

**Lexically Specific Verb Information:  
Understanding Sentence Processing in the Aphasic Population**

by

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Transitivity is the frequency with which verbs are used with a direct object (transitively) or without one (intransitively), and it has been shown that unimpaired adults use transitivity information as they read (Clifton, Connie & Frazier 1984; Trueswell, Tanenhaus & Kello, 1993; Garnsey, 1997; Staub, 2007) or listen to sentences (Arai & Keller, 2012) to predict upcoming words. The current study tested persons with aphasia and age-matched, unimpaired adults as they read sentences containing verbs which varied in their transitivity. Gahl (2000) reported that both people with aphasia and unimpaired controls show sensitivity to verb frequency information under the Lexical Bias Hypothesis. Results from the unimpaired group indicated no use of transitivity in their initial parsing of sentences. Results from people with aphasia showed a significant use of transitivity during sentence processing. The data suggests that in the wake of language impairment, an individual may rely on transitivity to glean information from a sentence.

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## 1.0 INTRODUCTION

Aphasia is a condition in which the comprehension and formulation of language is impaired. Aphasia is most often caused by a cerebrovascular accident (or stroke), leaving language centers of the brain damaged, while other cognitive abilities are left relatively unharmed. Symptoms of aphasia may vary depending upon the severity and site of lesion. A common problem among individuals with aphasia is impairment in verb processing (Davis, 2007) which is detrimental to sentence comprehension. Verb-related information is particularly important for sentence comprehension. Throughout the past three decades there has been much examination of how unimpaired adults identify and integrate linguistic cues to comprehend at the sentence level. In particular, research has focused on the role of the main verb within a sentence. Results of a landmark study exhibited the importance verbs hold in that they can help a listener predict what will subsequently arise in a given sentence (Altmann & Kamide, 1999). Central to our understanding of sentence processing is deciphering just how verbs are able to relay information about words that have yet to be encountered.

There is debate within the scientific community about what this process may be. Normal listeners are able to rapidly incorporate incoming words into a sentence structure with very high precision (Garnsey, 1997). This is possible despite the fact that we create novel utterances quite frequently. There are moments, however, when a sentence may shift in a way that is unexpected to a listener and create a garden-path phenomenon. For example, whether a verb is used

transitively, occurring with a direct object, or intransitively, occurring without a direct object, can ultimately change the way a sentence continues:

(1) *Because the boy will eat the cake...*

a. *...it may be missing a piece.*

b. *...may be missing a piece*

Because the word “eat” may or may not occur with a direct object, there is momentary ambiguity following the verb. This ambiguity can cause problems for a listener or reader. If the comprehender perceives “eat” in version (1b) to be used transitively, he or she will be ‘garden-pathed’ when he encounters “*may be missing ...*”, requiring revision to his or her initial understanding of the sentence.

The possibility of multiple continuations from a single verb arises quite often in sentences, yet listeners do not get repeatedly garden-pathed in everyday discourse. This suggests that there is a process involved in disambiguating the temporary uncertainty in a sentence. Over the years, there has been much debate about what this process is and which mechanisms are involved.

One theory called the Lexical Guidance Hypothesis suggests that there is pre-stored lexically specific information within a verb that dictates the possible syntactic frames that verb can occur in (Clifton, Connie & Frazier, 1984; Trueswell, Tanenhaus & Kello, 1993; Garnsey, 1997). This, in turn, should allow readers and listeners to rapidly predict and integrate possible continuations of a sentence based on the verb they encounter, and the bias towards which syntactic frame it holds.

Another theory suggests that verbs do not hold this strong predictive quality but instead, for moments when we are indeed garden-pathed, we have an integrated system that quickly and

efficiently corrects our misjudgment of a sentence (Ferreira & Henderson, 1990; Pickering, 2000). This implies verb bias is not initially used in guiding sentence processing.

This study is an attempt to add to the discussion of the role that lexical information plays in sentence processing both in impaired and unimpaired populations. This study will focus on how persons with aphasia and age-matched, unimpaired adults read and assess sentences that involve a specific component of verb information, transitivity. Many verbs can be used transitively or intransitively, and research has shown that most verbs in English have a tendency to occur as one versus the other (Connine, et al 1984), a phenomenon known as a transitivity bias. Verb transitivity biases will be compared with reading times and sentence-final judgment data to shed light on how persons with aphasia and unimpaired adults utilize transitivity bias information in sentence processing.

### **1.1.1 The Use of Verb-frame Information in Sentence Comprehension**

The Lexical Guidance Hypothesis as it relates to transitivity can be broken down further. If it is true that individuals quickly identify and integrate lexical information such as subcategorization frame (the appropriate syntactic argument that goes with a given verb), then what does a parser do with a verb that can take on multiple subcategorization frames? For instance, a verb such as *eat* can often be found transitively (1a) or intransitively (1b). A verb such as *herd* is heavily biased towards being used transitively (“the dog will *herd* the sheep”), but does have the grammatical ability to appear without a direct object (“the dog will *herd* all day long”). Conversely, a verb such as *arrive* is strictly intransitive and can never have a direct object attached to it. The question now becomes: does a parser commit to a continuation based on whether or not a continuation is grammatically permissible (verb-frame possibility) or based on

the bias of the verb to be used in a given form (verb-frame preference)? The following studies are evidence to support the rapid use of verb-frame preference and verb-frame possibility in sentence comprehension, respectively.

## 1.2 VERB-FRAME PREFERENCE

### 1.2.1 Clifton et al. (1984)

Clifton et al. (1984) provided evidence the claim that subcategorization information is used in the early stages of sentence processing, and is independent of semantic or pragmatic additions to the information provided by a verb. Clifton et al. were able to test their hypothesis through the use of optionally transitive verbs like *read* or *sang*. Participants read a sentence on a screen with each word appearing on the screen one at a time. A lexical decision task of judging whether or not a series of letters was a word or a non-word was administered immediately following the first word after the verb. In a transitive sentence form, the first word after the verb was typically a determiner or a possessive pronoun (such as *read the*, *sang the*), while in an intransitive sentence form a preposition usually followed (such as *read to* or *sang to*). Given that the lexical decision task was administered after revealing the syntactic frame the verb was used in, transitive or intransitive, but before any other information (semantic or pragmatic) about the following phrase was displayed, Clifton et al. postulated that reaction times on the lexical decision task were indicative of a participant's 'ease of processing' of the structure that he or she had just read. In other words, if a participant encountered a transitively biased word that was being used

transitively, he or she should have an easier time processing the sentence fragment and therefore a speedier reaction time. Conversely, if a participant reads a sentence in which a transitively biased verb is being used intransitively (or vice versa), processing may take longer and consequently delay reaction times. Clifton et al. found their hypothesis to be confirmed. Reaction times on the lexical decision task were faster when verb preference and sentence form matched than when they mismatched. This, in turn, supported the view that verb frequency information is available to a processor at the initial stages of sentence processing.

### **1.2.2 Trueswell et al. (1993)**

Trueswell et al. (1993) also supported the use of verb-subcategorization information in the early stages of processing. Trueswell and colleagues took advantage of the fact that English pronouns differ in morphological form depending on their case. For example, *him* is a noun-phrase complement when it follows a verb (the old man advised *him*), whereas *he* is the subject of a sentence complement (the old man hinted *he* [was tired]). Using this information, Trueswell and colleagues designed sentences which included verbs that are biased towards having either a noun-phrase completion or a sentential complement completion. Participants listened to the beginning of a sentence that consisted of a subject and a verb (e.g. *the old man advised*). Upon completion of the sentence fragment, the target word (either *him* or *he*) was presented on a screen. Subjects were told to name the word into a microphone as quickly as possible and were then asked to press a button, indicating if said target word was a “good continuation?” Trueswell and colleagues performed norming studies on the chosen verbs, and each verb strongly preferred one continuation over the other, noun-phrase complement or sentence complement. Building upon this, Trueswell and colleagues predicted that if a target word was shown that contradicted

the expected continuation, the parser would have a longer latency before naming the word. Furthermore, Trueswell et al. expected participants to judge *he* as a bad continuation of verbs that are biased towards noun-phrase complements, and judge *him* as a bad continuation of verbs that are biased towards a sentential complement. Trueswell et al found this hypothesis to be confirmed. Target words which contradicted the bias of the verb that preceded them had consistently higher response times to name the target word and were judged as having a “not good continuation” on a very high percentage of trials. Trueswell and colleagues attributed these phenomena to the parser’s ability to quickly access subcategorization preference information upon hearing a verb.

