were less likely to choose the agent image in plausible conditions than they were in implausible conditions (YN: β = −2.946, z = −7.344, p < .001; ON: β = −2.549, z = −6.245, p < .001) but showed no reliable effect of argument status on agent image selection (YN: β = −0.360, z = −0.962, p = .336; ON: β = −0.421, z = −1.118, p = .263). PWA showed no reliable effects of argument status or plausibility on their odds of selecting

the agent image (β = −0.080, z = −0.247, p = .805; and β = −0.406, z = −1.247, p = .212, respectively). No group showed an interaction between argument status and plausibility on agent selection (YN: β = −0.567, z = −0.757, p = .449; ON: β = −0.958, z = −1.272, p = .203; PWA: β = 0.196, z = 0.303, p = .762) (see Supplemental Material S1 for full model results).

Fixations

Fixation analyses provided a measure of how argument status and event-related plausibility affected anticipatory processing of the location for each group (PWA, ON, and YN). For each analysis, the number of fixations initiated to the image in question was calculated and was divided by the number of fixations initiated to the other images.

First, it is important to address the possible concern that differences in gazes to the target image across the plausible and implausible conditions may have been driven by inherent properties of those images (because they were different across the two conditions). To determine that, a model examined all participants' gazes at the target image during the 500 ms after image presentation but before the onset of any linguistic stimuli. That model showed no effect of plausibility (z = 0.693, p = .488), suggesting that participants were similarly likely to gaze at the plausible and implausible target images in the absence of linguistic input.

Gaze-pattern analyses were determined by participants' fixations for the first 2,000 ms after the offset of the pronoun ("… so the detective is tucking/looking at **it** wisely in…"). On average, the audio recording ended about 1,087 ms after the pronoun. Beginning the analysis at the offset of the pronoun ensures that gazes during approximately the first half of that window occur before hearing the preposition. These gazes are, therefore, anticipatory and likely driven by the verb. Fixations of less than 50 ms were discarded. Analyses were performed using generalized linear mixed-effects logit models, on the log odds of initiating a fixation on the image in question (e.g., location, theme, agent). Fixed effects were structured like the response-accuracy analyses, and random effects were modeled using the maximal structure supported by the data, as noted.

The first models of gaze patterns examined the gross-fixation patterns exhibited by the three groups of participants for the entire 2,000-ms window of analysis. Gross-fixation analyses revealed a positive effect for plausibility on gazes at the location image for all three participant groups (YN: β = 0.834, z = 8.768, p < .001; ON: β = 1.001, z = 9.827, p < .001; PWA: β = 0.472, z = 2.330, p = .0198). Thus, all three groups were more likely to fixate on the location when it was a plausible-event location. Participants in the ON and YN groups were also more likely to initiate location gazes in argument as opposed to adjunct conditions (YN: β = 0.202, z = 2.261, p = .0238; ON: β = 0.198, z = 1.996, p = .0459), but participants in the PWA group were not (β = 0.245, z = 1.468, p = .142). None of the groups showed a reliable interaction of argument status and plausibility on initiation of location gazes (YN: β = 0.008, z = 0.045, p = .964; ON: β = 0.082, z = 0.417, p = .677; PWA: β = −0.156, z = −0.543, p = .587) (see Supplemental Material S2 for full model results).

Gazes at the nonlocation competitor image provide complementary measures of anticipatory processing of the location. Gazes at the theme image were negatively affected by plausibility in the YN and ON groups (YN: β = −0.408, z = −3.634, p < .001; ON: β = −0.351, z = −2.81, p = .005). Both YN and ON participants were less likely to gaze at the theme image when the location was plausible. Neither the YN nor the ON group showed an effect of argument status on gazes to the theme image (YN: β = −0.093, z = −0.863, p = .388; ON: β = −0.143, z = −1.104, p = .269). In the PWA group, theme gazes were negatively affected by argument status (β = −0.266, z = −2.061, p = .039), and there was a marginal, negative effect of plausibility (β = −0.265, z = −1.873, p = .061). None of the groups showed an interaction of argument status and plausibility on initiation of theme gazes (YN: β = 0.127, z = 0.605, p = .545; ON: β = −0.098, z = −0.404, p = .686; PWA: β = 0.051, z = 0.207, p = .836) (see Supplemental Material S2 for full model results).