### **1.2.3 Arai & Keller (2012)**

Arai and Keller (2012) add to the discussion of verb frequency in the second of their two experiments which examined frequency information in prediction. Specifically, Arai and Keller examined whether the frequency with which a verb is used in the past participle allows sentence processors to create structural predictions.

Arai and Keller utilized verbs that were either biased towards infrequently being used as a past participle (Low PastP: *watch*) or towards frequently being used as a past participle (High PastP: *record*). Participants wore an eye-tracker and viewed a visual scene with three Clip Art images. The sentence stimuli were assembled as follows:

(2)

- a. Reduced relative clause/ Low PastP: *The videotape watched by the student was found under the chair.*



- b. Unreduced relative clause: *The videotape that was watched by the student was found under the chair.*
- c. Reduced relative clause/ High PastP: *The song recorded by the nun was about the flower.*
- d. Unreduced relative clause: *The song that was recorded by the nun was about the flower.*

Arai and Keller were interested in the eye-movements of participants when the verb was heard. 2b and 2d were not expected to be difficult to interpret, as the complementizer *that* disambiguated the sentences. However, 2a should generate a “processing deadlock.” A deadlock would occur for multiple reasons. First, at the position of the verb, the processor has only heard ‘*the videotape watched*’ which is a semantically implausible subject-verb combination. Second, the visual scene (which is a made up of a chair, videotape, and student) would not facilitate processing at that moment because there is no direct object in the scene that would fit the highly implausible pairing of ‘*the videotape watched.*’ Lastly, and most importantly, *watch* has a low past participle frequency and would not provide sufficient information for listeners to infer that ‘*the videotape*’ is the theme of ‘*watched*’ and then predict an appropriate agent.

In contrast, it was predicted that participants would not struggle with sentences such as 2c. The high frequency with which *recorded* is used in the past participle should disambiguate any uncertainty in the sentence. In other words, participants were not predicted to attach an agent role to ‘*the song*’ due to the common usage of the verb *record* as a past participle. It was expected that swift eye-movements to the nun in the visual scene (which consisted of a nun, sheet music, and a rose) would occur, as the nun is the only plausible agent.

Arai and Keller's predictions were borne out. Participants struggled to find an appropriate direct object during the reduced, Low PastP verb sentences. Eye-patterns between the reduced and unreduced Low PastP sentences varied greatly. In contrast, there were no differences found when a High PastP verb was heard in the reduced or unreduced relative clause conditions. These results support the rapid use of verb-frame frequency information in making predictions of upcoming information.

#### **1.2.4 Garnsey et al. (1997)**

Garnsey et al (1997) examined lexical preference in sentence processing with an emphasis on plausibility. Garnsey et al. discuss that there may be an intuition among speakers that when ambiguity arises, the semantic factor of plausibility may hold more weight in helping people resolve the ambiguity. Garnsey et al speak to the fact that, on some level, we actively process the meaning of sentences, making decisions about their plausibility. The same "clear intuitions" cannot be made with respect to verb biases which are processed on a more subconscious level. However, other studies, such as Tanenhaus, Dell, & Carlson (1987) suggest that verb bias may outweigh plausibility in providing information which disambiguates a sentence. Due to the fact that verb bias is encoded within a single word (the verb itself), retrieval of other information along with the verb could occur more quickly as it is all packed into a single unit. Plausibility, on the other hand, requires the combination of multiple words.

To test the strength of plausibility as it relates to lexical information, Garnsey et al conducted an eye-tracking study and a self-paced reading study. Sentences involved direct object bias verbs (DO-bias), sentential complement bias verbs (SC-bias), and verbs which were unbiased towards DO or SC complements (EQ-bias). Garnsey et al created sentences such that

the noun-phrase following the verb was actually a subject of an embedded clause. Furthermore, if a parser tried to make a DO attachment to the noun-phrase, half of the noun-phrases would be implausible direct objects. Some sentences were also ambiguous and did not contain the disambiguating complementizer “that.” For example:

(3) DO-bias

- a. Plausible: The talented photographer *accepted* (that) the *money* could not be spent yet.
- b. Implausible: The talented photographer *accepted* (that) the *fire* could not have been prevented.

(4) SC-bias

- a. Plausible: The ticket agent *admitted* (that) the *mistake* had been careless and stupid.
- b. Implausible: The ticket agent *admitted* (that) the *airplane* had been late taking off.

(5) EQ-bias

- a. Plausible: The sales clerk *acknowledged* (that) the *error* should have been detected earlier.
- b. Implausible: The sales clerk *acknowledged* (that) the *shirt* should have been marked down.

Garnsey et al predicted three distinct patterns, one for each verb type. For DO-bias cases, Garnsey predicted that readers will assume the noun phrase is a direct object, guided by the verb's preference, and experience difficulty in the implausible condition (3b). Garnsey predicted that even though the resulting fragment is implausible (*the talented photographer accepted the fire...*), the readers will still attach *the fire* as the object of *accepted*. This, in turn, suggests that the verb's preference will be the greatest factor in predicting reading times.

In SC-bias cases, Garnsey et al predict that the bias of the verb to take on sentential complements (and not direct objects) will dissuade the reader from attaching *the mistake/airplane* to the verb. Reading times on the noun and disambiguating verb should not be slower.

Finally, for EQ-bias cases, plausibility should play a major role in that a noun-phrase that is implausible as a direct object should be interpreted not as a direct object but as the subject of a sentential complement. This should remove any difficulty at the disambiguating verb, but a noun-phrase that is plausible should cause difficulty. This is due to the lack of strong verb preference in this case. Because *acknowledged the error* is plausible, readers should incorrectly create a direct object analysis and then slow down at the disambiguating verb *should*. On the other hand, *acknowledged the shirt* is implausible, and should deter the reader from assuming a direct object analysis.

The results of Experiments 1 and 2 supported these predictions. When individuals read sentences that contained SC-bias verbs there was no difficulty at the disambiguating region, following the verb. On the other hand, sentences containing DO-bias verbs resulted in difficulty at the disambiguating region (first-pass reading time on ambiguous versus unambiguous sentences= 365 vs 332 msec, Experiment 2). However, neither of these two patterns interacted

significantly with plausibility. Conversely, in sentences with EQ-bias verbs, plausibility had a stronger effect. When the noun-phrase following an EQ-bias verb was plausible, readers exhibited difficulty at the disambiguating verb, and when the noun-phrase was implausible there was no difficulty.

A crucial result which supports an initial use of verb bias information comes from the lack of an effect of plausibility on the ambiguous noun-phrase in sentences with SC-bias verbs. In sentences with DO-bias verbs, first-pass times on an implausible noun-phrase in an ambiguous sentence were slower than reading times on that same noun-phrase in the unambiguous sentence and on plausible noun-phrases in ambiguous sentences. This effect was nowhere to be found in sentences with SC-bias verbs, which suggests that the direct object interpretation was not ever considered. This result shows the influence of verb-preference on initial sentence processing.

### **1.3 VERB-FRAME POSSIBILITY**

#### **1.3.1 Arai & Keller (2012)**

In addition to these effects of verb-frame preference on rapid sentence processing, there is also evidence for rapid effects of verb-frame possibility. Arai and Keller (2012) had findings that support a parser's ability to predict upcoming information based on verb-frame possibility. In their first experiment, participants were connected to an eye-tracker and viewed a visual scene with three images. Two of these images were animate (a nun and an artist) and one was

inanimate (a tea kettle). While viewing these images, participants heard one of three types of sentences:

(6)

- a. *Surprisingly, the nun punished the artist.*
- b. *Surprisingly, the nun disagreed with the artist.*
- c. *Surprisingly, the nun disagreed and the artist threw the kettle.*

The verb *punish* in (6a) is a transitive verb, while *disagree* in sentences (6b) and (6c) is an intransitive verb. Arai and Keller examined if verb-specific subcategorization information can be readily assessed upon hearing the verb and therefore drive eye-movements towards a certain entity. They predicted that for transitive verbs such as *punish*, eye-movements would immediately fixate on the first plausible object, *the artist*. Arai and Keller also predicted that eye-movements would fixate on this same object upon hearing *disagreed with* because this too is a plausible complement for the verb and preposition together. However, the same fixations would not occur after the phrase *disagree and*, because *disagree* does not take an object (since it is intransitive) and there are many different continuations possible with this conjunction. However, if predictions are not made on the basis of verb-specific subcategorization information all together, there should be no difference in anticipatory eye-movements between sentences (6a) and (6b). Important to note is that only the target object, *the artist*, is a plausible direct object for the transitive verb (*the nun punished the kettle* would not be plausible).

The results aligned with Arai and Keller's predictions. Anticipatory eye-movements to *the artist* were more likely upon encountering transitive versus intransitive verbs. Results showed a significant difference between the transitive, *punish*, condition, and both intransitive,

*disagree*, conditions (Transitive vs. Intransitive+PREP, coefficient = -0.57,  $z = 2.81$ ,  $p < .01$ ; Transitive vs. Intransitive+CONJ, coefficient = -0.70,  $z = 3.43$ ,  $p < .001$ ). There were no significant differences between the two intransitive conditions (coefficient = -0.15,  $z = 0.72$ ,  $p = 0.47$ ). Furthermore, participants made predictions following the intransitive verb *disagree* after hearing the preposition *with* but not after the conjunction *and*. Participants gazed at an upcoming word immediately following a transitive verb, but not an intransitive verb. These findings support the rapid use of subcategorization information by the parser.

## 1.4 LEXICAL FILTERING APPROACHES

### 1.4.1 Ferreira & Henderson (1990)

On the other end of the spectrum, Ferreira and Henderson (1990) conducted eyetracking studies that support Frazier and Rayner's (1982) garden path model of sentence comprehension. This model claims that verb information (specifically the subcategorization preferences of verbs) will not influence initial parsing of a sentence. Instead, a "minimal attachment principle" takes effect. The minimal attachment principle states that "words are assigned the syntactically simplest analysis, and only if the analysis turns out to be incorrect does the parser compute a second, more complex structure," (Ferreira & Henderson 1990). In this model, verb-frame preference will influence this second stage of processing. As part of their study, Ferreira and Henderson asked participants to read sentences on a screen. The sentences were designed in such a way that the noun phrase following the main verb was the subject of an embedded clause (as opposed to a direct object). Ferreira and Henderson proposed that, based on the minimal attachment principle,

participants in their study should process the noun phrase after the main verb as a direct object (as opposed to the subject of an embedded clause) because that is the simpler syntactic structure.

(7)

*a. He wished / Pam / needed / a ride / with him*

*b. He wished that / Pam / needed / a ride / with him*

*c. He forgot / Pam / needed / a ride / with him*

*d. He forgot that / Pam / needed / a ride / with him*

For experimental purposes (and unbeknownst to the participants) each sentence was broken up into five regions. The first region contained the subject, verb, and for half of the sentences, the complementizer “that.” The second region was labeled the “ambiguous region” and contained the noun phrase. This region was ambiguous because at the moment the parser reads the noun phrase, it is not entirely clear as to whether the noun phrase takes on the role of direct object or the role of subject of an embedded clause. The third region was the “disambiguation region” and contained the embedded verb. This region of the sentence was termed the “disambiguation region” because at this point in the sentence, participants should have an understanding that the previous noun phrase they encountered was in fact the subject of an embedded clause. The fourth and fifth regions were the post-disambiguating region and the final region, respectively. Ferreira and Henderson examined participant’s eye movements and suggested that based on the garden-path model, the ambiguous region should be minimally attached to the verb regardless of the verb’s preference to take on the noun phrase as a direct object. Using verbs that were biased towards accepting a direct object (transitive) or rejecting a



direct object (intransitive) allowed Ferreira and Henderson to test whether or not participants were making minimal attachments of the noun phrase regardless of their bias.

The results showed that participants were as likely to make a direct object analysis of the noun phrase when the verb was biased towards not accepting a direct object as they were to make the analysis when the verb preferred a direct object. This was shown by the lack of an effect of first fixation durations on the noun-phrase. However, there was an effect on total reading times. This suggests that there may not have been an initial use of verb bias, but that there was reanalysis after participants encountered the disambiguating region. These results undermine the Lexical Guidance Hypothesis.

However, the strengths of the biases used in this study were later called in to question by Trueswell et al (1993). There was also criticism of the choice of ambiguous noun phrases which were often implausible as direct objects (*Ed disputed/asserted eggs*). As described above, Garnsey, et al (1997) found that the plausibility of the noun phrase and the verb bias can work together, which may have affected Ferreira & Henderson's findings.

#### **1.4.2 Pickering et al. (2000)**

Pickering et al. (2000) also found evidence against a frequency-based account for sentence processing. During this study, participants read sentences off a screen and were asked simple comprehension questions after the presentation of the sentence. Pickering et al chose verbs that were found to prefer a sentential complement clause during normative testing, such as *realize* in sentences (8a) and (8b):

(8)

- a. *The young athlete realized her potential one day might make her a world-class sprinter.*
- b. *The young athlete realized her exercises one day might make her a world-class sprinter.*

Following the verb, Pickering employed objects that varied in their plausibility depending on whether a participant used a sentential-complement analysis or an object analysis. In an object analysis, (8a) (*The young athlete realized her potential*) is plausible, but sentence (8b) (*The young athlete realized her exercises*) is implausible. However, due to the fact that *realize* is biased towards a sentential—rather than an object—analysis, the Lexical Guidance Hypothesis theorizes that an individual should not be deterred when encountering *exercises*, as he or she will know this to be the subject of an embedded clause. Pickering et al did not find this to be the case. Participants routinely constructed an object analysis on sentences such as (8a) and (8b), reading the noun phrase more slowly in (8b), despite the bias towards a sentential complement. This finding greatly challenges the Lexical Guidance Hypothesis.

## **1.5 PROBABILISTIC VERB BIAS VERSUS CATEGORICAL VERB PROPERTIES**

Staub (2007) provides results that support a view in which a verb's subcategorization frame is not ignored and can rapidly affect processing. What is intriguing about Staub's study is the contrasting way in which intransitive verbs act within his experiments. Through the use of transitive, unergative, and unaccusative verbs, Staub uncovers further intricacy in the inherent behavior of verbs.

In Experiment 1, Staub tackled what had previously been inconclusive results as to whether or not a parser attaches a direct object to an intransitive verb. Mitchell (1987) obtained results that suggested that readers had attached a direct object to intransitive verbs such as *sneeze*. These results were later challenged due to the methodological design of the experiment, which may have unintentionally endorsed an uncommon analysis of these verbs. In Mitchell's self-paced reading design, participants first saw the fragment, *After the child had sneezed the doctor*, followed by, *prescribed a course of injections*. It is possible that participants used the segmentation as a clue to underlying syntax and were persuaded that the noun phrase went with the verb, even though the verb was intransitive.