Agent gazes were also negatively affected by plausibility in the YN and ON groups (YN: β = −0.372, z = −3.883, p = .001; ON: β = −0.477, z = −3.967, p < .001). Both YN and ON participants were less likely to gaze at the agent image when the location was plausible. In the YN group, participants were also less likely to initiate fixations to the agent in the argument condition than in the adjunct condition (β = −0.189, z = −1.964, p = .050), but participants in the ON group were not (β = −0.197, z = −1.638, p = .101). Participants with aphasia did not show any reliable effects of plausibility (β = −0.027, z = −0.16, p = .873) or argument status (β = −0.147, z = −0.881, p = .378) on the proportion of gazes initiated to the agent image. None of the groups showed an interaction of argument status and plausibility on initiation of agent gazes (YN: β = −0.064, z = −0.334, p = .739; ON: β = 0.038, z = 0.160, p = .873; PWA: β = 0.020, z = 0.069, p = .945) (see Supplemental Material S2 for full model results).

The second set of models of gaze patterns (bin-by-bin analyses) examined the unfolding pattern of gazes to the location and other images during the course of the 2,000-ms window. The 2,000-ms analysis window was divided into 100-ms bins, and separate models were fit for the proportion of gazes initiated to the target in each bin. The average number of fixations initiated within each bin remained roughly stable across the window of analysis, with a slight decline in the final five bins. Overall, each participant initiated an average of 11.3 fixations per bin, with an average of 11.5 in the first bin, 11.8 in the 10th bin, and 9.5 in the 20th bin. Given the small bin size, the data for each model could only support a minimal random-effects structure, including random intercepts for participants and items.

YN participants showed an immediate, positive effect of plausibility on the proportion of their gazes to the location (the target) after pronoun offset (z = 3.330, p < .001). They had higher log odds of gazing at the location when it

was plausible than when it was implausible. This effect continued for 500 ms, disappearing briefly in the 500- to 600-ms bin ($z = 1.593$, $p = .111$), and then reappearing for the remainder of the analysis period (see Figure 3). Argument status also positively affected the initiation of location gaze at several points in the analysis period, including 100–200 ms, 400–500 ms, 700–1,000 ms, and 1,400–1,500 ms after pronoun offset ($p < .05$) (see Supplemental Material S3 for full model results). No reliable interactions between argument status and plausibility were apparent at any point in the analysis for the YN participant group.

Similar to the YN group, ON participants demonstrated an immediate effect of plausibility for their gazes at the location ($z = 2.313$, $p = .021$), which continued throughout the rest of the analysis period, with brief interruptions at 200–300 ms ($z = 1.921$, $p = .055$) and 700–800 ms ($z = 1.761$, $p = .078$). The ON adults also showed intermittent positive effects of argument status on target fixation, at 200–300 ms, 800–900 ms, and 1,200–1,300 ms ($p < .05$) (see Figure 4 and Supplemental Material S3 for full model results). These effects of argument status for ON adults were present in fewer bins overall and generally appeared later and for shorter durations than they did for the YN participants. A single interaction of argument status and plausibility, such that the plausible condition generated a positive effect of argument status but implausible sentences displayed a negative effect of argument status, was present at 300–400 ms after pronoun offset ($z = 2.031$, $p = .042$).

Unlike the other two participant groups, PWA did not demonstrate an immediate, facilitative effect of plausibility on location fixations; this effect was delayed by 100 ms, compared with the other groups, appearing at 100–200 ms after the pronoun offset ($z = 1.996$, $p = .046$). That bin was, nonetheless, before preposition onset. Also unlike the other groups, the plausibility effect was inconsistent throughout the analysis period, reappearing only briefly at 500–600 ms and 1,300–1,500 ms ($p < .05$) (see Figure 5 and see Supplemental Material S3 for full model results). Consistent with the gross-fixation analysis, no reliable effects of argument status were observed in any of the bin-by-bin models. A late interaction of argument status and plausibility, such that argument status positively affected gazes at the location in the implausible condition, but negatively affected location gazes in the plausible condition, was observed at 1,800–1,900 ms after pronoun offset ($z = -2.042$, $p = .041$).

The potential contribution of several measures of language ability to the performance of PWA on this task was explored using Spearman's rank correlational analyses. Sentence-level performance was measured by participants' performance on noncanonical sentence types (passives, object *wh*- questions, object clefts, and object relative clauses) the NAVS Sentence Comprehension Test. This score provides a measure of grammatical comprehension ability. The correlation between this score and participants' tendency to gaze at the location during the window of analysis was not significant ($R = .011$, $p = .974$), suggesting that the degree of agrammatical comprehension impairment was not related to participants' anticipation of the location.