In response to this, Adams, Clifton, and Mitchell (1998) recreated the study using eye-tracking as opposed to self-paced reading. Adams et al. did not find increased reading times on post-verbal phrases after intransitive verbs as Mitchell did. These results supported the use of subcategorization information in the initial processing of sentences. However, these results later differed from those of van Gompel and Pickering (2001) who indeed found reading disruptions on post-verbal phrases following intransitive verbs.

In an effort to fully and carefully resolve this unsettled debate, Staub separated the intransitive verbs into two categories: verbs that categorically prohibit a direct object, unaccusatives, and verbs that will allow a direct object in certain structures, unergatives. In Experiment 1, participants were connected to an eye-tracker and read sentences with unaccusative (*arrived*), unergative (*struggled*), and transitive (*scratched*) verbs. For example:

- (9) *When the dog / arrived-struggled-scratched / the vet / and his / new assistant / took  
off the muzzle*

Staub labeled *the vet* as ambiguous region 1, *and his* ambiguous region 2, *new assistant* ambiguous region 3, and *took off the muzzle* as final region. Staub hypothesized that for transitive verbs, like *scratched*, participants would have slower reading times on the final region. This final region contains the disambiguating verb. What was unclear was how the reading times following unergative and unaccusative verbs would play out.

Ultimately, Staub found significant differences between transitive and unergative/unaccusative verbs in ambiguous region 1. There were longer first pass and go-past times for the unergative and unaccusative verbs. In addition, there were longer go-past times at the final region for transitive verbs, as expected. This meant that there was clear disruption on the post-verbal noun-phrase following the intransitive verbs, a result that was not found in Adams et al (1998). Interestingly, reading times of sentences utilizing unergative and unaccusative verbs did not significantly differ from one another. The unergative verbs were interpreted just like verbs that categorically prohibit direct object continuations.

In Experiment 2, Staub examined why there seemed to be processing difficulty on post-verbal phrases following intransitive verbs found in Experiment 1 (as well as in van Gompel and Pickering, 2001). Van Gompel and Pickering speculated that the inflated reading times may have been due to a “processing cost” linked to beginning a new clause. Staub also postulated that there may be another processing cost due to the absence of a comma. It is possible that participants correctly identified the start of a new clause, because of categorical properties of the intransitive verbs, and naturally slowed down at this point.

To test these hypotheses, Staub created sentences using intransitive verbs that varied in two ways: the presence or absence of a comma, and the presence or absence of disambiguating information following the verb:

(10)

- a. Short No Comma: *When the dog arrived the vet and his assistant went home*
- b. Short Comma: *When the dog arrived, the vet and his assistant went home.*
- c. Long No Comma: *When the dog arrived at the clinic the vet and his assistant went home*
- d. Long Comma: *When the dog arrived at the clinic, the vet and his assistant went home*

Staub suggested that if the results from Experiment 1 were indeed due to a misanalysis of the post-verbal noun-phrase as the direct object, there should be longer reading times on *the vet and his assistant* in the Short No Comma sentences than in the Short Comma sentences. This is because the Short Comma sentences eliminate the possibility of attaching a direct object to the verb. This effect should not be seen in either of the long sentences, as *at the clinic* should rule out the possibility of attaching a direct object to *arrived*. Conversely, if the effect from Experiment 1 is due to the processing cost found by beginning a new clause, there should be no differences observed across conditions. Lastly, if the effect is due to a processing cost associated with the absence of a comma, then there should be longer reading times on the Short No Comma and Long No Comma sentences, and no observed interaction between comma and length.

Staub's prediction of a processing cost due to the absence of a comma appeared to be correct. There were longer reading times on both sentences which had omitted commas and there were no interactions reported. This finding suggests that readers decided that the verb *arrived* was at the end of a clause, because it is intransitive, and they had trouble if there was not a comma at the end of the clause.

In Experiment 3, Staub examined how a parser analyzes verb bias in filler-gap sentences. Filler-gap constructions occur when one part of a sentence “moves” from its original position to an earlier one. It has been reported that a parser is eager to posit a gap in the first location available (Staub 2007, citing Crain & Fodor, 1985; Frazier & Clifton, 1989; Pickering & Traxler, 2003; Stowe, 1986; Traxler & Pickering, 1996). Staub investigated whether this effect was present even if positing a gap created an implausible scenario for the reader and if verb-frame preference swayed a reader towards positing a gap or not. Staub assembled the sentences as follows:

(11) Noun-phrase bias

- a. Gap: *The gadget that the manager called occasionally about after the accident still didn't work*
- b. No Gap: *The manager called occasionally about the gadget after the accident*

(12) Prepositional-phrase bias

- a. Gap: *The truck that the pilot landed carefully behind in the fog shouldn't have been on the runway*
- b. No Gap: *The pilot landed carefully behind the truck in the fog*

(13) Unaccusative

- a. Gap: *The party that the student arrived promptly for at the fraternity house was late in getting started*
- b. No Gap: *The student arrived promptly for the party at the fraternity house*

If a parser read sentence (12a) and attached *truck* as the object of *landed*, it would create an implausible scenario (a truck that a pilot landed) and disruption may occur. However, the verb-frame preference of *landed* might affect processing this way: *landed* prefers to be followed

by a prepositional-phrase (as in ‘landed on the runway’) rather than an object (as in ‘landed the plane’). This preference might cause readers not to decide that *truck* is attached to *landed*, much like Garnsey, et al found for SC-bias verbs.

The three conditions Staub used in this experiment were noun-phrase biased verbs (11: *called*), prepositional-phrase biased verbs (12: *landed*) and unaccusative verbs (13: *arrived*). What is of great importance here is whether or not participants will try to posit a gap in the unaccusative case, where the attachment of a direct object is prohibited.

Results showed that disruption occurred for both noun phrase preference and prepositional phrase preference verbs in sentences with a gap structure. There were significantly longer first fixations on these verbs in the gap structure sentences than in the no gap structure sentences. This suggests that readers assumed that the preceding noun phrase (gadget, truck) was the object of the verb in both the NP-bias and the PP-bias conditions. A very different effect was obtained in the unaccusative condition. There was no disruption whatsoever in these sentences. In fact, participants were even faster to read the verb in the gap condition than in the no gap condition. This, in turn, strengthens the results found in Experiment 2 which found that a parser will not attach a noun-phrase to be the direct object of a strictly intransitive verb.

Intriguingly, the prepositional-phrase preference verbs (verbs that are not biased towards taking on a direct object, meaning that they have an intransitive verb-frame preference) behaved similarly to the noun-phrase preference verbs. The first fixations on the verbs in these two conditions were significantly longer in the gap structure than in the no gap structure. This is in contrast to the behavior of unergative verbs (which also have an intransitive verb-frame preference) in Experiment 1 that behaved more like unaccusatives. Recall that in the first experiment, sentences involving unergative and unaccusative verbs were read with no significant

differences by participants. This is not the case here. The only time participants did not posit a gap was when the verb was an unaccusative completely forbid a direct object attachment. Staub did in fact have one theory as to why unergatives behaved as unaccusatives in his experiment. Staub described a linguistic analysis that suggests that the direct objects of unergative verbs are not truly direct objects. Instead, they are “cognate objects” which are more of a description of a preceding verb than the object of one. For example, in the sentence “They danced the tango” *the tango* is not the recipient of the action of the verb, but adds to the description of the event by the verb. This would suggest that the unergative verbs used within the study did not have true direct objects attached to them, which allowed for the similar behavior of unergatives and unaccusatives in Experiment 1.

These findings beg the question: is verb-frame information categorical or probabilistic in nature? That is to say, does a parser commit to a continuation based on whether or not a continuation is allowed, or based on the frequency with which a verb is commonly used in a given form? Based on the consistent behavior of unaccusative verbs throughout the experiments to forbid a direct object analysis, it may be safe to say that a parser will not ignore the intransitivity information that categorically prohibits the attachment of a direct object. This is supported by the contrasting behavior of unergatives that will, at times, accept a direct object analysis.

There is evidence to support the claim that individuals do exhibit sensitivity toward categorical versus probabilistic cues. Through the use of the P600 (ERP associated with syntactic anomaly), Osterhout (1993) found that the P600 amplitude was larger when violations were in relation to verb subcategorization (verb-frame possibility) than verb subcategorization biases.



Staub ultimately concludes that a parser will not commit to a syntactic structure that violates a verb's subcategorization restrictions, but will, at times, assign an analysis which is not consistent with a verb bias. This would explain why readers assumed that the preceding noun phrase was the object even for PP-bias verbs like *landed* in Experiment 3. This possibility has also been suggested by Ferreira and McClure (1997).

## **1.6 THE LEXICAL BIAS HYPOTHESIS**

Whether it is verb-frame preference or verb-frame possibility, or some combination of both, that is responsible for a parser's commitment to a sentential continuation is still undecided. Clifton et al (1984), Trueswell (1993), Garnsey et al (1997), and Arai and Keller (2012) have contributed results supporting verb-frame preference, while Pickering (2000), Staub (2007), and Osterhout (1993) have each found verb-frame possibility to be the leading force behind guiding sentence completions. The notion that verb bias may be a main component of sentence comprehension is important to consider in studying the aphasic population. Do individuals with aphasia continue to maintain sensitivity towards verb bias? According to the Lexical Bias Hypothesis (discussed below), verb bias information is indeed preserved and utilized in sentence processing.

### **1.6.1 Gahl (2002)**

Gahl (2002) studied how the Lexical Bias Hypothesis affected sentence comprehension in people with aphasia. This hypothesis states that lexical biases influence sentence comprehension in both aphasic and unimpaired listeners. The only previous study that tested sensitivity to verb-frame

preference in people with aphasia was Russo, et al (1998). This study recreated the Clifton et al (1984) paradigm with people with aphasia. Participants read a sentence off a screen with each word appearing on the screen one at a time. A lexical decision task of judging whether or not a series of letters presented to them was a word or a non-word was administered immediately following the first word after the verb. It was hypothesized that if a participant encountered a transitively biased word that was being used transitively, he or she should have an easier time processing the sentence fragment and therefore a speedier reaction time. Conversely, if a participant read a sentence in which a transitively biased verb is being used intransitively (or vice versa), reaction times should be delayed. Russo, et al found that the participants with aphasia did not show signs of sensitivity to the lexical bias of the verb. Gahl argued that a pattern may not have been found due to the heterogeneity of aphasia types among the participants. As a result, Gahl separated results by nonfluent and fluent aphasia types (an additional analysis was also conducted which separated anomia from fluent aphasia types).

Additionally, Gahl examined the effect of lexical factors and syntactic structure. Previous studies suggested that many difficulties with aphasic comprehension are associated with sentence structures that deviate from the canonical word order of the language (Bates, Friederici, & Wulfeck, 1987). In English, this word order is Subject-Verb-Object. While the advantage of this order is present in people with aphasia and unimpaired populations, there is no evidence which provides an explanation for the canonical order benefit. Menn (2000) directly speaks to this phenomenon in a paper entitled "What makes canonical form simple?" Gahl hypothesized that perhaps this occurrence can be explained by lexical biases, rather than the syntactic structure alone.

To test this theory, participants heard three types of sentences: active transitive, passive, and intransitive. In half of the sentences, the bias of the verb matched the syntactic structure it was in (concordant condition), and half mismatched (discordant condition).

(14) Concordant

- a. Active transitive: *The researchers dissolved the crystals.*
- b. Passive transitive: *The crystals were dissolved by the researchers.*
- c. Intransitive: *The butter melted in the pot.*

(15) Discordant

- a. Active intransitive: *The cook melted the butter.*
- b. Passive intransitive: *The butter was melted by the cook.*
- c. Intransitive: *The crystals dissolved in the solution.*

If syntactic structure is the sole contributor to sentence comprehension then the concordant group and the discordant group should be equally easy or difficult to understand (depending on the syntax). However, if verb bias, specifically transitivity bias, has an influence in sentence comprehension, then the discordant sentences should be more difficult to comprehend. The verb *dissolve* trends towards a transitive usage, while *melt* is more likely to be used intransitively. If individuals rely upon verb bias, then sentences (15a) and (15b) will cause problems because *melt* is being used transitively and (15c) will cause difficulty because *dissolve* is being used intransitively.

To determine listeners' comprehension, half of the sentences were plausible and half were implausible. A judgment as to whether or not these sentences were plausible was given by

the participant at the end of each stimulus by pressing a button. The implausible sentences were the reverse of the plausible sentences, for example:

(16)

- a. Plausible: *The cook melted the butter*
- b. Implausible: *The butter melted the cook*

The results showed that unimpaired participants made few errors in general. These participants did, however, make significantly more errors on discordant sentences than on concordant sentences, suggesting that lexical bias factored into sentence comprehension.

As a group, participants with aphasia showed a significant effect of match, having higher error rates when verb bias and sentence structure were discordant. This effect was present in the group of participants with fluent aphasia, but only marginally significant in the anomie, fluent aphasic participants. Nonfluent aphasic subjects showed no significant effect of match.

Syntactic structure also appeared to play a role in comprehension. There was a significant effect of syntactic structure ( $F(2, 32) = 16.06, p < .001$ ), reflecting that error rates were lowest in active sentences for both the plausible and implausible conditions.

Gahl's findings contradicted those of Russo, et al (1998), who found no effect of lexical bias in individuals with fluent aphasia. The results showed that participants with fluent aphasia were indeed influenced by verb bias in a sentence structure. These results, along with the data from the unimpaired participants, support the Lexical Bias Hypothesis in that at least some individuals with aphasia do show sensitivity to verb bias.

### 1.6.2 DeDe (in press)

DeDe (in press) also studied the effects of mismatched sentences (between verb transitivity bias and sentence structure) in people with aphasia. Based on the Lexical Bias Hypothesis presented by Gahl (2002), the prediction is that people with aphasia will have difficulty understanding a sentence if the transitivity preferences of the verb do not match the structure of the sentence (if transitive verbs are being used intransitively and vice versa). DeDe also suggested that people with aphasia will favor a subject-verb-object (SVO) sentence form, and will therefore have an easier time with transitive sentences. To test these hypotheses, DeDe constructed four sentence types:

(17)

Verb Bias	Sentence Type	Match	Example
Intransitive	Intransitive	Yes	a. The couple/danced/every/Friday night/last summer.
Intransitive	Transitive	No	b. The couple/danced/the tango/every/Friday night/last summer
Transitive	Intransitive	No	c. The agent/called/from overseas/to make/an offer
Transitive	Transitive	Yes	d. The agent/called/the writer/from overseas/to make/an offer

This study utilized a self-paced reading task. Reading times were recorded and a comprehension question was asked after each sentence stimuli. Longer reading times were considered an indication of a participant's struggle with the presented segment. Both people with aphasia and controls had disrupted reading times on the post-verbal phrase in sentences that mismatched. This effect was larger in people with aphasia, but there was no interaction between

match and group. Interestingly, the effect of match was only present in intransitive sentence types with transitively biased verbs (such as 17c). Reading times on the post-verbal phrase of an intransitive sentence which utilized a transitive verb were significantly longer than any other sentence type. The study also showed that, in general, people with aphasia struggled more with intransitive sentences than transitive sentences. This finding is consistent with the prediction that people with aphasia would find SVO sentences easier.