Conceptual–semantic knowledge regarding actions was measured by participants' performance on the KDT. This score also had no relationship with task performance ($R = .049$, $p = .879$). This suggests that the relative impairment of PWA in their access to conceptual–semantic representations was not related to their anticipatory processing of event locations in this study.

Numerically stronger relationships were found between verb comprehension and production and task performance. Participants' tendencies to gaze at the target images were weakly correlated with their performances on the NAVS Verb Comprehension Test (VCT; $R = .400$, $p = .223$) and the Verb Naming Test ($R = .343$, $p = .301$). Although these correlations are not reliable statistically, they suggest that

Figure 3. Fixations initiated by younger neurotypical adults to target image in 2,000 ms after pronoun offset. adj = adjunct; imp = implausible; plaus = plausible; arg = argument.

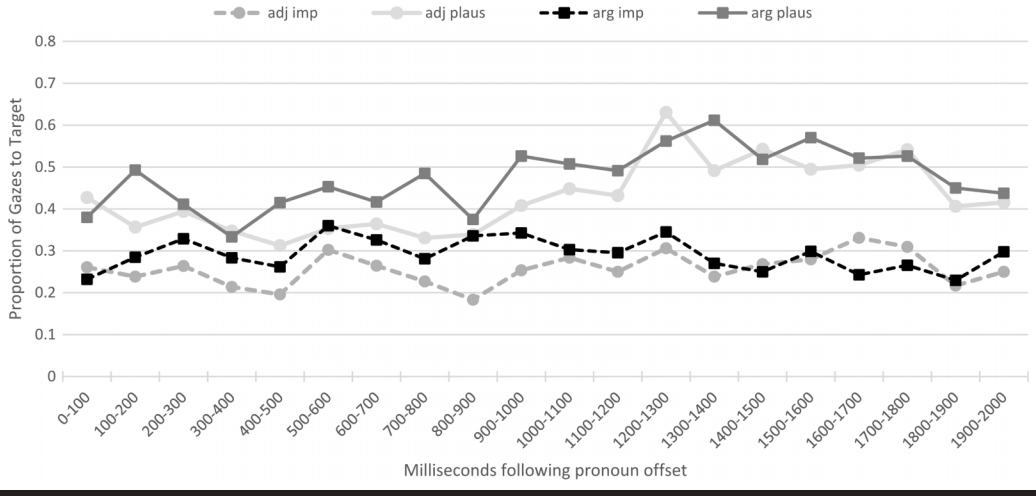
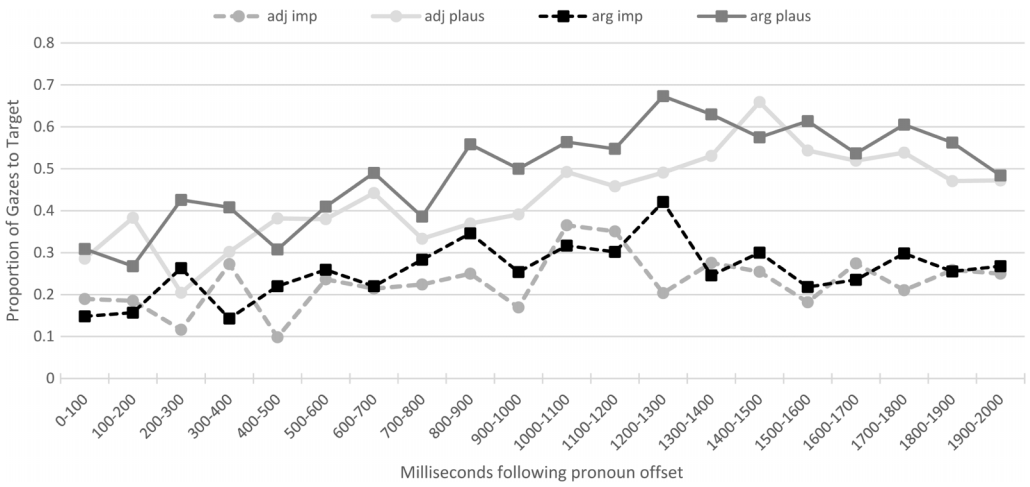


Figure 4. Fixations initiated by older neurotypical adults to target image in 2,000 ms after pronoun offset. adj = adjunct; imp = implausible; plaus = plausible; arg = argument.



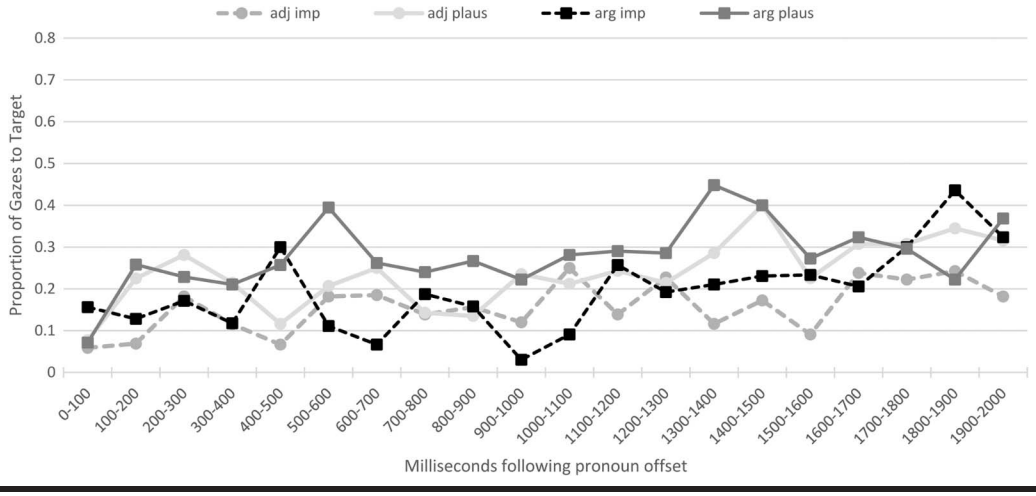
the ability to retrieve and comprehend verbs may have been comparatively more important to anticipation of locations than to either overall sentence comprehension ability or conceptual–semantic knowledge regarding actions.

Although participants' attention to the location did not strongly relate to measures of their language performance, their inhibition of distraction showed a stronger relationship to these measures. As previously discussed, participants with aphasia demonstrated a negative effect of argument status on their tendency to gaze at the theme, suggesting that they inhibited the distracting effect of the theme more in the argument than in the adjunct condition. This effect, represented by a difference score in proportion of gazes to the theme in the argument condition versus the adjunct condition, showed moderate, but unreliable, negative correlations with performance on the KDT ($R = -.511$, $p = .089$) and the VCT ($R = -.447$, $p = .168$). These results suggest that participants who successfully inhibited attention to a verb-related distractor in the argument condition tended to perform better on tasks requiring verb comprehension and retrieval of action-related semantic information. The score for the difference in theme gaze showed no relationship with the Verb Naming Test ($R = .005$, $p = .989$) or with comprehension of noncanonical sentences on the NAVS ($R = .107$, $p = .741$).

Discussion

The first goal of the current study was to investigate the ways in which argument status and event-related

Figure 5. Fixations initiated by people with aphasia to target image in 2,000 ms after pronoun offset. adj = adjunct; imp = implausible; plaus = plausible; arg = argument.



plausibility affect anticipation of argument and adjunct locations among PWA and ON adults. The second goal was to determine whether PWA exhibit less anticipatory behavior than age-matched controls do (cf. Mack et al., 2013), either for arguments (facilitated by argument–structure representations) or for adjuncts (facilitated by event-related world knowledge). ON adults showed effects of both plausibility and argumenthood on their patterns of both image selection and eye gaze. These participants were more likely to click on the target image when the location was plausible and when it was an argument. The effects of plausibility on eye movements were early and sustained: ON adults were more likely to gaze at the location when it was plausible than when it was implausible, from pronoun offset until the end of the trial. This advantage appeared in both the gross-fixation analysis (looking at overall likelihood of fixating on the location across the 2,000-ms analysis window) as well as in several bins in the bin-by-bin analyses. Effects of argumenthood also appeared in gaze patterns, both in the gross-fixation analysis and the bin-by-bin analyses. The argument advantage appeared later than the plausibility effect in the bin-by-bin analyses.

Similar to the ON adults, PWA showed clear effects of plausibility on their processing of the locations in both image selection patterns and fixation analyses (although this advantage for likely locations appeared 100 ms later than it did for ONs in the bin-by-bin analyses). However, they did not show an advantage for predicting or selecting argument locations in either the fixation analyses or the image selection analyses. These contrasting patterns suggest that it is event-related world knowledge that drives predictive processing of verbal arguments among PWA. This is consistent with previous findings suggesting that PWA strongly rely on event-related world knowledge during language comprehension (e.g., Caramazza & Zurif, 1976; Gibson, Sandberg, Fedorenko, Bergen, & Kiran, 2015) and extends this reliance on world knowledge to predictive processing among PWA. These findings are somewhat surprising if verb–argument information strongly drives comprehension among PWA (DeDe, 2013b; Gahl, 2002). At minimum, the current findings suggest that predictive processing of verbal arguments among PWA is not driven by verb–argument information, even if that knowledge is intact for some or all PWA (DeDe, 2013a, 2013b; Gahl, 2002; Gahl et al., 2003; Shapiro et al., 1993; Shapiro & Levine, 1990).