Overall, the results supported the Lexical Bias Hypothesis, showing that both people with aphasia and controls had disrupted reading times in sentences where verb transitivity bias and sentence structure did not match.

Based on Gahl (2002) it appears that people with aphasia utilize verb bias information in sentence processing and comprehension. Unimpaired adults trended towards the use of verb bias in processing in Gahl (2002) (there were higher error rates for discordant sentences), but this effect was not significant. DeDe (in press) also showed that there is an influence of verb bias in people with aphasia and unimpaired controls, but this effect was only present in intransitive sentences with transitively biased verbs. There are clear fluctuations in how verb bias affects people with aphasia and normal controls between these results. However, all of these results are in-line with the Lexical Bias Hypothesis which simply states that all people are sensitive to this information. The hypothesis does not make a claim towards whether one group is more sensitive than the other or the degree of sensitivity—only that there is lexical influence of some type. The current study will further examine if both people with aphasia and unimpaired controls show sensitivity to lexical information.

## 2.0 CURRENT STUDY: GOALS AND QUESTIONS

This study aims to add to the discussion of the role that lexical information plays in sentence processing both in impaired and unimpaired populations. The specific research questions are as follows:

1. Are people with aphasia and unimpaired controls sensitive to transitivity biases?
  - Do people show an influence of lexical bias in their sentence comprehension as proposed by Gahl (2000)?
2. Does the parser utilize verb-frame preference in the initial stages of processing?

To answer these questions, participants performed two self-paced reading studies with stimuli from Warren and McConnell (2007). The purpose of those studies was to examine the effects of semantic factors related to a verb on sentence comprehension among older adults and people with aphasia. For example, do people with aphasia experience disruptions when reading an implausible sentence like *the woman used some bleach to clean the carrots*? The current study tests the effect of verb preference on comprehension of these sentence stimuli (see description of sentence stimuli in design below).

## 2.1 DESIGN

Because these stimuli belong to experiments that ultimately examine the effects of semantic disruptions on people with aphasia, it is likely that towards the end of the sentences, the ascribed condition (plausible, implausible, and impossible) will be the main contributor to reading times.

The semantics should also be the key factor in acceptability judgments, used in Experiment 1, and sentence final comprehension questions, used in Experiment 2. What is unclear is how the article will be read by people with aphasia and unimpaired controls. The verb and the article are the point at which participants receive information about the transitivity bias of the verb and the sentence structure, much like on Clifton, et al's (1984) study.

Participants read sentences like:

(18)

- a. Condition 1—Plausible: *Maria used a knife to chop the large carrots before dinner last night*
- b. Condition 2—Implausible: *Maria used some bleach to clean the large carrots before dinner last night*
- c. Condition 3—Impossible: *Maria used a pump to inflate the large carrots before dinner last night*

If verb preference is maintained and relied upon by individuals with aphasia (as suggested by the Lexical Bias Hypothesis) then there should be an effect of transitivity on reading times for the article. In this case, the more transitively biased a verb is the faster the reading times should be on the article.



An effect of transitivity bias might also be expected on reading times for the noun in plausible sentences. Because there is no competing effect of plausibility in these cases (the sentences are semantically acceptable), the transitivity bias of the verb may also enhance reading times for these noun phrases. Verbs with a strong transitivity bias (leading participants to strongly expect a transitive structure and a noun-phrase object) might be expected to have faster reading times for the noun phrase in the plausible condition.

If people with aphasia or unimpaired adults do not rely upon transitivity in sentence processing, then there should be no effect of transitivity on reading times of any part of the sentence.

## **2.2 HYPOTHESIS**

Because language resources are limited in people with aphasia, it is expected that these participants will fall back on lexical biases to help guide processing in sentences, as suggested by the Lexical Bias Hypothesis. Given the results of Gahl (2002) and DeDe (in press), it is predicted that people with aphasia will show sensitivity to transitivity biases while reading the article of all sentences, and the noun of semantically plausible sentences. These sensitivities should arise in the form of faster reading times for transitively-biased verbs, which are more frequently used with a direct object. In correspondence with the Lexical Bias Hypothesis, it is predicted that unimpaired controls will also exhibit sensitivity to transitivity bias in these same regions. Conversely, transitivity bias should not affect reading times on the adjective, noun (of the implausible and impossible sentences), or acceptability judgments/comprehension questions of the studies due to the reliance on semantic factors in these regions.

## 2.3 PARTICIPANTS

Participants were divided into two main groups: people with aphasia and cognitively unimpaired participants. All subjects were required to have normal or corrected-to normal vision and hearing, were between the ages of 42 and 88, and had no history of neurological, neuropsychological, or neuropsychiatric conditions that could cause language problems. Cognitively unimpaired participants had no history of language disorder; participants with aphasia had no history of language disorders before their current condition.

Unimpaired age-matched controls were community dwelling volunteers from the greater Pittsburgh area. The mean age of the 35 older participants was 70, ranging from 63 to 88. Participants completed a series of secondary tests, including tests of working memory, such as the Forward and Backward Digit Span (Table 1). It should be noted that the 35 controls took part in Experiment 1, which differed only from Experiment 2 in the acceptability/comprehension task at the end of the sentences. These 35 controls did not take part in Experiment 2.

**Table 1.** Working Memory: Unimpaired participants

	<b>Forward Digit Span (/70)</b>		<b>Backward Digit Span (/70)</b>	
	M	SD	M	SD
Unimpaired Participants	57	0	42.94	-19.54

The 11 participants with aphasia were recruited using the Western Pennsylvania Patient Registry. The Western Pennsylvania Patient Registry is a database of stroke survivors who have gone through the UPMC system and consented to be contacted for participation in research studies. The mean age of these participants was 65, ranging from 42 to 69. The participants with

aphasia varied from mildly to moderately impaired (WAB AQ range: 50.3-92.8), with a range of aphasia types (6 anomic aphasia, 3 Broca's aphasia, 1 transcortical motor aphasia, 1 conduction aphasia). Eight of the eleven people with aphasia participated in both Experiment 1 and Experiment 2, however, these studies were conducted one year apart from one another and no testing effects are thought to exist. Details of each participant with aphasia can be found in Table 2.

**Table 2.** People with aphasia profiles

Participant	WAB AQ (/100)	Aphasia Type	Spontaneous Speech (/20)	Fluency (/10)	AC	Repetition	Naming	RCPM (/36)	ABCD	Pyramid & Palm Trees	Forward Digit (/70)	Backward Digit (/70)
PWA 1	77	Anomic	11	5	8.95	9.4	9.1	31	100	92	42	33
PWA 2	50.3	Broca's	9	2	7.95	2.6	5.6	32	75	N/A	27	18
PWA 3	75.3	Transcortical motor	12	4	8.75	8.6	8.3	30	150	77	27	18
PWA 4	70.3	Conduction	14	5	8.05	4.6	8.5	32	123	N/A	20	13
PWA 5	55.2	Broca's	11	4	7.50	3.1	6.0	32	87.5	92	20	20
PWA 6	52.6	Broca's	10	2	7.50	3.2	5.6	36	100	88	12	7
PWA 7	88.9	Anomic	17	9	8.45	9.3	9.7	30	100	94	43	25
PWA 8	90.6	Anomic	18	9	9.00	9.3	9.0	11	105.88	62	30	N/A
PWA 9	85.5	Anomic	18	9	8.75	8.4	7.6	27	84	85	38	24
PWA 10	73.7	Anomic	13	5~6	7.95	7.6	8.3	34	118	N/A	20	N/A
PWA 11	93.8	Anomic	18	9	9.50	9.4	10	26	116.67	N/A	48	23

## **3.0 MATERIALS**

### **3.1 SCREENING TESTS**

Participants with aphasia completed the following screening tests: WAB-R, RCPM, ABCD, Pyramids and Palm trees, and Forward and Backward Digit span.