This conclusion may shed light on the Mack et al. (2013) finding that PWA successfully identify, but may not anticipate, upcoming verbal arguments. The fact that the PWA in their study were slower to process upcoming theme arguments than were the older controls may derive from the weaker influence of verb–argument information on the predictive processing of PWA. As noted at the beginning of this article, anticipation of a likely upcoming theme is driven by both verb–argument structure information and event-related knowledge (Altmann & Kamide, 1999; Kamide, Altmann, & Haywood, 2003). If verb-related knowledge and event-related knowledge both independently contribute to the anticipation of upcoming event participants, then the decrease for PWA in their use of verb–argument information in anticipation may have led to reduced facilitation for theme arguments compared with ON adults. Another possibility is that the design of the Mack et al. study may have implicitly encouraged participants to rely more on verb-specific properties and less on event-related world knowledge when engaged in their task. This could explain reduced prediction for the PWA, given that the current study showed that event-related world knowledge is a particularly strong contributor to prediction in PWA. In contrast to the semantically contentful, definite descriptions and detailed event descriptions in the current study, the linguistic stimuli in the Mack et al. (2013) study always contained a proper name as the subject of a single verb, with no other descriptive information regarding the event. These relatively impoverished contexts may have limited the activation or influence of world knowledge regarding likely event participants in the Mack et al. study.

A third question addressed by the current experiment was whether ON adults exhibit less anticipatory processing of locations than YN adults do. Mack et al. reported delayed or reduced verbal-argument prediction for their older controls but did not directly compare the performance of ON and YN adults in their study, so the current study is the first, to our knowledge, to address this issue directly. Across analyses, in the current experiment, older and younger adults showed similar patterns of effects of both event-related plausibility and argument status. This similarity held even for the time courses for those effects in the bin-by-bin analyses. This finding stands in contrast to some previous findings suggesting that older participants are less likely to engage in prediction during comprehension than younger participants are (DeLong et al., 2012; Federmeier & Kutas, 2005; Wlotko, Federmeier, & Kutas, 2012; Wlotko et al., 2010). One possible reason for this disparity could be that the contexts of prediction in the current study versus those in the previous studies may have different properties. The current study tested the prediction of upcoming verbal arguments, which are licensed by a very specific and limited set of elements in the context of the preceding sentence, are in a consistent and local, structural relationship with one another. In contrast, the studies by DeLong et al. and Federmeier et al. used highly constraining sentences as stimuli and tested the facilitation of target words. In this case, predictions for the target words were typically licensed by multiple cues spread throughout the context of the preceding sentence. Older adults, many of whom have reduced processing speed (Salthouse, 1996) or working-memory capacity (Salthouse & Babcock, 1991), may have more difficulty than younger adults do in combining those cues rapidly to generate predictions. Consistent with that possibility, younger adults also predict less when a faster presentation rate reduces the time available to generate predictions (Wlotko & Federmeier, 2015). However, recent work has suggested that the type of contextual constraint is also important for whether ON adults exhibit reduced prediction compared with YN adults: The two groups exhibit much smaller differences for

strong-constraint contexts (Wlotko et al., 2012). Perhaps the prediction of an upcoming verbal argument is more akin to predictions licensed by these strong-constraint contexts. Further work is needed to disentangle these possibilities.

The fourth research question, whether PWA with different language-impairment profiles exhibit different patterns of predictive-processing performance, was addressed by the correlational analyses examining the relationship between location gazes and different, specific language impairment among the PWA. These analyses did not find any strong relationships between degree of sentence comprehension impairment (agrammatical comprehension), conceptual–semantic impairment, or verb-processing impairment, on the one hand, and prediction of an upcoming location, on the other. This finding suggests that the differences between the current study's results and those of Mack et al. is likely not due to the Mack et al. (2013) study testing only PWA with agrammatical language-impairment profiles and the current study testing PWA with a wider array of language-impairment profiles. Furthermore, the numerical relationship between verb-processing performance and degree of prediction of the location is intriguing and is worthy of further study with larger samples of PWA. The finding that verb processing and action event-related semantic knowledge by PWA were related to inhibitory advantages in the argument condition for specific types of distractors (themes) also warrants further study.