1. Western Aphasia Battery-Revised (Kertesz, 2007): The WAB is a standardized measurement test of language function in people with aphasia. The purpose of the test is to determine the existence, severity, and type of aphasia. Furthermore, this test provides a baseline for a patient's level of performance, which can be utilized to detect change over time.
2. Raven's Coloured Progressive Matrices (Raven, 1965): The RCPM is a test to determine a participant's nonverbal reasoning ability.
3. Arizona Battery for Communicative Disorders of Dementia (Bayles & Tomeoda, 1993): The ABCD test requires the participants to listen to a story and repeat it- once after the story was initially told, and again after a certain passage of time. The test is used to measure language-related memory.
4. Pyramids & Palm Trees (Howard & Patterson, 1992): This test determines the degree to which a participant can extract meaning from pictures and words.

5. Forward and Backwards Digit Span: This task is used to measure working-memory using a string of numbers. Participants are given a list of numbers and must repeat them back in the same order. If completed successfully, the chain of digits will become longer (a number will be added on). In the backward digit span, the participant must recall and repeat the given digits in the reverse order.

In addition to the tasks outlined above, participants completed a questionnaire inquiring about their personal medical history, handedness, language status (i.e. whether English is their native language), and vision status. All also participants took part in a short hearing screening of pure tones at 500, 1000, 2000, and 4000 Hz at 40 dB.

### **3.2 CORPUS DATA**

The transitivity biases used in this study were obtained from a large corpus of English verbs and the syntactic frames they occur in, using half of the British National Corpus, which contains around 50 million words (Schulte im Walde, 1998). The transitivity biases for each verb were calculated using the same method as in Dickey & Bunker (2011). The number of times a verb occurred in a transitive syntactic structure was divided by that number of occurrences plus the number of times that verb occurred in an intransitive structure. This ratio was used as an estimate of the verb's transitivity bias, with higher values indicating that a verb was more frequently used transitively.

### 3.3 PROCEDURE

This was a self-paced reading study. Participants were asked to read a sentence, a word or phrase at a time. Participants read off a screen and pressed the spacebar on a keyboard for the next word or phrase in the sentence to appear. Reading times for each segment were collected down to the millisecond. Each participant saw one of three versions of a sentence that was plausible, implausible, or impossible. There were a total of 150 sentences of which 90 were analyzed for the current study (see Appendix A). Participants were read instructions and there were four practice items to familiarize them with the task. There were five breaks during the entire study.

(19)

- a. Condition 1—Plausible: *Maria / used / a knife / to chop / the / large / carrots / before dinner / last night*
- b. Condition 2—Implausible: *Maria / used / some bleach / to clean / the / large / carrots / before dinner / last night*
- c. Condition 3—Impossible: *Maria / used / a pump / to inflate / the / large / carrots / before dinner / last night*

Slashes indicate presentation segments in the self-paced reading task. After each sentence in Experiment 1, the word ‘ACCEPTABLE’ appeared. Participants pressed keys marked ‘Y’ or ‘N’ to say whether the sentence was acceptable. In Experiment 2, a comprehension question appeared after each sentence, such as:

(20)

- a. Did Maria cut the carrots?

b. Did Maria wash the carrots?

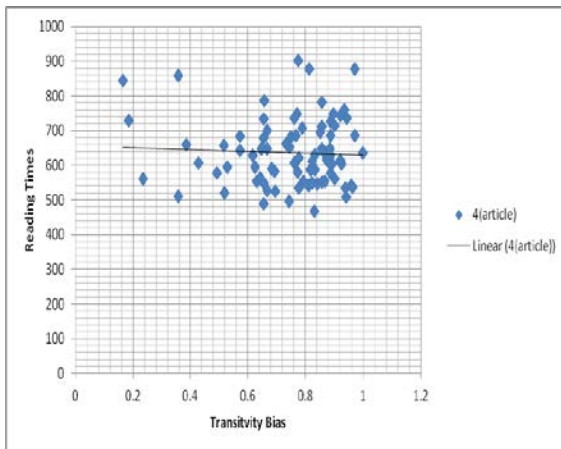
c. Did Maria blow up the carrots?



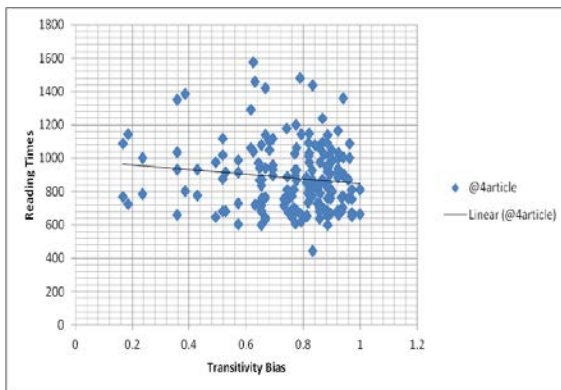
## 4.0 RESULTS

This was an experimental study which utilized a cross-sectional design. Two participant groups, persons with aphasia and older cognitively normal participants, experienced three different sentence conditions: plausible, implausible, and impossible. Within-subject independent variables included the three sentence conditions and the transitivity biases of the verbs, and the between-subjects independent variable was involvement in one of the participant groups. The dependent variables were reading time measurements of the verb, article, adjective, and noun of each sentence, as well as the acceptability judgment/comprehension question at the end of each sentence.

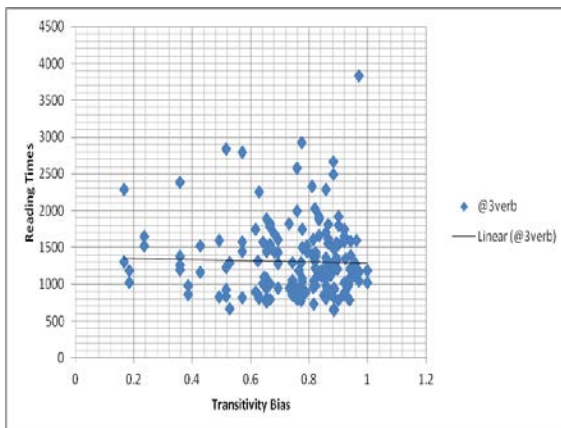
## 4.1 REGRESSION ANALYSIS



**Figure 1.** Control group reading times on the article.  $p = .685$



**Figure 2.** People with aphasia's reading times on the article.  $p < .075$



**Figure 3.** People with aphasia's reading times on the verb.  $p < .05$

Linear regressions were performed on the data, first with all conditions compiled together (plausible, implausible, impossible), then again with separated sentence conditions. It was expected that the unimpaired participants would show a significant effect of condition on reading times of the noun and on acceptability judgments/comprehension questions because of the heavy reliance on semantic cues utilized in the study. For clarity, acceptability judgments and comprehension questions have been compiled and are reported as “acceptability judgments” here.

For control participants, condition significantly predicted reading times for the noun ( $R^2=.119$ ; Beta=.303,  $t=2.918$ ,  $p<.01$ ) and acceptability judgments ( $R^2=.777$ ; Beta=.880,  $t=16.731$ ,  $p<.005$ ). Surprisingly, when the sentences were separated out by condition, there was a significant effect of transitivity bias on the reading times of the adjective in condition 1 ( $R^2=.167$ ; Beta=.409,  $t=2.369$ ,  $p<.05$ ). There was no effect of transitivity bias on any other reading time or acceptability measurement.