The current results also shed light on the nature of language-comprehension differences between PWA and neurotypical adults. Comprehension failure was much more likely for PWA than it was for the YN or ON adults, as evidenced by the greater likelihood of PWA choosing a nontarget photo (see Figure 2). They also exhibited abnormal online processing, in that they showed no effects of argument status on their tendency to gaze at the location image, in contrast to ON adults. This is distinct from other findings showing that PWA may fail in their ultimate interpretation of sentences but, nonetheless, show typical online processing (Caplan, Waters, DeDe, Michaud, & Reddy, 2007; Dickey, Choy, & Thompson, 2007; Dickey & Thompson, 2009). These findings, therefore, suggest that abnormal sentence–final comprehension may be associated with, or stem from, abnormal online processing, in this case, predictive processing.

Furthermore, when PWA did choose a nontarget image, they were much more likely to choose the theme than the agent. There are multiple reasons why the theme might have been the preferred image when comprehension failed. Theme arguments appear to be inherently salient and show a strong advantage in anaphora resolution tasks (Stevenson, Crawley, & Kleinman, 1994), and the theme immediately precedes the preposition, which may confer a recency advantage. Regardless of which of these explanations of the theme preference for PWA is ultimately correct, this pattern is another example of PWA choosing a salient but grammatically impermissible interpretation when sentence comprehension fails (Dickey & Thompson, 2009; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011). Because participants tended to inhibit attention to this tempting distractor more in the argument condition than they did in the adjunct condition and because that tendency was numerically related to both verb-comprehension performance and conceptual–semantic knowledge regarding actions, individuals with aphasia may use verb-related information in some capacity during processing, but doing so does not aid them in identifying the desired target.

Study Limitations

The current study was limited in several ways. First, the mean age of the ON control group was nearly 1 *SD* younger than the PWA group. That age difference between PWA and neurotypical controls could have contributed to their differences in performance, although the age difference between the ON and YN adults had almost no effect on performance. Future research might follow a pairwise-matching strategy to more closely control for age-related differences. Second, no data were collected regarding the working-memory or processing-speed performance of the ON adults (Salthouse, 1996). Such data would be useful in helping to determine whether those abilities might undergird age-related differences in cognition, including predictive processing (even though there were not strong age-related differences in the current study). Third, the stimuli consisted of relatively lengthy and complex sentences. These stimuli may have created a cognitive load, especially a memory load, significant enough to divert processing resources away from prediction generation. That high load may have reduced predictive processing, particularly among PWA. Future research on predictive processing in aphasia might use shorter sentences that do not impose such a load but that still provide enough context to support the use of event-related world knowledge (e.g., Dickey, Warren, Milburn, Hayes, & Lei, 2015). In addition, the verbs in the argument and adjunct conditions were not carefully matched for length, frequency, or syntactic characteristics, meaning that differences between the two conditions may have been at least partially driven by differences other than the argument structure of the verbs themselves. Therefore, the bin-by-bin analyses used to examine the time-course information involved multiple comparisons across multiple 100-ms bins. These comparisons may have inflated the risk of Type I errors, as each set of 20 comparisons might be expected to have one spurious result, given an α level of .05. However, even without the detailed time-course information that those analyses provided, the patterns of the relative impact of event-related plausibility information and verb–argument information on the predictive processing of locations by PWA and ON adults are clear.

Conclusions

The current study paints a picture of how event-related world knowledge and argument status contribute to anticipatory behavior in aphasia and in healthy aging. All

participant groups—YN adults, ON adults, and PWA—showed increased facilitation of targets that were supported by event-related world knowledge (more plausible) in measures of both online visual attention and ultimate interpretation. This effect of plausibility was greater for the neurotypical participants than it was for the PWA but was notably very similar for the ON and YN participants. In contrast, the contribution of argument status to prediction did differ across age groups and language abilities. YN participants showed larger effects of argument status than did ON participants, and PWA showed almost no effect of argument status. The finding that PWA rely more heavily on plausibility information than on argument status to inform online visual attention and offline conscious anticipation underlines the importance of event-related world knowledge in facilitating verb-related performance among PWA (Edmonds et al., 2009). It also suggests that clinicians might leverage event-related knowledge to facilitate understanding in contexts where argument structure might normally cue comprehension.

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