In contrast to controls, participants with aphasia showed a marginal significant effect of transitivity bias on the reading times of the article ( $R^2=.018$ ; Beta=-.134,  $t=-1.792$ ,  $p=.075$ ). Surprisingly, there was a significant effect of transitivity on the reading times of the verb ( $R^2=.045$ ; Beta=-.170,  $t=-2.301$ ,  $p<.05$ ). Similar to the results of the unimpaired controls, condition effected reading times on both the noun and sentence-final acceptability judgments significantly ( $R^2=.045$ ; Beta=.211,  $t=2.870$ ,  $p<.01$  and  $R^2=.077$ ; Beta=.250,  $t=3.451$ ,  $p<.005$ , respectively). When the sentences were separated by condition, there was a significant effect of transitivity bias on the reading times of the verb in condition 3 ( $R^2=.153$ ; Beta=-.391,  $t=-3.234$ ,

p<.005). Additionally, there was marginal significance of transitivity bias on reading times of the noun in condition 1 ( $R^2=.053$ ; Beta=.230,  $t=1.798$ ,  $p<.077$ ).

## 5.0 DISCUSSION

The current findings show that people with aphasia behave in a way that is in-line with the Lexical Bias Hypothesis proposed by Gahl. The participants with aphasia reliably used transitivity bias as a tool during their initial parsing of sentences. Regression analysis showed that there was a significant effect of transitivity bias on reading times for the verb and a marginally significant effect on reading times for the article. That is, people with aphasia were faster to read more transitively biased verbs, and faster to read the article following such transitively biased verbs. The pattern that appears on the article is similar to the findings of Clifton, et al., (1984), who showed that people were faster to process an article when it followed a transitively-biased verb. This was not the pattern for the unimpaired controls, who did not appear to rely on transitivity in sentence processing. They did not show effects of transitivity bias on reading times or acceptability judgments.

The significant effect of transitivity bias on the verb was a surprising finding. Transitivity bias should dictate reading times that one may expect *after* the verb, but not on the verb itself. One way to reconcile this phenomenon is to look at the total reading times for people with aphasia versus controls. People with aphasia had reading times on each segment that were much higher than those of the controls. Because this was a self-pace reading study, participants were able to take the time they required on each segment. It may be the case that reading slowly gave

people with aphasia the time needed for the factors associated with the word to become activated such as transitivity bias.

Overall, one conclusion that may be drawn from this pattern is that in the wake of language impairment, an individual may rely even more strongly on verb-based transitivity to guide his or her understanding of a sentence. This may occur through “local connections” within a sentence, whereby the reader will establish appropriate sentence structure on a word by word basis. This, in turn, suggests that sensitivity to transitivity remains intact after injury to language function.

Moreover, these results suggest that people with aphasia use verb preference information in the initial parsing of a sentence. This supports the proponents of the Lexical Guidance Hypothesis such as Clifton et al (1984), Trueswell (1993), Garnsey et al (1997), and Arai and Keller (2012). However, the unimpaired controls showed no influence of verb preference in initial parsing of the sentences. This is consistent with Pickering (2000), Staub (2007), and Osterhout (1993), who suggest that verb frame preference is not initially utilized.

One area of inquiry that should be discussed is why there is such variation within the field for the use of lexical information. For example, Garnsey et al (1997) and Pickering and colleagues (2000) reported directly contrasting results on their studies of verb preference and plausibility. Garnsey found no effect of plausibility on the ambiguous noun-phrase in sentences with sentential-complement bias (SC-bias) verbs. This suggested that a direct object interpretation for the sentence was not considered. As a result, it appeared that verb preference was used in the initial parsing of the sentences. Pickering and company found the opposite. When participants read an SC-bias verb followed by an implausible direct object, verb preference did not facilitate the SC analysis (in which the implausible noun-phrase is in fact not

the object of the verb). Reading times were disrupted. These disruptions were attributed to attempts by participants to assemble a direct object analysis on the sentences.

One possibility for why these contrasting results are present is due to the very nature of verb preference as a continuous trait. Although meticulous norming was conducted for both of the studies mentioned above, the concept that is being dealt with here is one that lays on a continuum and is hard to categorize. That is to say, the demarcation line as to what constitutes a transitive versus intransitive verb is often fuzzy. There are two main reasons why categorizing verbs into transitive and intransitive verbs may cause problems. The first is that when classifying verbs in this way, there is a large portion of verbs that cannot be treated. These are verbs such as the equal-bias verbs described in Garnsey et al (1997), which do not have a strong bias towards being transitive or intransitive. Simply comparing strongly biased verbs leaves out this middle class of verbs, which may show very different behavior, as Garnsey, et al found.

A second reason why categorizing verbs into groups may be detrimental to a study is due to the variation within the grouped verbs themselves. That is to say, there is a loss of sensitivity to verb bias in grouping the verbs in the first place. These verbs are now all treated equally and are predicted to behave the same way, even though there may be variations among them. For instance, the categorization of verbs may be why DeDe (in press) found varied results of verb bias in certain sentence structures. DeDe found participant sensitivity to verb bias only when transitive verbs were used in an intransitive sentence structure, but not when intransitive verbs were used within a transitive sentence. However, it may not be the case that there is simply no effect of intransitive verbs in transitive formats, but instead, it may be due to the sample of verbs present. These particular intransitive verbs may be less strongly biased toward intransitive uses than other intransitively biased verbs. Consequently, while they do fall in the category of being

intransitively biased, they may be at the more transitive side of that category. This is a reasonable assumption, as all of these verbs were required to be grammatical within a transitive sentence structure. This bias may have diminished the effects of verb preference for the intransitive verb-transitive sentence condition.

Due to the variability which arises after verbs are categorized one way over another, a more useful way to examine whether verb frequency information is present among readers is to perform regression analyses which maintain the continuous nature of verb preference. The current study utilizes this kind of analysis and has shown that verb preference does have an effect among people with aphasia in processing sentences. A follow-up to this would be to examine how persons with aphasia treat verb-frame possibility (such as the unaccusative verbs in Staub (2007)) in sentence parsing. If verb-frame preference appeared to be a reliable factor for processing in this study, one would predict an even more robust effect on verbs that categorically prohibit continuations of a certain variety.

## **5.1 LIMITATIONS**

### **5.1.1 Unequal Observations of Transitivity**

The current study utilizes sentence stimuli that consistently had a transitive structure. Because of this, most of the present verbs are biased towards a transitive structure. Future studies should include more equal numbers of transitively and intransitively biased verbs. Also, future studies should look at transitively biased verbs occurring in intransitive sentence frames, which is where DeDe (in press) found the largest effects of mismatch.



### **5.1.2 Many types of Aphasia**

Another limitation of the current study is that the reading times for different types of aphasia were not looked at separately. This may have been a beneficial factor to analyze as Gahl (2002) found differing effects of verb bias on different aphasia types.

## 6.0 CONCLUSION

The major finding of this study is that people with aphasia do utilize verb preference information, specifically transitivity, in their initial parsing of a sentence. There was no effect of transitivity found in the unimpaired participants. Based on these results, it can be said that individuals with aphasia strongly rely on verb-bias information when language processing is impaired, even more strongly than unimpaired adults. The behavior of people with aphasia is in-line with the Lexical Bias Hypothesis and the Lexical Guidance Hypothesis which claim that frequency information is used during sentence processing.

Based on the varied results of studies which tested for an effect of verb frequency information in processing, it is suggested that further examination of this effect be carried out in a different way. It may be unfavorable to test for this effect by grouping verbs which are biased one way or another. To remedy this, studies should test for an effect of preference as a continuous variable rather than through a categorized approach.

## APPENDIX A

### SENTENCE STIMULI

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 blow 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.

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